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COVID-2019 Impacts on Education Systems and Future of Higher Education

Edited by

Kelum A.A. Gamage

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Preface to "COVID-2019 Impacts on Education Systems and Future of Higher Education"

The rapid outbreak of the COVID-19 has presented unprecedented challenges on education systems. Closing schools and universities and cancelling face-to-face activities have become a COVID-19 inevitable reality in most parts of the world. To be business-as-usual, many higher education providers have taken steps toward digital transformation, and implementing a range of remote teaching, learning and assessment approaches. This book provides timely research on COVID-19 impacts on education systems and seeks to bring together scholars, educators, policymakers and practitioners to collectively and critically identify, investigate and share best practices that lead to rethinking and reframing the way we deliver education in future.

Kelum A.A. Gamage
Editor

education sciences

Review

Online Delivery of Teaching and Laboratory Practices: Continuity of University Programmes during COVID-19 Pandemic

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Abstract: A great number of universities worldwide are having their education interrupted, partially or fully, by the spread of the novel coronavirus (COVID-19). Consequently, an increasing number of universities have taken the steps necessary to transform their teaching, including laboratory workshops into an online or blended mode of delivery. Irrespective of the measures taken, universities must continue to maintain their high academic standards and provide a high-quality student experience as required for delivery of learning outcomes associated with each degree programme. This has created a challenge across the higher education landscape, where academics had to switch to remote teaching and different approaches to achieving laboratory delivery. As a result, students have not been receiving face-to-face teaching, and access to laboratory facilities has been limited or nearly impossible. This paper reviews numerous approaches taken by universities to deliver teaching and laboratory practices remotely, in consideration of the COVID-19 pandemic, whilst also considering the potential impacts on the student learning experience. This review is primarily focused on the fields of engineering, science and technology, based on published literature including books, reviewing web-based provision of selected universities, institutional and national policy documents.

Keywords: COVID-19; pandemic; higher education; student learning; online delivery; laboratory workshops

1. Introduction

In study sectors such as chemistry, physics, engineering, biology, computing, psychology, languages, nursing, medicine, and other allied professions, programme outcomes stress the importance of developing theoretical (content) and practical (processes) aspects. When developing the practical aspects, special emphasis is given to the activities that teach students experimental methods, how to synthesise observations, a range of lifelong and communication skills and laboratory practices.

In December 2019, for the first time, Wuhan City in China officially declared the presence of an unknown virus (now called COVID-19) that soon gained pandemic status, taking many lives around the world (https://www.nature.com/articles/d41586-020-00154-w). The COVID-19 pandemic quickly led to the closure of universities and colleges following the advice of public health officials to maintain social distancing [1]. Consequently, educational institutions quickly adopted e-learning under the distance education mode [2,3]. Even though this approach works well for knowledge building through delivering content and oversight of some processes, it has limitations of developing one's practical laboratory skills. For example, if working in a laboratory setting, one would often encounter many types of expensive and complicated instruments and machines. However, operating under a distance learning mode denies valuable hands-on exposure to such facilities and to appreciate the subtleties of being immersed in such an environment. Therefore, it is important to review how universities are currently introducing lab-based practical experiments to students, how they were introduced through online delivery in the pre-COVID-19 period, and what approaches must be taken in the post-COVID-19 period, especially to achieve learning outcomes whilst maintaining a high-quality educational experience.

In this review, we first discuss online teaching and laboratory practices before COVID-19, while summarising examples from published literature. This is followed by presenting the transformation from traditional face-to-face delivery to online delivery, in which we examine technologies used for online delivery, including associated challenges and impacts on assessment practices implemented as a result of COVID-19. There follows a discussion on student experience, highlighting the impacts on their learning experience as well as on their wellbeing. Finally, consideration is made of the policies implemented by educational and other agencies to support universities to uphold quality assurance procedures during online delivery of teaching.

2. Online Teaching and Laboratory Practices: Pre-COVID-19

With the advancement of e-learning during the first decade of the 21st century, online approaches have become more widely used in many educational setups [4]. For example, web-based activities are used extensively in distance education courses, whereas blended approaches are used to support teaching and learning activities in campus-based courses. Dantas and Kemm discuss a blended learning approach in which web-based e-learning tools are used to undertake hypothesis testing and predictions prior to the practical class, interpret the results and review the submitted predictions after the class [5]. Goldberg and Dintzis discuss a blended laboratory class carried out at Johns Hopkins University for the 'Organ Systems Histology' course [6]. Pre-laboratory instruction on a web-based overview lecture, a series of web-delivered slide-specific micro-lectures and a set of virtual slides with annotations are introduced to the traditional laboratory experiment.

The class and associated laboratory exercise "Use of PCR for detection of genetically modified sequences in soybean DNA" were discussed in Gibbins, Sosabowski and Cunningham [7]. Two sets of learning materials, manuals for instructor and students (traditional approach), and web-based support centered on a computer aided learning (CAL) package were used for two groups. Both sets of supporting materials were designed to meet the same educational objectives and used descriptive text, static diagrams, and problem-based learning. However, the CAL package has interactive animated diagrams, instant feedback on problems, a hyperlinked glossary, and a simulated optimisation exercise.

An interactive, online dynamic laboratory manual was developed by the Bristol ChemLabS project (www.chemlabs.bris.ac.uk/). The manual incorporates video clips, interactive simulations, formative and summative assessments, and eliminates the need for lab recordings after every class. Some of the complex concepts and techniques can be easily illustrated by videos, which students find a useful resource to prepare them before the actual laboratory work. This also enables students to understand the level of hazards associated with laboratory work as well as to follow safe practices to prevent such conditions.

In a completely different class, Quinn and Robert describe the development of practices of art-making using the internet [8]. They briefly touch on trends in digitally mediated art-making practices, including digital photographic manipulation and collaboration. These art-making methods are important in art education because they increase the possibilities of idea generation and image making for artists in the field, and provide a source of inspiration for students in art classrooms. Such methods for eliciting creativity have potential application in subject matter taught in laboratory-based environments where creative thinking is required.

Endean and Braithwaite report a preliminary study carried out to investigate longer-term collaborative working between the Faculties of Science and Maths, Computing & Technology (MCT) and East China University of Science and Technology (ECUST) in Shanghai, China [9]. The work reported informs a plan to jointly develop an online experiment. The outputs from this preliminary project reveal the similarities and differences in approaches to the development of computer-based experiments in each institution; potential for and challenges in the adaptation of software and hardware for use in both locations; practicable approaches to sharing common facilities for the use of students of either institution; possibilities for creating inter-institution student teams to enhance learning and promote inter-cultural awareness.

The MARVEL project reported by Müller and Ferreira helps to arrange online labs, combined with simulation training and learning-by-doing on real-life systems, in an enriched learning environment [10]. It comprises learning tools or media, learning places and learning activities. The paper gives two examples of online labs, one providing access to a purely remote electronics experiment through LABVIEW and the other one combining remote devices and simulation models in a mixed-reality electro-pneumatics experiment. The equipment and devices used are connected to remote users via the internet. The trials conducted within this project led to conclusions that online labs provide flexible working hours with ubiquitous access and students were able to carry out the real experiments without safety concerns.

3. Transformation from Traditional to Online Delivery

It is recognised globally that higher education institutions are highly vulnerable to community transmission of the COVID-19 virus and almost all universities suspended face-to-face academic activities, implementing alternative ways of teaching. One of the techniques adopted by many universities was switching to online delivery. COVID-19 is not the only time universities have switched to online delivery; for example, according to Murphy [1], in Fall (autumn) 2009 some universities switched from face-to-face classes to online delivery during the H1N1 Influenza virus. Further, after Hurricane Katrina's landfall in August 2005, a consortium of 153 colleges and universities reacted quickly to create an online catalogue of more than 1300 courses.

Endean discusses a number of points to be considered when developing online experiments. The author states that it is important to offer virtual experiments while incorporating pictures/data of actual equipment, show good results from real experiments and to connect to real industrial processes [9].

Crawford discusses the responses of higher education institutions in 20 different countries including China, USA, Germany, UK, Singapore, India, and Hong Kong to COVID-19 and how academic programmes were conducted [11]. Even though the paper provides a comprehensive review, no particular information is provided for the delivery of laboratory experiments except mentioning that in Hong Kong, laboratory work was suspended.

3.1. Technologies

In the majority of studies described in the previous section, laboratory classes are performed in the real laboratory setups that would not be practical during a pandemic like COVID-19. However, virtual labs, remote control labs or video-based labs are good choices when students are not physically located on campus [12]. For virtual labs, simulation tools and virtual reality are used. Remote laboratories allow the undertaking of experiments through the internet, whereas video-based activities provide a step-by-step overview of a real lab so that students can visualise the whole experimental process and its environment through a video. Zhai, Wang and Liu provide an example for some of the above labs in electrical engineering [12]. According to their findings, the laboratory design enables students to carry out experiments while incorporating autonomous, interactive and collaborative learning of electrical engineering experiments. Further, the article states the electrical online laboratory design breaks the space limitation for traditional experimental work and provides a collaborative learning environment where teachers and students can interact and perform laboratory experiments.

Goldberg and Dintzis discuss the steps to implement virtual microscopy via three levels. In the basic level students can be provided with digitised images from a light microscope; this approach is simple to deploy and inexpensive to implement but is limited in terms of functionality [6]. In the intermediate level, a remote-control functionality could be incorporated with a light microscope. When fitted with an electronic stage and focusing controls, a user is able to control the microscope from an offsite location. The more advanced option is to provide slide scanning and virtual microscopy software. This is the most versatile option, but it is an expensive solution as slides are digitised using a slide scanner, and the files are stored on a high-capacity server.

Odeh discusses a remote lab system named the Virtual Instrument Systems In Reality (VISIR) used in the Engineering Faculty at Al-Quds University in Jerusalem, Palestine [13]. VISIR is a remote lab for designing, wiring, and measuring electronic circuits. The user has the ability to access the lab remotely at any location by using the internet. It comprises of a web-based user-interface using any web browser, measurement server, equipment server and switching matrix. The web interface enables the user to perform the same actions as if she/he is in a hands-on lab. The Measurement Server acts as a virtual instructor that controls the commands passing from the web interface to the equipment server to prevent hazardous circuit designs and to protect the instruments. The Equipment Server receives the commands from the Measurement Server to be executed on the real instruments. The Switching Matrix performs the connections between the components and instruments that the user has carried out in the web interface.

Endean lists approximately 160 online experiments delivered as 'simulations', 'virtual experiments', or 'remote control experiments' offered at ECUST in Shanghai [9]. The list covers subjects such as chemistry, physics, chemical engineering, machine principles, controls, computer networking, electrical machines, electrical circuits, transducers, materials engineering, basic mechanical engineering, computer graphics, and monitoring technologies.

A report by Lewis critically reviewed the pedagogical benefits and pitfalls of the increased use of virtual laboratory tools across the Biological Sciences [14]. According to the report, the performance in examinations revealed that the virtual laboratory tools were as equally effective as traditional laboratories in increasing student knowledge and understanding as they facilitate active, enquiry-based learning. Further, their use also overcomes health and safety constraints and ethical issues. The main pitfall of their use is that they do not provide hands-on experience of individual techniques or training in the use of individual items of equipment. Further, students do not gain experience of analysing and interpreting incorrect or uncharacteristic data. Furthermore, the report stresses the importance of integrating high-quality virtual laboratory tools with traditional laboratory sessions within curricula.

Adams states that for online teaching and laboratory practices in the biosciences field, enquiry-based learning (EBL) is often more effective than traditional based learning [15]. Some advantages in the EBL method are recognised as learning by discovery, interacting more effectively with peers and tutors and maintaining students' enthusiasm for laboratory work.

3.2. Challenges of Online Delivery

High level aims of experimental work in engineering curricula are: (a) developing experimental, design, problem-solving and analysis skills; (b) developing data-recording and analysis skills; (c) familiarising students with equipment techniques and materials; (d) developing practical skills; (e) developing communication and interpersonal skills; (f) developing technical judgement and professional practice; (g) integrating theory and practice; (h) motivating students [16]. Even though online delivery of practical components may be carefully designed to achieve most of these aims, (c) and (d) may be difficult to achieve through the online mode. Further, aims (a) to (g) are achieved by different approaches such as demonstration, exercise, structured inquiry, open-ended inquiry and student-led projects. The online delivery of laboratory experiments can be effectively designed to achieve most of these approaches except certain elements of hands-on, practical exercises.

Online teaching and learning demands reliable resources to get online and a computer, laptop, tablet or a smart phone at home. According to the National Center for Education Statistics (USA), only 87% of U.S. households own or use a computer at home and where only 77% had access to the Internet [17]. It also reported that the United States had higher percentages of students with computer and internet access in comparison with other countries. This clearly highlights the scale of the challenge of reaching every single student during an online delivery mode. An article by Mezzacappa and Wolfman-Arent stated, "to ensure equity, remote instruction should not be provided to students, including through the internet, technology at home, by phone, or otherwise" [18].

With the spread of COVID-19, Lanka Education and Research Network (LEARN) is providing uninterrupted connectivity to students and academic, research and support staff of research and education institutions in Sri Lanka. The University Grants Commission (UGC) and Telecommunication Regulatory Commission of Sri Lanka (TRCSL) has come to an agreement with network providers in Sri Lanka to provide free access to University Learning Management System (LMS) for the academic community during the period of the COVID-19 outbreak [19].

3.3. Impacts on Assessment

Assessment is the measurement of learning that comprises measuring knowledge, skills, and abilities of a student. Assessment normally has two components: formative assessment through continuous means and summative assessment as mid- or end-of-semester examinations. With the outbreak of COVID-19, the end-of-year or end-of-semester examinations in the northern hemisphere had been cancelled or suspended by many examining bodies, with a knock-on impact in the southern hemisphere [20]. In some universities, personalised online examinations were held.

Khan discusses the assessment techniques that can be used when delivering a module through synchronous or asynchronous modes [21]. Out of different techniques such as assignments, Assessment Portfolios, Multiple Choice Questions, Open Book Exams, Objectively Structured Practical/Clinical Examination and Viva Voces, only the last two options are available for assessment of laboratory examinations. However, both these options require a good internet connection between the examiners and students as the requirement is that they be carried out synchronously.

Related to the assessment process, online evaluation has become one of the most concerning aspects of the COVID-19 pandemic for two reasons. First, educators should redesign their on-site evaluation in order to meet distance learning and assessment requirements. Secondly, it is unclear how to ensure that students follow the instructions and do not use additional material (deemed to be inappropriate) in their evaluation tests without the direct supervision of teachers [22]. The paper also discusses four methods that can be used for assessment: linear tests (which require all students to take the same assessment in terms of the number and order of items during a test session); computer adaptive test—CAT (which allows dynamic changes for each test item based on previous answers of the student); Multiple Choice Questionnaires (in which a single correct answer must be chosen from a pool of possible answers shown by the system); Open Answer Tests (in which the statements include at least one parameter that will change its value with each execution of the application). Even though most of these assessment methods work for online delivery of content, it is difficult to use them for online delivery of practice. However, Open Answer Tests can be used with customised parameters to minimise student plagiarism and misconduct.

4. Student Experience

The COVID-19 outbreak has disrupted learning activities and the university life of students, and introduced anxiousness about when life will return to "normal". Even though face-to-face teaching is now substituted by online options, very little has been done to fulfil the myriad of opportunities provided by university life for entertainment, leadership, socialising, community engagement, etc.

During the university closure and lockdown, students may be developing feelings of fear, stress, worry, and isolation. Many universities are providing online help for students to overcome these feelings. For example, the University of Melbourne advises students to move to activities that they can do while staying at home so as to continue learning, such as maintaining studies, reading a book, listening to a podcast, trying out a new hobby or skill, starting a virtual book or movie club, joining an online group or peer forum, etc. [23]. In addition, students will have plenty of opportunities to expand their education. There are a good number of options such as Coursera, FutureLearn, and edX available for one to pick from, develop skills and acquire knowledge.

There is a high probability of graduating some of the COVID-19 cohort of students without adequate laboratory skills and practice; they may be at a long-term disadvantage, compared to those who studied "normally," when they move to another level of study or enter the labour market [20].

The opportunities to obtain collaborative learning experiences enhance the effectiveness of learning. Müller and Ferreira report how online labs allow students to work together as peers, applying their combined knowledge to the solution of a problem and to test and refine their understanding [11]. Furthermore, they pointed out how the interactions among students provide opportunities to acquire various soft-skills, such as the ability to work in teams and to achieve objectives in co-operation with others and to integrate the know-how of others in order to accomplish a given task. Online delivery through a solely asynchronous mode at best hampers and at worst denies most of the above opportunities.

5. Quality Assurance

For quality assurance, benchmarking is used to identify examples of excellence and best practice, and then these examples are used as the standard of comparison. Ensuring quality in online education is not primarily a question of IT support, but of academic strategy and educational design. Oliver states that the successful application of e-learning depends on such aspects as the scope and nature of the learning materials, appropriate selection of the learning design and resources and the manner in which it is delivered and supported [24]. These elements can be isolated and identified for benchmarking purposes.

The European Association for Quality Assurance in Higher Education published a document with standards and indicators for quality assurance for e-learning courses [25]. It states that the institutional policies for e-learning may include the constituent elements of quality such as institutional support, course development, teaching and learning, course structure, student support, faculty support with compulsory e-learning training for new members of staff, technological infrastructure, student assessment (learner authentication, work authorship and examination security) and certification, and electronic security measures.

The UK Quality Assurance Agency (QAA) issued a set of guidelines for Practice and Lab-based Assessment [26]. QAA has developed this guidance with their members and sector bodies for the benefit of the UK higher education community. It recognised that often there exists an element of psychomotor skill and competence involved in using or manipulating equipment and states that the method of assessment of these can be modified so that it can take place remotely. The alternative methods that can be used for remote assessments include presenting students with datasets and asking them to interpret them, using remote simulations such as an experiment being conducted in a video presentation where students can see the data being produced and finding programming tasks that can be undertaken remotely rather than in a laboratory. The QAA document also states that such remote assessment methods should consider the degree to which the learning outcomes assess skill and competence in the use of equipment, and if the learning outcomes require the demonstration of laboratory skills using laboratory equipment, then those assessments have to be postponed. However, if the competence in handling equipment has already been demonstrated elsewhere in the course, then even if such a skill is listed as a learning outcome of the module, the assessment of that particular competence can be ignored.

6. Discussion

Several of the key issues for online methods of laboratory and workshop-based learning have been identified and discussed. Perhaps one of the most profound is the student experience, referred to, often universally, as a stalwart of higher education programmes. Many university promoters lament that the student experience is made worthwhile by the presence of people in the place of campuses. Laboratories might well be viewed through the lens of one of these communities within a community. This raises the question of the importance of culture and environment in the learning experiences of students; the accidental, serendipitous, casual encounters in which bonds are formed with peers and learning is convivial will be replaced. It is important that these connections amongst learners are not eradicated and that they persevere as a pivotal part of any good programme, in a different format. The social development of group cohesion, trust, respect, and belonging in order to build a community of learning [27] will be one that we have a responsibility to maintain, no doubt using ingenuity and innovative approaches to establish and build connections.

As Garrison states: "cohesion and sense of belonging are essential attributes in a community of inquiry" [28]. The student experience of the near future will require universities to respond differently to the challenges bought about by COVID-19. Universities will have to continue to think carefully about how provision for well-being is delivered. Laboratories contribute substantially to the social development of scientists and engineers where the exogenous relationships formed with others teach the life skills required in communication and teamwork. In a world where less face-to-face interaction is being actively encouraged, this poses a risk to students who may find it too easy to become even more disengaged with their peers and networks. The exacerbation of isolation can be mitigated by the blending of in-person teaching with high quality online learning: the latter is a place where the interactivity of the learner with others is more important than ever. This will help ensure the student experience continues to be a major distinguishing feature and developmental benefit of university education.

Effective university teachers will, in the future, alter their methods of instruction to support high quality learning and engagement that is enriching. The goal here is to seize the opportunity of reaping benefits, which include customised training, increasing engagement in learning, use of multimedia, acceleration of expertise through scenarios, and learning through digital games [29]. All of these have potential application in laboratory-based training. In attempting to elicit such benefits, teachers themselves will be subject to significant learning both in a move to different pedagogic approaches as well as needing to become expert users in the technologies employed. Acquainting themselves with the pedagogic theory of online-learning is the first step and many are doing this; such a transition needs to be followed by enacting best practice such as the five-step approach to e-moderating model [30] put forward by Salmon. The use of certain methods such as discussions can help students interrogate, reflect on and revise their ideas [31].

As the plethora of challenges emerge in a post COVID-19 era, naturally many are looking to technology to provide large parts of the response and to feature heavily in the future of distance learning. Some advocates view technology as the panacea that has enabled large portions of the developed world to work and learn remotely. Indeed, we have described earlier how solutions utilising cutting-edge virtual reality technology have been shown to be remarkably well-placed to help deliver remote sessions for laboratories. Access to the internet, however, is far from equal across the globe, and some commentators have argued that its access should be a basic human right [32], but with 19% of individuals in the least-developed countries accessing the internet [33], the pandemic has brought into clear focus existent inequality. Having materials and strategies for teaching via distance learning post COVID-19 is only the second half of the battle; the first is to ensure our learners have the infrastructure to be able to access the content, via the internet.

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Online Education in the Post COVID-19 Era: Students' Perception and Learning Experience

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Abstract: Students' learning experiences and perceptions are markedly influenced by the use of digital technology during the COVID-19 pandemic. Exploring students' perception of blended online learning, amid the adaptations of the higher education sector in the wake of uncertainty, has become more critical than ever. This paper reflects on the experience of learning and teaching the Research Methods and Techniques subject in the postgraduate programme of MA Urban Design at Cardiff University during COVID-19 in the UK. To do so, we designed and carried out an online survey to explore students' perception of online teaching and learning activities, feedback and assessment, and digital platforms based on their experience during the subject delivery period in the 2020–2021 academic year. One of the significant findings of this paper was that students agreed with the impact of eye contact on their virtual learning experience but as long as this was aligned with their rights to see others, including their peers and instructors, rather than reciprocal rights to be seen. In addition, students felt that facilitating synchronous communication through effective interaction among diverse peers has been quite challenging in small-group online reading seminars. The majority of respondents also reported that attending live online lectures was more helpful than watching pre-recorded lectures. Online formative feedback and synchronous interim reviews also allowed students to reflect on their progress and develop their projects further before their summative assessment. The outcomes of this paper can effectively assist educators who consider delivering programmes, adopting a blended online learning environment design model, in the post COVID-19 era. The findings of this study can also provide guidance for further developments and improvements in using digital technology and blended online learning in urban design education and pedagogy.

Keywords: student experience; postgraduate; online learning and teaching; higher education; online education; blended online learning; COVID-19; post-pandemic; public health; pandemic; technology; urban design; research methods

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1. Introduction

The rapid changes and disruptions caused by the unprecedented spread of the COVID-19 pandemic continue to transform learning and teaching experiences and the broader higher education landscape. The dynamics of online education, across different contexts during the pandemic, have received a considerable scholarly focus in the higher education literature to date [1–3]. Institutions' fast-paced move into the blended or hybrid models and the widespread adoption of digital technologies for course redesigns and pedagogical transformations have engendered significant challenges for both students and academic communities [4,5]. These discussions have extensively influenced the understanding of the impacts of emergency use and integration of online and other types of digitalised learning and teaching on the role of university instructors and post-pandemic higher education. There has been, however, far less scholarly attention devoted to the role that the technology-enabled online course delivery can play in students' perceptions and learning experiences.

This paper focuses on the experience of teaching and learning the Research Methods and Techniques subject in the postgraduate programme of MA Urban Design at Cardiff

University amid COVID-19 in the UK (Spring 2021). The subject was delivered using a blended online delivery mode. We begin from the view that exploring students' perception and learning experience, particularly in terms of the capacities and challenges of the online mode of delivery, is integral to the ways in which the relevant learning and teaching communities can engage with embracing a post-pandemic evolution and initiating effective adaptations in higher education.

The overall nature of the present study is exploratory with a single case study approach. The importance of case study, in the context of education research, as a key method has been previously acknowledged [6], which offers instructors a range of experiences to become prepared and more effectively cope with various situations. To collect information on students' perceptions of online learning and teaching activities, we designed and carried out an online survey. In this paper, we start by summarising the existing literature on online learning and teaching in higher education, digital technology and student perception, and COVID-19 and Online learning and teaching. We then discuss methods with a particular focus on online survey design and dissemination, which is followed by case study analysis and discussion of the findings in relation to the key themes of online learning and teaching activities, feedback and assessment, and digital platforms.

2. Higher Education and the COVID-19 Pandemic

2.1. Online Learning and Teaching in Higher Education

The capacities and challenges of online education have been extensively studied and discussed worldwide over the past two decades [7–10]. In light of the rapid evolution of information and communication technology (ICT), academic discourse and educational practices of teaching and scholarship have changed markedly. The fast-changing speed and power of communications technology as well as the enhanced capacity to link space and time for teaching methods and higher education objectives, have been further acknowledged [11,12]. As such, today's higher education community has faced a new generation of individual learners—what Prensky [13] calls the "digital natives"—whose thinking and learning are deemed as different from the less digitally-proficient instructors —"digital immigrants". It is notable that educators today attend to these differences and the ways in which this knowledge can be used to enable a more engaging, interactive, and, indeed, more effective learning environment [14]. This is a generation of students heavily influenced by the pervasive digital media that have not only developed certain skills and qualities in adopting digital technology but also have acquired a range of new learning styles and skills utilising them. Dede [15] outlines such learning styles as "active learning based on experience", "learning based on collectively seeking, sieving, and synthesizing experiences", "co-design of learning experiences personalized to individual needs and preferences", "expression through non-linear, associational webs of representations rather than linear stories", and "fluency in multiple media".

The literature on online learning and teaching in higher education has seen a growing interest in the study of key challenges in relation to the online mode of delivery besides the associated capacities. Dumford and Miller [9] argue that the students enrolled in online courses are often less engaged in collaborative learning, student-faculty communication, and discussion with their peers than their counterparts in traditional face-to-face courses. It has also been noted that major challenges for online education include developing core professional qualities—namely, the acquisition of interpersonal and practical skills, communication skills, sustaining student retention rates, and effective use of online technologies [16]. Challenges have also been raised by educators whilst adapting some activities, such as performance assessment, to the virtual learning environment avoiding the loss of content knowledge or effective interactions between learners and/or educators [17].

The emergence of a range of learning scenarios and pedagogical models have extensively informed practices of online learning and teaching in the higher education context [7,18]. Nevertheless, a less addressed challenge is "not whether online courses will replace classrooms, but whether technology will drive the redesign of teaching and learning" [16] (p. 1). Making clear distinctions between online and on-campus models of learning and teaching has been at the forefront of online education discourse. What matters here is to understand how to best support innovative and collaborative learning and teaching activities, utilising emerging instructional technologies regardless of the medium of delivery. It is also useful to understand what form of technology—varying between online recorded lectures, in-built assessment, collaborative digital subjects with flexible learning environments, and remote simulation [16]—enable a certain pedagogy or changing the existing pedagogical model [19]. As Johnson et al. [20] indicate, "simply capitalising on new technology is not enough; the new models must use these tools and services to engage students on a deeper level" (p. 9). This also lends itself well to other researchers' arguments that giving primacy to technology over pedagogy is a barrier to successful technology integration and, indeed, effective teaching and learning strategies in higher education [21,22].

Online learning and teaching can act as complementary to the dynamics involved in face-to-face learning. This accords with today's blended learning approaches and designs as the most popular pedagogical concepts and course delivery models in higher education [23]. As Garrison and Vaughan [24] outline, a blended learning environment is featured by the mix of rigorously selected online and face-to-face methods and designs in alignment with students' performance and learning objectives of certain coursework. To bring about more effective blended learning and teaching, a multifaceted approach is then required [18]. The remaining question here would be to understand which course delivery model stands as the students' favoured learning and teaching design—blended, fully face-to-face, or online choices.

2.2. Digital Technology and Student Perception

Students' perceptions, attitudes, preferences, and expectations regarding higher education providers are influenced markedly by the use of digital technology. Norton, Sonnemann, and McGannon [16] indicate that competition between different online and on-campus courses will be most likely, according to which desires and motivations to blend digital technology and in-class learning and teaching will come to the fore. Despite the commonly held critique that digital technologies are "transforming" the nature of university learning and teaching or, in some cases, even disrupting the "student experience", digital technologies will inevitably continue to be integral to the future of university education and higher education community around the world [25–28]. According to a recent study, students support certain forms of blended learning, primarily due to the in-class lectures with the possibility to enable effective engagement with the course materials, teaching staff, and other learners, and they view digital technologies as an integral tool to promote and sustain such a level of engagement [29]. Nevertheless, another recent report outlines the key challenges that can impede technology adoption as "the evolving roles of faculty with ed tech strategies", "increasing demand for digital learning experience and instructional design expertise", "improving digital fluency", "rethinking the practice of teaching", and "advancing digital equity" where the first two seem to be the most solvable [23].

Digital technology is a seminal aspect of the postgraduate students' perceptions and learning experiences. Hence, there has been scholarly attention paid to the capacity of digital technology to support and enhance students' experience during their university learning and teaching. Moreover, as discussed in the previous section, today's new generation of students, as "digital natives", are more digitally attuned and adept than previous generations. In this sense, Wright et al. [30] have discussed how university learners, as digital "residents", are accustomed to perceiving digital technologies as seamless and interactive social spaces. In this case, digital spaces (e.g., the internet) act as a way of life rather than merely a form of functional tool. Hence, a central question here is to address why students engage with certain forms of digital technology in university learning and teaching. More recently, Henderson, Selwyn, and Aston [25] seek to answer this question and explore those aspects that individual learners consider notably helpful. To this end, they investigate 1658 undergraduate students' actual experiences of digital technology. Results revealed 11 particular digital "benefits" varying between the flexibility of place and location and organizing and managing the logistics of studying to the ability to review, replay, and revise digital learning materials [25].

2.3. COVID-19 and Online Learning and Teaching

The past year's disruptions and rapid changes by the unprecedented spread of the COVID-19 pandemic have transformed the higher education landscape. As such, the dynamics of online education, across different contexts during the pandemic, has received a considerable scholarly focus in the higher education literature to date [1–4]. The fast-paced move into the online dimensions of blended learning and the widespread adoption of digital technologies for course redesigns and pedagogical transformation have engendered significant challenges for both students and the academic community [4,5]. Gamage, de Silva, and Gunawardhana [1] discuss how the COVID-19 pandemic, and the increased use of learning technologies to support online course delivery, have posed challenges to academic integrity management and assessment security. A more recent study investigated the experience of online teaching during the COVID-19 lockdown in the UK, as well as the opportunities and challenges associated with the online mode of course delivery [4]. The study found that focusing on pedagogy should be prioritised over focusing on technology following the emergency transition to distance learning. This further highlighted the importance of challenging and exceeding fixed pedagogies to enhance the productive capacities of resilient and adaptive approaches to online teaching and remote learning [3]. In another UK-based survey, a large number of academic respondents from various disciplines and positions debated critically about the dark side of the rapid digital transformation, whereas only a small group of optimistic academics articulated the capacities and viewed the pandemic as an opportunity to deliberate its impacts on higher education [2]. Evidence for these impacts includes "exceeding the tokenism of pedagogic credentialism" (p. 636)—i.e., embracing higher education as a participatory and socially immersive learning experience [2]. These discussions have extensively contributed to the understanding of the impacts of emergency use and integration of online, and other types of digitalised learning, and teaching on the role of university instructors and post-pandemic higher education. Nevertheless, far less scholarly attention has been devoted to the role the technology-enabled learning, teaching, feedback, and assessment can play in students' perceptions and learning experiences.

2.4. Urban Design and Teaching Research Methods and Techniques

Urban design is an area of study in progress, cutting across multiple intersecting disciplines such as Urban Planning, Architecture, Geography, Urban Studies, and Social Sciences, to name a few. Since its establishment as an academic discipline, the primary focus of its education has been on design studio teaching and theory subjects and, further, on urban design research methods. A sophisticated understanding of urban design research methods and techniques can enable a more informed approach to design intervention. Undertaking what is known as "research-based" or "evidence-based" design intervention relies on a nuanced understanding of research methods, which can most effectively inform urban analysis and design practice.

Urban design thinking is essentially multi-disciplinary and, as such, addressing any research questions is geared to informed selection and analysis of case studies, as well as looking hard at cities [31], and using multiple scales and methods of analysis [32]. Teaching research methods and techniques offers a key medium in urban design pedagogy, assisting individual learners to critically observe, understand, explore, and analyse cities [4]. It is then critical for students to articulate rigorous and non-reductionist methodological frameworks for urban design investigations. This is to say that there is no single research method that explains the multi-disciplinary and multi-scalar conceptual frameworks in urban design thinking [33,34]. In this pursuit, the best urban design research methods teaching inspires learning about various relationships, liaisons, and capacities of urbanity. There has been a limited scholarly focus on developing practical pedagogical frameworks, based on multiple urban design research methods, which can become effective in a state of uncertainty such as the COVID-19 pandemic. In this paper, we study students' perception and learning experience of online teaching and learning environment in the Research Methods and Techniques subject in the MA Urban Design postgraduate programme at Cardiff University amid the COVID-19 in the UK. This subject enables individual learners to develop methodological understanding and critical thinking in relation to the less empirically explored questions of urban design [4,32] and to how cities work in relation to sociality and spatiality, as well as expression and materiality [35,36]. We carried out an online survey (discussed in more detail in the next section) on students' perceptions of online learning and teaching activities, based on their experience during the subject delivery period in the 2020–2021 academic year.

3. Methods

The present study is exploratory in nature and adopts a single case study approach [37] to diagnose and describe processes by observing their developments and contextual impacts [38]. Timmons and Cairns [6] have addressed the importance of case study, in the context of education research, as a key method for instructors to encounter a range of experiences that can train and prepare them to more effectively cope with various situations. For the delivery of the Research Methods and Techniques subject, we chose the blended online delivery mode—what has been referred to as "blended online learning environment design model" [39]. The article was initially written after the completion of the subject assessment and student evaluation in July–August 2021.

3.1. Survey Design

The online survey was designed to collect information on students' perception of online learning and teaching activities, based on their experience in the Research Methods and Techniques subject, in the 2020–2021 academic year. Students' perspectives were deemed as important to the learning and teaching community, and the questions in the online survey were designed to help us understand students' learning experience and perception of the online mode of delivery, particularly in relation to the capacities and challenges of online learning, teaching, assessment and formative feedback, and digital platforms. To this end, the online survey was designed and disseminated using the Google Forms survey platform. When the participants commenced the survey, they were provided with information about the research project aim and were notified that their participation in the online survey was entirely voluntary, anonymous, and would, in no way, impact their subject assessment. The students were also informed of their rights to withdraw from the online survey at any stage. This research project received ethics approval from the Welsh School of Architecture Ethics Committee at Cardiff University. Students were also notified that all their responses would be kept confidential in accordance with the ethical considerations. Participants did not need to answer any or all questions, and they could also decide not to take part in the online survey at any point. The first question collected information about relevant demographic information (i.e., gender). This was followed by closed-ended questions—Likert Scale questions (i.e., strongly agree, somewhat agree, neither agree nor disagree, somewhat disagree, strongly disagree)—designed to explore respondents' experience and perception of the online mode of delivery. Finally, respondents were asked to share any other comments that were not covered in the previous questions of the survey.

3.2. Survey Dissemination

After being thoroughly tested to ensure accuracy, the online survey questions were shared with the Welsh School of Architecture Ethics Officer. In the light of some comments and recommendations regarding the clarity of the survey questions and the functionality of the online survey as a whole, we updated the related questions before the survey was disseminated to the students. The target population for this survey was about 82 MA Urban Design students at Cardiff University in the 2020–2021 academic year. The link to the online survey was distributed utilising the announcement page on Learning Central (LC) online platform—Cardiff University's primary virtual learning and teaching environment. In addition, students were sent multiple emails with relevant information and a link to the online survey. Students were also reminded of their participation in the online survey in the live online lecture and small-group reading seminars by the subject leader and tutors. Students had the opportunity to respond to the survey that was active online for about 40 days. The survey gathered N = 28 responses from students, and the respondents were evenly representative between females and males, with 50% (N = 14) female and 50% (N = 14) male respondents.

3.3. Case Study

The Research Methods and Techniques subject was delivered online using a mix of synchronous and asynchronous learning and teaching activities. Table 1 shows how the subject was delivered online in relation to the key themes of learning and teaching activities, assessment and feedback, and digital platforms. Table 2 shows the student responses in relation to the survey questions (N = 28).

Table 1. The Research Methods and Techniques subject online mode of delivery.

			Delivery Mode
Learning and teaching activities	Lecture		Online and often synchronous with subject leader/invited guest lecturers with supplementary asynchronous online material (e.g., recorded lectures)
	Small-Group Reading Seminar		Live online synchronous reading seminars with tutors
	Discussion Session		Live online synchronous discussion sessions with the subject leader
Assessment and formative feedback	Formative Feedback	Sessional oral feedback	Live online during synchronous lectures and discussion sessions by the subject leader with supplementary asynchronous online material
		Interim review sessions	Online parallel sessions with the format of individual student presentations followed by feedback from critics
	Summative Assessment		100% research proposal (2000-word); Electronic submission online; Written feedback online using a consistent structure
Digital platforms	Synchronous		Zoom (e.g., live online sessions)
	Asynchronous		Learning Central (e.g., weekly module maps, reading lists)

Table 2. Survey Questions (Q1–Q18) with responses (N = 28).

Survey Questions	Response (%)
Q1. What is your gender?	50% Female 50% Male
Q2. The use of the weekly module maps has been helpful for your learning experience.	32.1% Strongly agree 64.3% Somewhat agree 3.6% Neither agree nor disagree 0% Somewhat disagree 0% Strongly disagree
Q3. Interim presentation and live online formative feedback will be helpful for your learning experience.	42.9% Strongly agree 50% Somewhat agree 7.1% Neither agree nor disagree 0% Somewhat disagree 0% Strongly disagree
Q4. Students attending live online sessions should be expected to switch on their cameras for the duration of the session.	21.4% Strongly agree 28.6% Somewhat agree 39.3% Neither agree nor disagree 10.7% Somewhat disagree Strongly disagree
Q5. Switched on cameras will be helpful for your learning experience during the live online lecture sessions.	22.2% Strongly agree 40.7% Somewhat agree 25.9% Neither agree nor disagree 11.1% Somewhat disagree 0% Strongly disagree
Q6. Switched on cameras will be helpful for your learning experience during the live online reading seminars.	42.9% Strongly agree 32.1% Somewhat agree 21.4% Neither agree nor disagree 3.6% Somewhat disagree 0% Strongly disagree
Q7. Switched on cameras will be helpful for your learning experience during the live online discussion sessions.	50% Strongly agree 28.6% Somewhat agree 21.4% Neither agree nor disagree 0% Somewhat disagree 0% Strongly disagree
Q8. Your computer and the technology you used are good enough for online learning and teaching.	39.3% Strongly agree 39.3% Somewhat agree 10.7% Neither agree nor disagree 10.7% Somewhat disagree 0% Strongly disagree
Q9. You have had access to fast and stable internet connection.	21.4% Strongly agree 53.6% Somewhat agree 10.7% Neither agree nor disagree 14.3% Somewhat disagree 0% Strongly disagree
Q10. Your accommodation/home environment has been appropriate for online learning and teaching.	35.7% Strongly agree 32.1% Somewhat agree 21.4% Neither agree nor disagree 10.7% Somewhat disagree 0% Strongly disagree
Q11. How satisfied were you with the quality of the online learning and teaching in this module?	35.7% Very satisfied 42.9% Somewhat satisfied 17.9% Neither satisfied nor dissatisfied 0% Somewhat dissatisfied 3.6% Very dissatisfied

Table 2. *Cont.*

Survey Questions	Response (%)
Q12. How satisfied are you with the live online delivery of the lectures?	32.1% Very satisfied 50% Somewhat satisfied 7.1% Neither satisfied nor dissatisfied 7.1% Somewhat dissatisfied 3.6% Very dissatisfied
Q13. How satisfied are you with your interaction with the module leader in the live online discussion sessions?	37% Very satisfied 51.9% Somewhat satisfied 3.7% Neither satisfied nor dissatisfied 7.4% Somewhat dissatisfied 0% Very dissatisfied
Q14. How satisfied are you with the live online reading seminars?	32.1% Very satisfied 50% Somewhat satisfied 7.1% Neither satisfied nor dissatisfied 7.1% Somewhat dissatisfied 3.6% Very dissatisfied
Q15. How satisfied are you with your interaction with the tutors in the live online reading seminars?	42.9% Very satisfied 42.9% Somewhat satisfied 3.6% Neither satisfied nor dissatisfied 7.1% Somewhat dissatisfied 3.6% Very dissatisfied
Q16. How satisfied are you with your interaction with the other students in the live online reading seminars?	10.7% Very satisfied 35.7% Somewhat satisfied 25% Neither satisfied nor dissatisfied 14.3% Somewhat dissatisfied 14.3% Very dissatisfied
Q17. Attending live online lectures will be more helpful than watching pre-recorded lectures.	42.9% Strongly agree 39.3% Somewhat agree 14.3% Neither agree nor disagree 3.6% Somewhat disagree 0% Strongly disagree
Q18. Please share any other comments that have not been covered in the previous questions.	*"Pre-recorded Lecture were very helpful. I did feel that interaction in some cases was more in online session rather than face to face sessions. However, many students (with cameras off) were sidelined in the online sessions due to non participation."* *"...only 2/3 students talk in the seminar reading sessions"* *"PLEASE let us back to the in-person class as much as u can..."* *"There's a tendency for monologue rather than dialogue, even with question and discussion part of zoom meetings, which reduces engagement."* *"Because of pandemic majority of modules (lectures and seminars) became online. However, I strongly believe that having face-to-face lectures and seminars (especially seminar) will be more productive if they will be held offline."*

4. Analysis

4.1. Learning and Teaching Activities

The subject was delivered through an online mode of delivery, incorporating a mix of synchronous and asynchronous learning and teaching activities and materials. A range of urban design methods was introduced in lectures/guest lectures and further discussed live online in small-group reading seminars. The academic content of the subject was primarily delivered via a series of lectures and guest lectures. These lectures presented the core knowledge that learners required to develop their individual research proposals.

Online lectures and invited guest lectures were primarily synchronous, using Zoom as the main online platform. In addition, some asynchronous pre-recorded lectures about literature search and annotation, library resources, research ethics, unfair practice, and referencing conventions were made accessible via the Learning Central online platform. As Table 1 shows, in addition to lectures and small-group reading seminars, live online weekly discussion sessions were designed to further support students and address possible questions. A weekly drop-in session was also allocated for informal discussions and possible questions to support individual learners throughout the process. All live online sessions took place over Zoom during the teaching weeks of the subject. A considerable number of students (78.6%) were satisfied with the quality of the online learning and teaching in this subject. Nevertheless, a small number of respondents (3.6%) were dissatisfied with the online learning and teaching activities. More particularly, the satisfaction rate among our respondents was 88.9% for the live online delivery of the discussion sessions and 82.1% for the live online delivery of the lectures and reading seminars. For the majority of our respondents (82.2%), attending live online lectures was more helpful than watching pre-recorded lectures. Only 3.6% of students were somewhat against this viewpoint. In their specific comments, students found live online lecture recordings quite helpful for their learning experience. The idea of recording the live online lectures, and making them available on Learning Central, facilitated asynchronous learning and enabled students to review lecture materials at their own time and pace.

The possibility to interact with the subject leader in the live online weekly discussion sessions was perceived as high, with 88.9% satisfaction rate among students. Using Zoom for such live online sessions provided individual learners with opportunities to use a mix of text-based and oral communications with their subject leader. Several reticent learners seemed to be more comfortable communicating through a textual, rather than oral, medium. This has also been evidenced in student comments where live online sessions in this subject have been perceived as more interactive compared to face-to-face sessions in their other subjects. While the satisfaction rate was significantly high (85.8%) regarding students' interaction with their tutors in the live online reading seminars, it was relatively low (46.4%) regarding students' interactions with other students in the same live online seminars (i.e., with 28.6% dissatisfaction rate). According to some student comments, facilitating synchronous communication through effective interaction among diverse peers has been quite challenging:

> *"There's a tendency for monologue rather than dialogue, even with question and discussion part of zoom meetings, which reduces engagement."*

> *"... many students (with cameras off) were sidelined in the online sessions due to non-participation."*

In addition to the core learning and teaching material of the subject, "Weekly Module Maps" (WMMs) were developed to provide students with an overview of the key learning and teaching activities, in relation to indicative time commitments per week, and outlining where the related material is located on Learning Central. The key takeaways of the learning activities and the ways they were related to the assessment criteria and learning outcomes of the subject were further specified. The WMMs were made accessible on Learning Central prior to the commencement of the subject, so individual learners could navigate through the subject schedule outline, content, and the associated learning and teaching activities. Students were offered the opportunity to plan as appropriate and to reflect on their learning experience and progress, particularly in relation to the learning activities and outcomes. We also mapped the primary learning and teaching activities, using consistent colour codes across the relevant documents of the subject, to enhance the readability of the WMMs. The importance of WMMs for students learning experience was also highlighted by many survey respondents (96.4%).

4.2. Assessment and Feedback

The subject incorporated a mix of formative feedback and summative assessment. The summative assessment, in this subject, included a 2000-word written research proposal attracting 100% of the total mark. The design of the summative assessment aimed at enabling constructive alignment with the related learning outcomes and activities. A detailed coursework brief document called "Assessment Proforma" was provided to identify and communicate the key information, such as learning outcomes, mode, and type of assessment, length and duration of the assessment, percentage contribution to subject mark, marking criteria, submission date, moderator, marking team, and feedback return date and method. It also provided detailed instructions regarding the choice of potential supervisors (for the following dissertation subject) in alignment with each supervisor's research expertise, research proposal structure, formatting, and referencing conventions. Such specific and structured instructions could support individual learners in developing their research proposals for summative assessment and enable a degree of fairness and consistency in their assessment.

Formative feedback allowed subject tutors to gauge students' learning progress through synchronous interim review sessions. These innovative interim review sessions were designed and implemented in the last teaching week of the subject to provide students with equal opportunities to individually present a copy of their work-in-progress research proposals and receive focused and timely feedback from internal/external critics. The critical role of such interim review sessions, and their capacity to feed forward, in the context of urban design education have been discussed elsewhere [40]. As such, students could most effectively develop their research proposals for summative assessment. Furthermore, the provided formative feedback was aligned with the assessment criteria identified and communicated in the Assessment Proforma. In addition to interim review sessions, live synchronous lectures, discussions sessions, and small-group reading seminars offered learners the opportunity to receive sessional oral feedback from both their instructors and peers (particularly in reading seminars). According to the survey results, 92.9% of the respondents thought live online formative feedback and interim reviews were useful for their learning experience. Examples of the related individual comments are as the following:

> *"...interim presentations were very helpful."*
>
> *"Feedbacks are timely."*

4.3. Digital Platforms

As previously noted, Learning Central and Zoom were the primary digital learning and teaching platforms used in the online delivery of this subject. We identified some of the capacities and limitations of both these digital platforms for the online delivery of the subject. Learning Central was used as the key environment to facilitate asynchronous teaching and learning, whereas Zoom enabled various synchronous teaching and learning activities. Subject materials, including schedule outline, recorded lectures, lecture slides, reading lists, assessment brief, and other supporting documents and links, were made available on Learning Central to facilitate asynchronous learning. As such, individual learners could access and review the primary learning materials almost anywhere, anytime, and at their own pace. This is supported by the survey results that only 3.6% did not seem to be satisfied with the quality of the online learning and teaching in this subject, although 10.7% and 14.3% of survey respondents, respectively, noted their lack of good computer and technology as well as limited access to a fast and stable internet connection. All live online sessions took place over Zoom during the subject's teaching weeks. Unlike the Learning Central platform, the use of Zoom for live online sessions (lectures, discussion sessions, and reading seminars) offered students opportunities to use a mix of oral and text-based communications. More particularly, many respondents (82.2%) perceived live online lectures via Zoom as more helpful for their learning experience than watching pre-recorded lectures. Using cameras in online platforms to facilitate learning and enable social interaction has been a burgeoning challenge [3]. While using Zoom could enable the visibility of all the attendees with open cameras simultaneously during synchronous teaching and learning, only 50% of respondents thought students attending live online sessions should be expected to switch on their cameras for the duration of the session. Nevertheless, it is notable that respondents generally thought switched-on cameras would be helpful for their learning experience—i.e., 62.9% during the live online lecture sessions, 75% during the live online reading seminars, and 78.6% during the live online discussion sessions.

5. Discussion and Conclusions

The extent to which higher education transformations have taken root and will persist into the post-pandemic future remains a key question, particularly considering the surging need for developing and implementing adaptive teaching, learning environments, and incorporating innovative remote technologies and digital networks into course designs. At stake is the role of academia to remain reflective on its practices that will be important for shaping the future of learning and teaching in higher education. Adoption of online, blended, and hybrid models for course delivery, according to the ebbs and flows of the pandemic, has arguably accelerated the evolution of higher education. As such, the higher education sector has probably become somewhat inventive in creating a diverse spectrum of new course models to cope with such a challenging situation. Understanding and gauging students' perceptions and learning experiences are deemed as crucial in the processes of integrating online and in-person forms of course delivery, as well as implementing blended learning [41]. In the following, we will discuss our findings associated with the capacities and challenges of online learning and teaching with a particular focus on students' perception and experience of digital technology.

The use of digital technologies to enable and sustain communication and collaboration among fellow students has been viewed as a key challenge linked to the blended online mode of delivery. These issues were glaringly exposed by the pandemic and particularly came to the fore in the context of urban design education and pedagogy, which aim to help students develop interpersonal, communication, and teamwork skills through sharing ideas, exchanging information, and peer learning. This resonates with the idea that learner-learner communication and collaboration are crucial to effective small-group discussion and interactions in higher education environments [42]. The results from the student survey show that, while live online reading seminars enabled student-tutor interaction in small groups (with an overall satisfaction rate of 86%), it fell short in facilitating online synchronous communication through effective interaction between diverse students and their peers (with about 29% dissatisfaction rate). This partly supports the argument that, unlike face-to-face learning environments, online courses are less likely to offer students the opportunity to engage with their peers and develop close associations with each other [9,43]. As such, students cannot effectively develop core professional qualities such as interactivity, interpersonal, and practical skills which can, in turn, constrain their capacity to build a strong learning community [16]. Nevertheless, according to the survey results, live online discussion sessions were perceived as more effective, offering students a rich virtual setting in which they could raise and discuss questions using oral and/or textual means of communication in real time (synchronously). It is important to note that such synchronous discussion sessions are not without challenges. For instance, teaching staff are expected to manage multiple verbal cues and increased demands on time while keeping track of live non-verbal queries in the chat box and responding to them [3,44].

Students' capacity to effectively engage in online courses is subject to the accessibility of the internet as well as new, high-quality, regularly updated technological resources and tools necessary to handle the demands of their online coursework [3,43]. The importance placed on the value of this, for students' learning experience, is further supported by the survey results, as 14.3% of the respondents did not seem to have access to a fast and stable internet connection, and 10.7% of the respondents disagreed that the computer and the technology they used were good enough for online learning and teaching. To partly address this challenge, the teaching staff used a mix of synchronous and asynchronous learning materials in the blended online delivery of the subject to provide opportunities for different individual learners. It is nevertheless crucial to note that providing equal access to appropriate hardware and infrastructure needs to be addressed, which otherwise can have further negative impacts on those students who are likely to become less involved with teaching and learning activities. It is also critical to address this challenge before focusing on developing technological literacy skills among students. In the post COVID-19 era, there is likely to be a surge of demand for pedagogically sound and adaptive learning environments, as well as innovations in learning technology and design. As such, those higher education institutions investing in integrating more educational experts and digital learning designers will be more competent to strategically (re)design their curriculums and improve capacity and manoeuvrability within the broader area of digitalised educational landscape [5]. It is, however, worthy to note that any decisions about learning technologies should not be prioritised over the development and design of educational content and the learning objectives [44].

While designing and running synchronous interim review sessions were considerably resource-intensive, the value of such critique sessions to receive formative feedback was acknowledged by the majority of the students (about 93% of the respondents). The value of clear and timely feedback has been previously outlined in relevant higher education studies [45]. According to Sadler [46], timely formative feedback can help students reflect on their performance and progress. It is important to note that there has been limited research exploring the capacities of formative feedback and assessment in the context of urban design pedagogy and education. Reflecting on the performance and progress being made in relation to urban design, learning activities and assignments can be crucial for feeding forward with a focus on the key points that need to be addressed moving forward, so students can effectively develop their projects before the summative assessment [40].

Maintaining non-verbal communication, such as eye contact, is a key part of the learning process in higher education. Nevertheless, it has been a critical challenge for online courses to facilitate a degree of such non-verbal communication and enable learning as a social act using digital technology [3]. Whilst many participants highlighted the importance of switched-on cameras for their learning experience, particularly in the live online small-group reading seminars and discussion sessions, only 50% of the respondents reported that students attending live online sessions should be expected to switch on their cameras for the duration of the session. In other words, a certain number of students prefer not to be expected to switch on their cameras and to be seen by their tutors or other students during synchronous learning and teaching. This is a significant finding, as there has been a limited scholarly focus on this in previous research. We argue that individual learners agree with the impact of eye contact on their virtual learning experience, but only as long as this is aligned with their rights to see others, including their peers and instructors, rather than reciprocal rights to be seen. We further found that many respondents (82.2%) perceived live online lectures (via Zoom) as more helpful for their learning experience than watching pre-recorded lectures. This is also a key finding that can effectively inform the development and adaptation of teaching and learning frameworks in the post COVID-19 era.

We conclude by pointing to some of the related limitations and future research directions. The methodology of this study involved survey research, which often includes limitations, particularly when it comes to exploring the perceptions and experiences of participants. While the study used multiple approaches to encourage online survey participation among the postgraduate students, the response rate remained relatively low. It is important to note that there is no claim here regarding the representativeness of this sample of participants or its adequacy. We would argue, however, that this kind of research on perceptions and learning experiences of postgraduate students in relation to blended online modes of delivery, particularly in the midst of the adaptation of the higher education sector, is both rare and much needed. Following the significant findings of this study, the discussions regarding eye contact and non-verbal communication in a virtual learning experience, along with the questions of rights to see and to be seen among learners and educators, can be explored further in future research on blended online course designs.

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education sciences

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Article

Educational Impact on Ecuadorian University Students Due to the COVID-19 Context

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Abstract: The mobility restrictions imposed in different countries due to the pandemic of Sars-CoV2 has hugely impacted different areas in the world. In this work, impacts on the social areas of Ecuadorian university students such as education, economy, physical and mental health, and access to telecommunications are analyzed. For this work, in a snapshot between May to September 2020, 1841 students from 6 public and 5 private universities from Ecuador were surveyed through 47 questions, which were grouped into 7 mutually exclusive dimensions. The Partial Least Squares Structural Equation Model (PLS-SEM) was used to analyze the correlations between the responses of the questions and the relations between dimensions. Dimensional relations were used to analyze how students perceive online classes, teachers' preparation, mood, and the impact on their learning process due to their decreasing family income. Among the most important results, we found that 63.78% of students want to return to on-site classes regardless of their conditions of Internet connection and their available learning tools (computers, tablets, or cellphones). The results also show that family income has influenced how students access the Internet, Internet connection, technological resources for online learning, and mood. Regarding the relations between variables, we found that older students and students from higher semesters think that online classes are better than face-to-face classes and want to continue in online education.

Keywords: Sars-CoV2; COVID-19; PLS-SEM; university students; Ecuador; educational impact

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1. Introduction

The Sars-CoV2 virus, causing the COVID-19 disease, began in Wuhan, China, in December 2019. COVID-19 was declared a pandemic by the World Health Organization (WHO) on 11 March 2020, forcing the world population to go through curfews and quarantines [1]. By June 2021, almost a year and a half later, 177 million infected people and 3 million deaths were reported [2]. The disruptive effects of the COVID-19 outbreak have caused a considerable impact around the world in different areas such as physical and mental health, education, economy, and telecommunications. In this research, all of these social areas are analyzed among students of several universities of Ecuador.

1.1. Physical and Mental Health Impacts

The COVID-19 pandemic has not only brought regulations to ensure social distancing but also misinformation related to how to treat the disease. The high mortality rate in hospitals has affected the mental health of many people around the world. However, the form and degree of this impact largely depends on the health system, the policies imposed by the governments, and the culture of the country where people live [3,4]. During the curfews and quarantines because of COVID-19, the fear of being infected and the little social contact increased the cases of anxiety, depression, anger, confusion, and post-traumatic symptoms [5–10]. Some studies have reported that the social distancing, self-isolation, quarantines, economic problems, and misinformation are the major contributing factors towards unusual depressive feelings [11]. In Ecuador, people who suffered the biggest psychological impacts were women and young students according to [3,12].

Physical activity was also impacted during the pandemic [13,14]. According to [14], less than 30% of people achieved "sufficient" levels of activity during the lockdowns. Additionally, research shows that the pandemic originated variations in people's eating habits, causing considerable changes in their body weight [15].

1.2. Economy Impacts

By June 2020, the global growth was about −4.9% according to the International Monetary Fund [16]. However, according to the same entity, the expected growth for the end of 2021 is about 6% because of the early implementation of vaccination processes in many countries [17]. Socioeconomic inequality between countries is an important variable to consider when talking about people's mental health [4]. Most of the countries and companies have decreased their production due to the mandatory quarantines around the world. As a result, the income of many families has been lost or reduced [18]. In Latin America, most of the economical activity is based on the agro-industrial sector, which has been impacted by the confinement [19]. In this context, Ecuador reported a growth of −8.86% by the end of 2020 [20]. According to the study carried out by the United Nations Children's Fund (UNICEF), in Ecuador, it is estimated that 3.1 million of children and adolescents felt into multidimensional poverty by the end of 2020. This means that their homes suffered one or more deprivations in education, health, food, housing, work, or social security [21].

Regarding higher education, both public and private universities have been hit hard by the economic crisis [22]. The budget of public universities has been reduced [22] because governments have decreased their incomes. For its part, the budget of private universities has also been reduced because their incomes depend on the payments of the students [23].

1.3. Education Impacts

An area impacted a lot by COVID-19 is education. Since the pandemic began, more than 100 million teachers have been affected, and 1.6 billion of students have lost access to education [24]. In different countries, the academic activities have been greatly affected by generating new educational habits in students and teachers [25,26]. Additionally, the emotional and personal development of students are truncated due to the confinement. In this context, the universities changed their resources and material of the traditional onsite education system to online classes for the complete academic year [27–29].

Surprisingly, some university programs have been positively impacted by virtual education. In a survey of 2197 people, the students of Computer Science felt more prepared, comfortable, and in general they felt better [30]. Similarly, in social sciences, most of the students agreed that asynchronous virtual classes have positive consequences because it opens the possibility of a better time management [31]. However, in disciplines such as medicine or engineering, the negative impact has been significant. The access to the practical learning processes has been lost or changed to a virtual modality, leading to a loss of development of practical skills [32].

1.4. Telecommunication Impacts

During early 2020, the Sars-CoV2 virus rapidly spread worldwide, forcing many governments to impose strict lockdown measures to tackle this pandemic. This significantly changed the people's mobility and the use of their mobile networks and electronic devices. Different business have focused their interest and dependence on digital communication systems [33]. However, worldwide, approximately 3.6 billion people had no access to the Internet by April 2020 [33]. In the US, during 2020, the Internet traffic related to online meetings for work and study activities grew by 300% compared with the past years (before the pandemic). [34]. This problem is worse in Latin America, where only 14% of the rural population has access to the Internet [35].

1.5. Method for Exploratory Studies PLS-SEM

In different exploratory studies, Partial Least Squares Structural Equation Modeling (PLS-SEM) is commonly used for analyzing social areas through questionnaires or interviews [36–40]. For instance, in [40], PLS-SEM was used to analyze the facilities that universities offered to their students in green entrepreneurship intentions during the COVID-19 lockdown. The research proposed in [39] uses PLS-SEM to analyze the intention of university students to abandon online classes during the pandemic. For its part, the study conducted in [38] explores the emotional effects caused by the adoption of new technologies for online classes. Another study [37] used PLS-SEM to evaluate the economic impact and mental health of university students. In this context, the objective of our work is to analyze how the pandemic has affected the learning process of Ecuadorian university students.

1.6. Article Overview

The main contribution of this paper is the identification of relationships among different areas (dimensions) of Ecuadorian university students that have been affected during lockdown. For this analysis, data from 1841 students belonging to public and private universities of Ecuador were used. We have analyzed the factors which influence the students' perception of online classes, such as family income, mood, teacher preparation, and access to learning tools, among others. The exploratory study is carried out among dimensions and responses to questions using Partial Least Squares Structural Equation Modeling (PLS-SEM).

The rest of this paper is organized as follows. Section 2 presents the Materials and Methods, where we describe the dataset and methods used in this work. In Section 3, the creation of the proposed dimensions with each related question is described. In Section 4, the dimensional experiments to analyze the proposed hypothesis, and the results of these experiments are shown and analyzed. In Section 5, a discussion over the results is presented. In Section 6, the findings of this research as well as the outlines of the future work are mentioned.

2. Materials and Methods

2.1. Dataset

The participants in our study are students from 6 public and 5 private universities of Ecuador. The dataset was obtained between May and September 2020. The total number of participants is 1841, between 16 and 41 years old, who answered 47 questions. Of these, 1312 (71.27%) of the participants are men, and 529 (28.73%) are women, as can be observed in Figure 1.

2.1.1. Universities

Out of the 1841 participants, 1235 (67.08%) and 606 (32.92%) students come from public and private universities, respectively.

2.1.2. Provinces and Cities

The participants come from 90 different cities belonging to the 24 provinces of Ecuador. The main cities and their corresponding number of participants can be seen in Figure 2. It is important to note that Quito (in the Pichincha province) and Guayaquil (in the Guayas province) are the largest cities in the country.

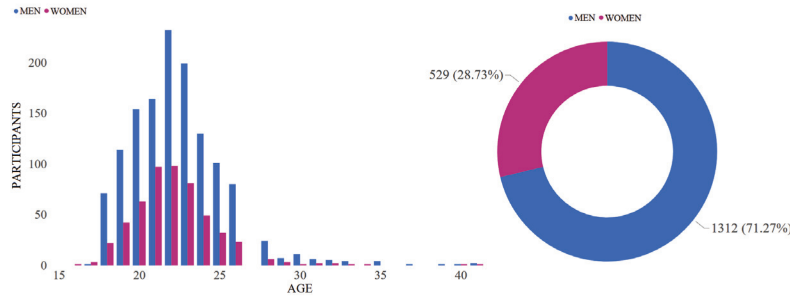

Figure 1. Age histogram of participants and percentage of women and men.

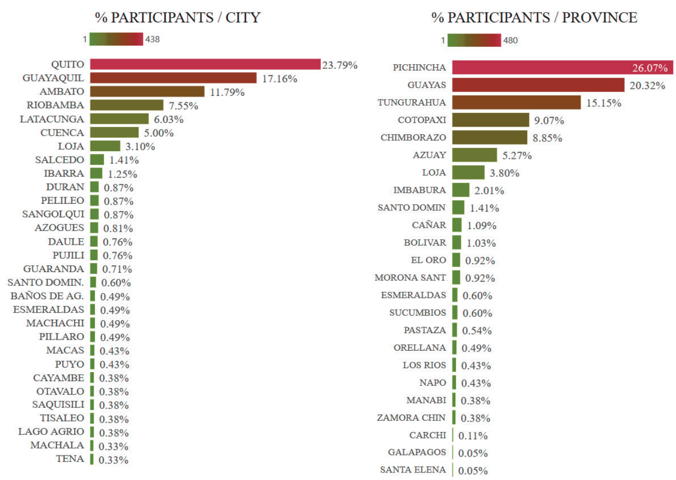

Figure 2. Percentage of participants according to city and province of Ecuador.

2.2. Hypotheses

Different hypotheses have been formulated in our research looking for relationships between responses of questions and latent variables. These hypotheses are described below:

Hypothesis 1 (H1). *Participants' information (age, semester, and educational level) does not affect their opinion about online classes (continue online, qualified teachers, and opinion of online classes).*

Hypothesis 2 (H2). *The mood (emotional state and financial need) affects the students' opinion of the online classes (continue online, qualified teachers, and opinion of online classes).*

Hypothesis 3 (H3). *Family income (income) influences how students access the Internet during online classes (simultaneous PC use, way of Internet access, Internet velocity, and tools for online learning).*

2.3. Method

For SEM, there are two approaches: the analysis of structures of Covariance-Based SEM (CB-SEM), and the Partial Least Squares (PLS-SEM) based on analysis of variance.

CB-SEM and PLS-SEM are commonly used for doing research in social areas [41–43]. To select an specific method, the following premises are recommended [44–47]:

- PLS-SEM is recommended for the identification and validation of the inputs corresponding to a specific dimension (latent construct).
- If the goal is to develop a theory evaluation, theory confirmation, or a comparison of two or more theories, CB-SEM is recommended.
- If the objective is to create an exploratory structural theory, which is our case, PLS-SEM is recommended.

In our work, PLS-SEM is implemented through SmartPLS software version 3.3.3. PLS-SEM methodology presents two measurement approaches: formative and reflective. Formative measures analyze the relationships between dimensions, and reflective measures analyze the influence of variables within a dimension [48]. Figure 3 shows the statistical tests used for the evaluation of the formative and reflective measurement models, and Figure 4 describes the parameters for global evaluation of the structural model.

Evaluation of measurement models

Reflective
1. Inner consistency
(Cronbach's Alpha, Composite Reliability (CR))
2.Convergent validity
(Reliability of the indicator, average variance extracted (AVE))

$$\rho_C = \frac{(\sum \lambda_i)^2}{(\sum \lambda_i)^2 + \sum_i var(\epsilon_i)}$$

$$AVE = \frac{\sum_{i=1}^{i} \lambda_i^2}{\sum_{i=1}^{i} \lambda_i^2 + \sum_{i=1}^{i} var(\epsilon_i)}$$

3. Discriminant validity

Formative
1. Convergent validity
2. Significance and relevance of the path weights

Figure 3. PLS-SEM parameters considered in evaluation measurements [49].

Evaluation of structural models
1. Determination coefficient R^2
2. Predictive relevance Q^2
3. Size and significance of the *path* coefficients
4. Effect sizes f^2
5. Effect sizes q^2

Figure 4. PLS-SEM parameters considered in structural models [49–51].

3. Dimensions

In our research, each question Q_{DN}, where N denotes the number of question, has been grouped into seven dimensions $D \in \{0, 1, 2, 3, 4, 5, 6\}$, where each dimension covers a particular topic. The questions selected for each dimension were selected based on the analysis shown in Section 4 (Experiments and Results). It is important to note that some questions were excluded from the analysis because of the lack of enough answers for these questions. These excluded questions are shown in the Appendix B.

3.1. Dimension Zero D_0—Participant's Personal Information

Six questions have been grouped in dimension zero (D_0). Out of the six questions, the following four questions were considered for the analysis. These questions are intended to collect the personal information of the participants (Appendix B.1), as described below:

- Q_{03}: What is your education level?
- Q_{04}: What semester are you taking?

- Q_{05}: What province are you currently in?
- Q_{06}: What city are you currently in?

3.2. Dimension One D_1—Online Classes

Three questions have been grouped in dimension one (D_1). These questions are intended to collect information about the satisfaction level of students with the new learning modality (Appendix B.2).

- Q_{11}: Based on your opinion, online classes, due to the pandemic, are better, the same or worse than face-to-face classes?
- Q_{12}: Based on your opinion, after the pandemic ends, would you like to continue attending online classes?
- Q_{13}: Based on your opinion, are your teachers trained to teach online?

3.3. Dimension Two D_2—Basic Instruments for Online Learning

Three questions have been grouped in dimension two (D_2). These questions are intended to collect information about how students access electronic devices, computers, tablets, or necessary tools to take online classes (Appendix B.3). The following questions are included in the current dimension:

- Q_{21}: Do you have a computer for all-day use?
- Q_{22}: How long do you have access to a computer per day?
- Q_{23}: Do you have a smartphone or tablet?

3.4. Dimension Three D_3—Internet Connection

Five questions have been grouped in dimension three (D_3). Out of the five questions, the following three questions were considered for the analysis. These questions are intended to collect information about students' internet access conditions (Appendix B.4):

- Q_{31}: How do you access Internet?
- Q_{32}: On average, how many people are using Internet simultaneously in your house?
- Q_{34}: What is the download speed of your Internet connection?

3.5. Dimension Four D_4—Mood and Physical State

Seven questions have been grouped in dimension four (D_4). Out of the seven questions, the following four questions were considered for the analysis. These questions are intended to collect information about the physical and emotional state of the students during the lockdown (Appendix B.5):

- Q_{41}: What has your mood been most of the time since March 2020 (start date of lockdown in Ecuador)?
- Q_{44}: Has your weight changed during the pandemic?
- Q_{45}: In one word, what have you missed the most during the lockdown?
- Q_{47}: In one word, what is the most negative thing that you have experienced during the lockdown?

3.6. Dimension Five D_5—Income and Financial Status

Seven questions have been grouped in dimension five (D_5). Out of the seven questions, the following four questions were considered for the analysis. These questions are intended to collect information about the financial status of the student (Appendix B.6):

- Q_{51}: If you are financially dependent, what is the monthly income of your family?. If you are financially independent, what is your monthly income?
- Q_{52}: Since March 2020 (start date of the lockdown in Ecuador), have you had any temporary or permanent problem caused by the pandemic to cover any basic need (health, food, housing, clothing, and education)?
- Q_{53}: What are these basic needs? (See Q_{52}).

- Q_{57}: Do you think that there will be a prosperous future in Ecuador after the pandemic ends?

3.7. Dimension Six D_6—Relatives Affected by COVID-19

Fourteen questions have been grouped in dimension six (D_6). These questions are intended to collect information about COVID-19 from the students' own experience (Appendix B.7). We have used these questions only to contrast the answers to the previous dimensions. These questions reflect the opinion of the participants as well as information regarding the period of time in which we conducted this research. These questions are not used in the construction of the final model. Out of the 14 questions, the following questions were attached for visualization:

- Q_{61}: Have you tested positive for COVID-19 (with a RT-PCR or a rapid test)?
- Q_{62}: If the previous answer is yes, have you recovered from COVID-19?
- Q_{65}: Do you have any relative who died from COVID-19?
- Q_{613}: What do you think about the origin of the Sars-CoV2?
- Q_{614}: When do you think we will return to the normal activities in Ecuador?

4. Experiments and Results

The experiments are based on identifying valid statistical relationships among the proposed dimensions. The results among dimensions $(D_0, D_1, D_2, D_3, D_4, D_5)$ (Section 4.2) as well as the results related to the input questions of each dimension (Section 4.1) are detailed below.

4.1. Dimensions

As an exploratory detail for D_1 (Section 3.2), the acceptance of the students in returning to on-site classes is presented in Figure 5. The information is ordered according to the Internet speed of the participants (axis X). The average result shows that 63.78% of students prefer to return to on-site classes regardless of their condition of Internet connection.

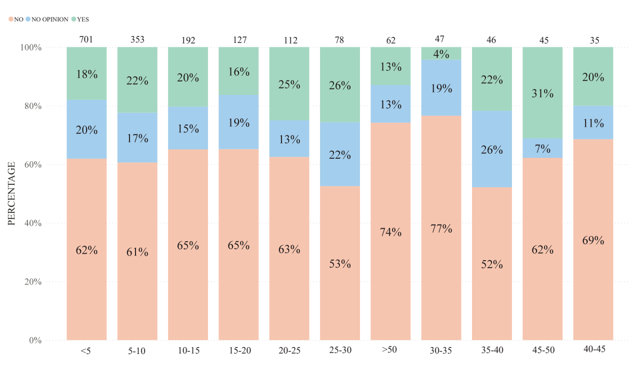

Figure 5. Students' acceptance of continuing in online classes regarding their Internet speed. Dimension D_1 (Section 3.2).

In Figure 6, the distribution of participants according to family income and Internet speed are exposed. The majority of participants have a low Internet connection speed. The result of the survey shows the polarization regarding Internet speed and the level of income during the lockdown period.

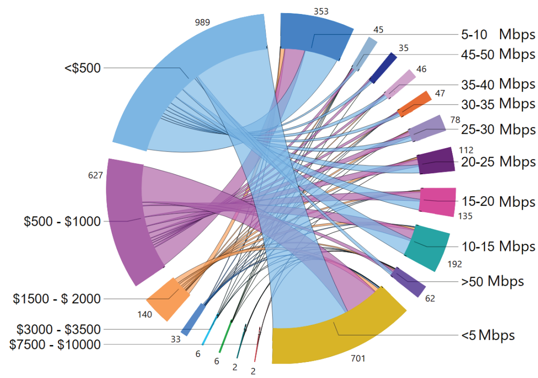

Figure 6. Participants' distribution according to family income and Internet speed. Dimension D_3, Section 3.4.

Figure 7 shows the changes in the physical state of the participants. The results indicate the gain or loss of weight of the participants during the period of the analysis. It can be noted that the 50.1% of participants suffered alterations in their body weight.

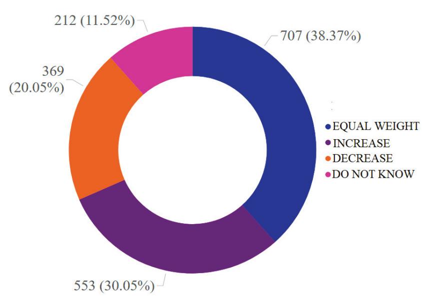

Figure 7. Changes in physical weight reported by the participants. Dimension D_4, Section 3.5.

In Figure 8, the results of the mood of the participants are presented. It can be seen that 74.24% of the participants show mostly stress, fear, boredom, sadness, or annoyance. For its part, normal and happiness states reach 23.1% and 2.66%, respectively.

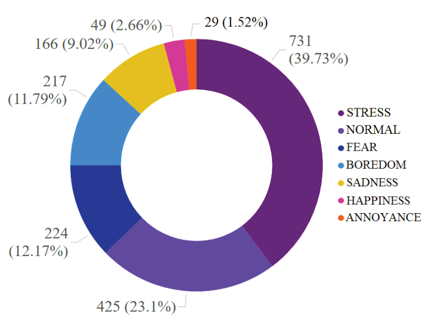

Figure 8. Mood reported by university students. Dimension D_4, Section 3.5.

An additional analysis such as mood (D_4) and income (D_5) can be found in Figure A1. The mood (D_4) and desire to continue in online classes (D_1) are exposed in Figure A2.

Internet speed (D_3) and income (D_5) are described in Figure A3. How students access the Internet ($D_{3.1}$) and their income (D_5) can be found in Figure A4. All figures are described in the Appendix A.

4.2. Structural Model

In our research, different models have been tested to obtain the best relationship between each input question and its dimension, as well as the relationships among dimensions (Figure A6). The best relationships obtained between each dimensional input question are presented in Figure 9. For instance, the best relation of dimension zero is obtained by combining the questions regarding age, educational level, and semester. This means that these three questions describe dimension zero by around 49.9%. In Figure 10, we can see the path with the t statistical value between connections of each dimension. For example, from dimension zero to dimension one, the model shows a t value of 8.386, which indicates a strong relationship.

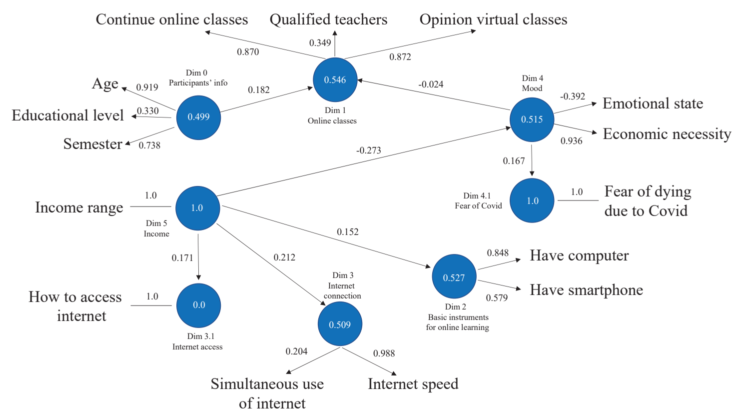

Figure 9. Model that evaluates the correlation among input questions of each dimension.

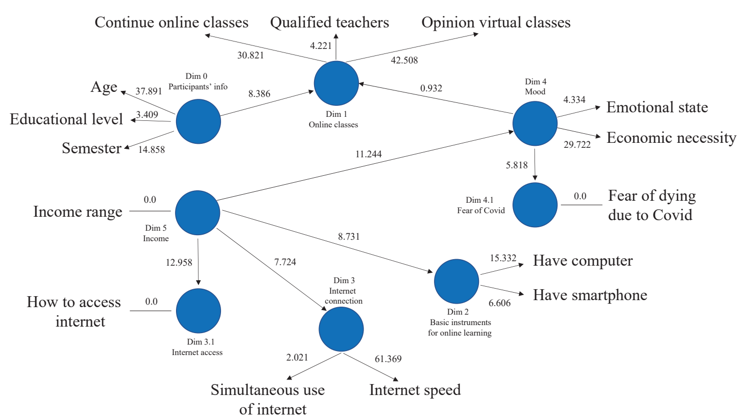

Figure 10. Model that evaluates the different relationships between each dimension.

Reliability and Validity Evaluation

The reliability of the variables was tested using Composite Reliability (CR) [52,53]. For this purpose, the overall sample was assessed, and the items with a factor less than 0.6 were discarded. However, few factors with a correlation value less than 0.6 were taken into account due to their strong path relationship with the dimension, as it can be observed in

Figure 9 (e.g., Educational Level for D_0). The Average Variance Extracted (AVE) [54] and CRs were higher or close to 0.500 and 0.700, respectively, which indicates that the model fitted to the data is valid. The AVE value, shown in each dimension in Figure 9, indicates the percentage of the description of that dimension with the considered input questions. In Table 1 the CR and the AVE values for each dimension are presented. For example, the AVE value for D_1 indicates that its inputs describe 54.6% of this dimension, whereas the CR value indicates a composite reliability of the inputs of D_1 of 0.763.

Table 1. Dimensions according to each input.

Dimensions	CR	AVE
D_0 Participant's Info	0.724	0.499
D_1 Online Classes	0.763	0.546
D_2 Instruments	0.683	0.527
D_3 Internet Connection	0.591	0.509
D_4 Mood	0.234	0.515
$D_{4.1}$ Fear of Covid	1	1
D_5 Income	1	1
Composite Reliability (CR), Average Variance Extracted (AVE).		

For the path model, in Table 2, we can observe the t statistics (the higher, the better) and the p value (the lower, the better) for all paths. Most of the t statistics are greater than 1.96 (95% of confidence level). The p value of the path $D_4 \rightarrow D_1$ is 0.352, suggesting that D_4 is not related to D_1. It means that the mood (D_4) does not have direct relation to online classes (D_1); consequently, Hypothesis 2 is rejected.

Table 2. Coefficient values related to path model.

Path	t Statistics	p Values
$D_0 \rightarrow D_1$	8.386	0
$D_4 \rightarrow D_1$	0.932	0.352
$D_4 \rightarrow D_{4.1}$	5.818	0
$D_5 \rightarrow D_2$	8.731	0
$D_5 \rightarrow D_{3.1}$	12.958	0
$D_5 \rightarrow D_3$	7.724	0
$D_5 \rightarrow D_4$	11.244	0

5. Discussion

Hypothesis 1: *Participants' information (age, semester, and educational level) does not affect their opinion about online classes (continue online, qualified teachers, and opinion of virtual classes).* Since the value of the t statistic is greater than 1.96 (8.207), this hypothesis is confirmed by the data. Additionally, our analysis indicates that the students want to return to on-site classes regardless of if they have the right tools to keep taking online classes.

Hypothesis 2: *The mood (emotional state and financial need) affects the students' opinion of the online classes (continue online, qualified teachers, and opinion of virtual classes).* The value of the t-statistic of 0.932 indicates that the mood has a relative influence on the perception of students about online classes. Therefore, we cannot categorically reject this hypothesis.

Hypothesis 3: *Family income (income) influences how students access the Internet during online classes (simultaneous PC use, way of Internet access, Internet velocity, and tools for online learning).* Since the values of the t statistical are greater than the recommended 1.96, (8.731 for the path D_5(Income) $\rightarrow$ D_2 (Basic instruments for online learning), 7.724 for the path D_5(Income) $\rightarrow$ D_3(Internet connection), and 12.958 for the path D_5(Income) $\rightarrow$ $D_{3.1}$(Internet access), this hypothesis is confirmed by the data.

Additionally, regarding the state of mind, we can observe that the students mostly present states related to feelings of sadness (9.02%), stress (39.73%), and fear (12.17%).

Similarly, the physical state of the students changed. The percentage of students who experienced a change in their weight is 50.10%.

Comparison of Studies Carried Out before and during COVID-19

The study carried out in [55] shows an analysis of several dimensions in the context of the pandemic of COVID-19 considering university students from Ecuador, Spain, and Italy. The data were acquired between March and April 2020. The study had responses from 300 participants. In Ecuador, 100 students from the Technical University of Machala participated in this research. One of the findings of this work is that online classes and the lack of enough tools (laptop, Internet, and smartphones) have contributed to negatively impacting the opinions of students about their learning process. In Table 3, the data show the negative perception about online classes, with 93.00% in Spain, 83.30% in Ecuador, and 64.80% in Italy [55]. Additionally, we add our results regarding the participants' desire to not continue taking online classes.

Table 3. Negative perception of online classes in the context of COVID-19.

Paper	Date	Participants	Country	Universities	Negative Perception
[55]	March–April 2020	100	Spain	1	93.00%
[55]	March–April 2020	100	Italy	1	64.80%
[55]	March–April 2020	100	Ecuador	1	83.30%
This paper	May–September 2020	1841	Ecuador	11	63.78%

To the best of our knowledge, in order to make a comparison between the results of our analysis during the COVID-19 pandemic and the results before this pandemic, the studies existing in Ecuador [56–59] do not have data of the variables analyzed in this work.

6. Conclusions

In this work, we surveyed 1841 Ecuadorian university students about the impact of COVID-19 in areas such as health, emotional state, perception of online classes, and economic income in a snapshot between May to September 2020. These students come from six public and five private universities. The analysis considered the responses to 21 questions out of a total of 47 questions, which were grouped to form 7 dimensions: participants' information, online classes, basic instruments for online learning, Internet connection, mood and physical state, income and financial status, and relatives affected by COVID-19. The 26 discarded questions have no relevant information for the areas of the analysis of this work.

The PLS-SEM technique was used to analyze the relations between six dimensions. The reason why the dimension "relatives affected by COVID-19" was excluded from this analysis is because only a small number of participants answered the questions of this dimension. The results of this analysis show that participants' income has a strong effect on the way how they access to the internet and the availability of electronic tools (computers, smartphones, and tablets) needed for online learning: The higher the income, the higher the speed of the Internet connection. Additionally, the higher the income, the larger the number of electronic tools and the longer the time of their availability.

We also found that the income affected the mood of the participants during the period of analysis. The participants with higher income experienced, most of the time, positive feelings: happiness and normal (such as before the pandemic); whereas the participants with lower income experienced, most of the time, negative feelings (sadness, fear, stress, and annoyance). The participants' information strongly influences their perception about online classes: Older students and students from higher semesters think that online classes are better than face-to-face classes and want to continue in online education. The mood does not have a strong influence regarding to the opinion about online classes. We also observed that students' perception about online classes is not affected by income, the availability of basic instruments for online learning, Internet connection, and the way they access the Internet.

In this research, we could not find reasons why students have a negative perception about online classes, which should be investigated in a future work. For another future work, a new study can be executed when students go back to face-to-face classes after the Sars-CoV2 pandemic. This study will evaluate again their perception about online and face-to-face classes and its results can be compared with the results of this work.

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Institutional Review Board Statement: All subjects who contributed on this study participated on an entirely free and voluntary basis through an online form. The participants were informed that the data collected will be used for research and academic purposes only. In addition, to avoid the identification of the participants, the data collected for this study do not include any private information.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Dataset is available at: Dataset https://github.com/laboratorioAI/Covid19_Educational_Impact.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Additional Findings

	Income							
Mood	<$500	$(500 - 1000)	$(1500 - 2000)	$(2500 - 3000)	$(3000 - 3500)	$(3500 - 4000)	$(4500 - 5000)	$(7500 - 10000)
ANNOYANCE	18	8	2					
BOREDOM	111	76	20	4	3	1		
FEAR	141	63	14	1				1
HAPPINESS	32	11	3	2			1	
NORMAL	201	157	41	12	2	2	1	1
SADNESS	97	60	6					
STRESS	399	253	55	14	1	3	1	

Figure A1. Mood of the participants in relation to their reported income. The color map is used to emphasize the number of people.

Continue online classes	Qualified teachers	ANNOYANCE NO	ANNOYANCE YES	FEAR NO	FEAR YES	STRESS NO	STRESS YES	SADNESS NO	SADNESS YES	BOREDOM NO	BOREDOM YES	NORMAL NO	NORMAL YES	HAPPINESS NO	HAPPINESS YES
NO	NO		5	13	15	59	53	8	13	19	20	32	21	3	2
	NO OPINION	1	8	19	18	81	88	16	19	36	25	52	19	1	5
	YES	5	2	19	29	100	81	20	24	41	27	72	42	6	11
NO OPINION	NO			2	5	7	8		2	1	2	2	4	1	1
	NO OPINION	1		4	13	29	34	3	8	7	8	24	10	1	4
	YES	1		14	13	27	19	10	7	6	2	24	15		2
YES	NO	2		3	4	10	14	2	2	2		5	6	1	1
	NO OPINION			4	5	12	19	2	1	4		12	6	2	1
	YES	1		15	25	33	48	10	13	5	9	47	22	4	3

Mood / Economic necessity

Figure A2. Participants' mood (D_4) regarding the opinion of the online classes and qualified teachers (D_1). The color map is used to emphasize the number of people.

Income	Have computer	<5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	>50
<$500	NO	86	37	21	16	5	5	6	6	1	1	4
	YES	362	163	77	46	43	26	15	20	17	14	18
$(500 - 1000)	NO	16	9	4	4	7	1	1	1	1		1
	YES	196	112	65	53	38	33	17	13	15	17	23
$(1500 - 2000)	NO	3	6	4	1		1		1			
	YES	27	22	14	11	15	10	5	4		6	10
$(2500 - 3000)	NO	2	1					1				
	YES	6	2	6	3	3	1	1			4	3
$(3000 - 3500)	YES	1	1		1			1			1	1
$(3500 - 4000)	YES	1					1		1	1	2	
$(4500 - 5000)	YES	1		1								1
$(7500 - 10000)	YES					1						1

Internet speed (Mbps)

Figure A3. Participants' Internet speed (D_3) according to their income (D_5). The majority of participants have an Internet speed lower than 5 Mbps and an income less than $1000. The color map is used to emphasize the number of people.

Internet access	Have computer	Have smartphone	<$500	$(500 - 1000)	$(1500 - 2000)	$(2500 - 3000)	$(3000 - 3500)	$(3500 - 4000)	$(4500 - 5000)	$(7500 - 10000)
I MUST GO TO A COMPUTER CENTER	NO	NO	3							
		YES	6							
	YES	NO	1	1	1					
SOMEONE WHO LIVES NEARBY ALLOWS ME TO ACCESS	NO	NO	15	1						
		YES	45	3						
	YES	NO	14	5						
		YES	81	12						
I HAVE INTERNET INSTALLED AT HOME	NO	NO	7							
		YES	121	41	16	4				
	YES	NO	40	22	3					
		YES	666	543	121	29	6	6	3	2

Income

Figure A4. Figure shows how participants access to the Internet ($D_{3.1}$) according to their income (D_5). Additionally, the availability of basic instruments for online learning (D_2) can be seen. The color map is used to emphasize the number of people.

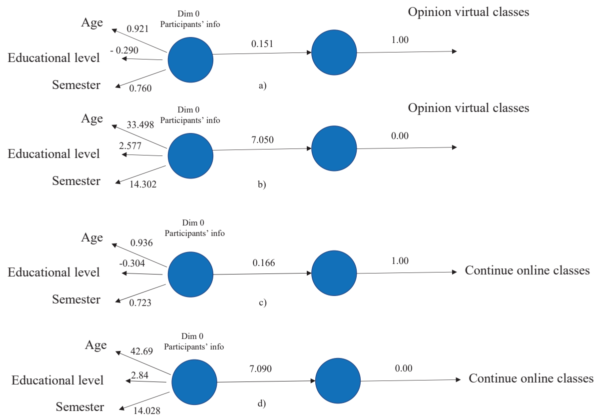

Figure A5. Different tested models: relation between participants' information and their opinion about virtual classes (**a**) CR, (**b**) *t*-statistics. Relation between participants' information and their opinion about to continue in online classes (**c**) CR, (**d**) *t*-statistics.

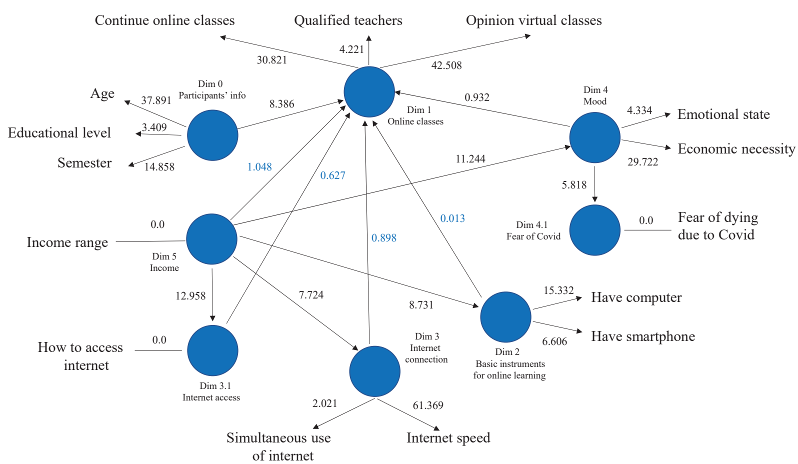

Figure A6. Model that shows no relationship between the perception of online classes (D_1) considering: income (D_5), mood (D_4), Internet connection (D_3), Internet access ($D_{3.1}$), and the availability of basic instruments for online learning (D_2).

Appendix B. Questionnaire

Appendix B.1. Dimension Zero—Participant's Personal Information

Table A1. Questions in Dimension Zero.

Dimension	Question
Q_{01}	What is your gender?
Q_{02}	How old are you?
Q_{03}	What is your education level?
Q_{04}	What semester are you taking?
Q_{05}	What province are you currently in?
Q_{06}	What city are you currently in?

Appendix B.2. Dimension One—Online Classes

Table A2. Questions in Dimension One.

Dimension	Question
Q_{11}	Based on your opinion, online classes, due to the pandemic, are better, the same, or worse than face-to-face classes?
Q_{12}	Based on your opinion, after the pandemic ends, would you like to continue attending online classes?
Q_{13}	Based on your opinion, are your teachers trained to teach online?

Appendix B.3. Dimension Two—Basic Instruments for Online Learning

Table A3. Questions in Dimension Two.

Dimension	Question
Q_{21}	Do you have a computer for all-day use?
Q_{22}	How long do you have access to a computer per day?
Q_{23}	Do you have a smartphone or tablet?

Appendix B.4. Dimension Three—Internet Connection

Table A4. Questions in Dimension Three.

Dimension	Question
Q_{31}	How do you access Internet?
Q_{32}	On average, how many people are using Internet simultaneously in your house?
Q_{33}	Which is your Internet provider?
Q_{34}	What is the download speed of your Internet connection?
Q_{35}	What is the upload speed of your Internet connection?

Appendix B.5. Dimension Four—Mood and Physical State

Table A5. Questions in Dimension Four.

Dimension	Question
Q_{41}	What has your mood been most of the time since March 2020 (start date of lockdown in Ecuador)?
Q_{42}	Have you ever thought about committing suicide due to the pandemic and the crisis caused by the Sars-CoV2 virus?
Q_{43}	During the lockdown caused by the SARS-COV-2, were you alone or with company?
Q_{44}	Has your weight changed during the pandemic?
Q_{45}	In one word, what have you missed the most during the lockdown?
Q_{46}	In one word, what is the most positive thing that you have experienced during the lockdown?
Q_{47}	In one word, what is the most negative thing that you have experienced during the lockdown?

Appendix B.6. Dimension Five—Income-Financial Status

Table A6. Questions in Dimension Five.

Dimension	Question
Q_{51}	If you are financially dependent, what is the monthly income of your family? If you are financially independent, what is your monthly income?
Q_{52}	Since March 2020 (start date of the lockdown in Ecuador), have you had any temporary or permanent problem caused by the pandemic to cover any basic need (health, food, housing, clothing, and education)?
Q_{53}	If the answer of the previous question is yes, what are these basic needs that you have not able to cover? (See Q_{52}).
Q_{54}	How do you rate the management of the pandemic by the Ecuadorian government?
Q_{55}	How do you rate the management of the economic crisis, caused by the pandemic, by the Ecuadorian government?
Q_{56}	What is your perception about the level of corruption in Ecuador?
Q_{57}	Do you think that there will be a prosperous future in Ecuador after the pandemic ends?

Appendix B.7. Dimension Six—Relatives Affected by COVID-19

Table A7. Questions in Dimension Six.

Dimension	Question
Q_{61}	Have you tested positive for COVID-19 (with a RT-PCR or a rapid test)?
Q_{62}	If the previous answer is yes, have you recovered from COVID-19?
Q_{63}	If you live with someone, has he/she tested positive for COVID-19 (with a RT-PCR or a rapid test)?
Q_{64}	If the previous answer is yes, has he/she recovered from it?
Q_{65}	Do you have any relative who died from COVID-19?
Q_{66}	Has a friend of you tested positive for COVID-19 (with a RT-PCR or a rapid test)?
Q_{67}	Has a friend of you died from COVID-19?
Q_{68}	Has somebody in your neighborhood been infected with COVID-19?
Q_{69}	Has somebody in your neighborhood died from COVID-19?
Q_{610}	What is the probability that you estimate of being infected with the Sars-CoV2 virus until 31 December 2020?
Q_{611}	Are you afraid of getting sick of COVID-19?
Q_{612}	Are you afraid of dying from COVID-19?
Q_{613}	What do you think about the origin of the Sars-CoV2?
Q_{614}	When do you think we will return to the normal activities in Ecuador?

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I Cannot See You—The Perspectives of Deaf Students to Online Learning during COVID-19 Pandemic: Saudi Arabia Case Study

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Abstract: The COVID-19 pandemic brought about many challenges to course delivery methods, which have forced institutions to rapidly change and adopt innovative approaches to provide remote instruction as effectively as possible. Creating and preparing content that ensures the success of all students, including those who are deaf and hard-of-hearing has certainly been an all-around challenge. This study aims to investigate the e-learning experiences of deaf students, focusing on the college of the Technical and Vocational Training Corporation (TVTC) in the Kingdom of Saudi Arabia (KSA). Particularly, we study the challenges and concerns faced by deaf students during the sudden shift to online learning. We used a mixed-methods approach by conducting a survey as well as interviews to obtain the information we needed. Our study delivers several important findings. Our results report problems with internet access, inadequate support, inaccessibility of content from learning systems, among other issues. Considering our findings, we argue that institutions should consider a procedure to create more accessible technology that is adaptable during the pandemic to serve individuals with diverse needs.

Keywords: education; e-learning; deaf and hard of hearing; accessibility; Saudi Arabia; COVID-19

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1. Introduction

The COVID-19 pandemic has necessitated the introduction of various public health measures to control its spread, including social distance measures. Such policies have affected nearly every sector of the economy, including education. Unfortunately, Gleason et al. [1] indicated that People With Disabilities (PWD) are often disproportionately affected in times of drastic and unintended changes. In the case of COVID-19, PWD are facing challenges in education because social distance measures have forced education institutions to shift from face-to-face learning to e-learning. As noted by Hanjarwati and Suprihatiningrum [2], some of the challenges faced include a lack of support, expensive internet access, the inability to work with the e-learning system, among others. It is important to raise awareness of how inclusivity in education can be achieved during the COVID-19 era, such as promoting the use of blended learning, providing sign language options, and improving support for disabled persons [3]. It is also important to resolve barriers to education for disabled students, which include technical problems, time, absence of simultaneous translation, among others [4].

In the last few years, studies on challenges associated with e-learning depended on the evolution as well the development of the e-learning system [5,6]. There are usually three types of interactions in e-learning systems, i.e., teacher to learner, learner to course contents, and learner to learner interaction [7]. Several studies have been conducted in Saudi Arabia to analyze the impact of COVID-19 on multiple factors, such as financial, psychological, political, and societal attitudes [8–11]. Furthermore, a number of studies investigated the use of online learning within Saudi Arabia during the COVID-19 period. For instance, research by Almekhlafy [12] focused on online learning of English courses using blackboard, and [13] examined the student satisfaction with the teaching quality of case-based discussion (CBD) sessions. Another study by Alshehri et al. [14] investigated the online learning facilitated syllabus delivery and assessments during COVID-19 and found that it was important to improve IT infrastructure, teacher training on online education, and student engagement, whereas [15] found that it was challenging to teach complex scientific concepts through online means, and there was low interaction between students.

However, studies performed in Saudi Arabia on disability, specifically with deaf students, are limited. There are only two studies that investigated deaf education during the pandemic. Madhesh [16] investigated the deaf students' situations through 20 ministry of education channels that were utilized during the locked down period. The goal of the study to provide an alternative educational method aimed for Deaf students. The second study was conducted by Alsadoon and Turkestani [4], where they investigated the obstacles that the instructors faced while they were teaching for online classes. Both studies were conducted on teachers of deaf students, but they did not examine the deaf students' challenges and concerns during the sudden shift to online learning. Our study is the first to focus on challenges deaf students have faced, when transitioning to online learning during the pandemic. More specifically, this study is unique since, compared to other countries, online learning is not very established in Saudi Arabia, and its implementation has mostly been heightened by COVID-19. Saudi society is also traditional and conservative, wherein the deaf culture is still new and not well-established [17]. Thus, such students may have low self-esteem in communication [18], which may affect how they learn using the e-learning platforms. Furthermore, the context of this research is unique in terms of its gender focus, given that the Technical and Vocational Training Corporation (TVTC) only admits male students, unlike the participants in other studies that were both male and female. Therefore, the context of this study is very unique and its findings will be a great contribution to the body of research on the subject.

The aim of the current study is to explore the e-learning experiences of deaf students during the COVID-19 period, focusing on the Technical and Vocational Training Corporation (TVTC) in the Kingdom of Saudi Arabia (KSA). To explore the e-Learning experiences of deaf students during the COVID-19 era at TVTC, a mixed-methods approach was used. First, we conducted an interview to collect preliminary insights. The interviews were performed on eight deaf students who voluntary involve in the study. Then, we perform a survey in order to obtain the views of deaf students whose education had been disrupted by the pandemic. The survey helped in discovering new insights and estimating the prevalence of some aspects using a larger population, as well as providing explanations for support or opposition to some questions. Since the education of deaf students via online learning have not been previously investigated, this study will shed light on issues and challenges that can occur for the deaf students while learning online. In this study, we investigate the following research question:

RQ_1: What are the challenges and concerns that deaf and hard-of-hearing students are having with an online education during COVID-19 pandemic?

This RQ will guide this research by investigating the difficulties, challenges, and concerns of deaf students in the pandemic period. We will answer this question by exploring the students' perspectives of TVTC college by interviews and survey investigating of the learning processes during COVID-19.

The contributions of this paper are:

- To explore the challenges faced by deaf students during the pandemic.
- To identify how issues faced by deaf students during the COVID-19 pandemic can be solved.

The rest of this paper is organized as follows: Section 2 presents background information on our case study (TVTC). Section 3 discusses related work. Section 4 provides an overview of the materials and methods used in this study to investigate the challenges of deaf and hard-of-hearing students of TVTC during the COVID-19 pandemic. Section 5 explains our research findings, and Section 6 discusses our results. Finally, Section 7 highlights the limitations of our research, and future work directions. Section 8 summarizes our conclusions.

2. Background

This section provides information on the TVTC training institution. It also discusses deaf education in the TVTC.

2.1. Case Study Selected

The Technical and Vocational Training Corporation (TVTC) is a public tertiary education institution in the Kingdom of Saudi Arabia, which was established in 1980. TVTC provides vocational education and training, making it important in workforce development. It consists of three sectors: vocational training centers, technical colleges, and secondary institutions, whose numbers are 65, 35, and 35, respectively. The TVTC has also provided accreditation to approximately 1000 private institutions. Thus, the TVTC is very instrumental in KSA's tertiary education and greatly contributes in providing labor supply to national and international labor markets [19].

2.2. Deaf Education in TVTC

There are four branches that deaf students can go to in TVTC, where they can access special education programs. The branches are distributed in the KSA, particularly in the middle and central areas. The numbers of such institutions, with their locations, are as follows: (1) Riyadh, (2) Madinah, (3) Buraydah, and (4) Dammam. All these branches teach two majors: business and computer technology. The number of the students are almost less than 100 at each campus. However, the deaf students in the institutions are not studying with other students without disabilities. According to Özokcu and Yildirim [20], disabled students are afraid to learn in inclusive classes because they are treated differently from others. In terms of teachers, the majority of the teachers are specialized (for specials educations), except for the general courses, such as English, Mathematics, or such other classes. Currently, most teachers are working without interpreters because they are conversant with sign language. For those teachers that are not familiar with sign language, they seek the assistance of interpreters. Currently, there are only three interpreters in the department because there are only a few students. If deaf students need assistance in any of the college services, they contact the department to provide them with an interpreter. Mostly, if students are holding seminars with spoken lecturers, they have to request for an interpreter before the session.

2.3. Pre-Pandemic Learning Process

The normal education process in Saudi Arabia involves face-to-face learning, which entails training in the classroom that has been conducted since the 1950s [21]. The face-to-face learning includes in-person lectures and text-book readings, which were mostly preferred in the pre-pandemic period because they emphasize on human–human interactions [22]. With the advent of technology, blended learning was introduced in Saudi Arabia, where face-to-face interactions were complemented with technology. For example, as of 2016, TVTC had introduced a Learning System Management (LMS) known as Doroob to make learning more interactive and student-centered [23]. The learning process at TVTC in the pre-pandemic period was as follows:

- Students did not have experiences on how to use the full functionality of Blackboard, except to review course materials [24].
- Students used to give their homework and projects as hand-outs or using Dropbox to submit them. For project courses, student used to email teachers about any updates and the final submission of the course delivery.
- Students used Rayat (a portal enables students/trainees to obtain many services such as the tracking training record and the attendance and grades, etc.) [25] to access their grades, personal information, and their process of attending their courses.

2.4. Learning Management Systems (LMSs)

Learning Management Systems (LMSs) have become very popular in modern universities because of their ability to deliver content remotely, enhance interactions, improve feedback, and provide analytics to teachers to assess performance [26–28]. The first LMS system was known as FirstClass and was developed in 1990 [26]. Some of the most popular LMS applications in Saudi Arabia today are: Blackboard (89% popularity), Moodle (7% popularity), and D2L (4% popularity) [26]. Therefore, Blackboard is the most popular LMS application in institutions of higher learning in Saudi Arabia.

In 2016, TVTC had introduced an LMS system known as Doroob to make learning more interactive and student-centered [23]. Before COVID-19, Saudi institutions, such as TVTC and King Saud University, were gradually adopting Blackboard LMS in order to improve their online learning channels [28]. However, the disruption of learning brought by COVID-19 in Saudi Arabia led to a sudden and quick shift towards Blackboard LMS [12].

3. Related Work

This section provides the related work to our study. We examine studies that studied the education of deaf and hard-of-hearing students and accessibility with deaf students. Then, we demonstrate how our work is different from the previous studies. We split the related work into two parts: (1) studies exclusively focused on deaf students during COVID-19 and (2) studies focused on accessibility with deaf students. Table 1 presents a summary of systematic analysis studies investigated on deaf and hard of hearing students during the COVID-19 pandemic.

3.1. Deaf Students during COVID-19 Studies

Several studies have addressed the subject of deaf and hard of hearing (DHH) studies. For instance, Kritzer and Smith [29] conducted a survey in the United States, which emphasized the need for parents to seek appropriate learning services and opportunities for their DHH children and communicate with them. Another study by Smith and Colton [30] utilized a literature review method and proposed using YouTube channels in teaching DHH students during the COVID-19 pandemic. The authors demonstrated how YouTube videos were made and shared and their usefulness in educating DHH students. Further, Sutton [31] utilized a literature review methodology and evaluated the best practices to help DHH students during COVID-19, such as providing speech-to-text services and facilitating communication through accommodation. Research by Lazzari and Baroni [32] investigated remote teaching experiences in Italy and found that remote teaching using technology helped learning during COVID-19, although some challenges were experienced, such as inadequate materials. Another study by Alsadoon and Turkestani [4] sought to identify the obstacles to e-learning and found that technical problems, time, and translation problems were severe challenges to DHH distance learning.

Research by Fernandes et al. [33] in Indonesia investigated how deaf voters were educated and indicated that videos effectively conducted voter education in Indonesia and visual and social media. Furthermore, in their study, Lynn et al. [34] evaluated how students were learning chemistry during the pandemic and found that access services, such as interpreters and captioners, were vital to DHH education, and making sufficient accommodations ensure inclusion. Another piece of research by Swanwick et al. [35] was conducted in Ghana to determine how the pandemic had affected deaf education and found that exclusion for DHH students was different in various cultural contexts and developmental areas. Research by Paatsch and Toe [36] utilized a literature review methodology and indicated that DHH students in typical classrooms developed pragmatic skills and proposed using the conversation model to deal with the challenges faced by such students. Finally, Tomasuolo et al. [37] conducted exploratory research in Italy and found that initiatives at the political and informal level promoted sign language and assisted in DHH education during the pandemic.

3.2. E-Learning System for Deaf Students

Previous studies have suggested the importance of introducing e-learning systems for deaf students. For example, a study by Alcazar et al. [38] found that introducing a speech-to-visual approach e-learning system had a great advantage when teaching deaf students because it enabled their comprehension of material and addressed their individual needs. Furthermore, a study by Batanero et al. [39] found that adopting an improved Moodle learning platform improved the academic performance of deaf and deaf-blind students by 46.25% and 87.5%, respectively. In addition, Batanero-Ochaita et al. [40] found that deaf students had a positive attitude towards the Moodle Learning Platform, although their perception differed on the ease-of-use and difficulty when using the platform.

3.3. Deaf Students in Online Learning

Several studies have looked at the subject of online learning for deaf students. For example, a study by Long et al. [41] focused on blended learning for deaf and hard-of-hearing students and found that the inclusion of online learning aspects improved their interactions with their teachers and other students. Another study by Slike et al. [42] found that, although there are many successes in teaching deaf students using online means, there are also challenges related to system 'glitches', lack of captions, teachers who are not used to handling deaf students in virtual classrooms, among others. In addition, a study by Yoon and Kim [43] suggested the need to improve learning materials in the classroom because it established that captions have a significant effect on the content comprehension of deaf students taking online courses.

A study by Burgstahler [44] was conducted to identify the online learning practices that are most suitable for students with disabilities and found the "Universal Design" (UD) strategy to be very effective in inclusive educational practices. Research by McKeown [45] found three types of challenges that faced deaf students when accessing online learning: course content and material challenges, learning management system (LMS) challenges, and course content and material challenges. A study by Carpenter et al. [46] established that online technology had improved deaf education and made communication easier and proposes the use of best practices that can boost the utilization of online learning. Another research by Mohammed [47] found that deaf students participating in online education faced problems related to institutional support, social inequalities, and inappropriate sociolinguistic history. Another study by Musyoka and Smith [48] found that, since online deaf learning involves the use of English and American Sign Language (ASL), language barriers were considered a challenge. A study by Long et al. [49] reported that online learning for deaf students provides special benefits that were realized through academic achievement and the quality of interaction in online learning platforms greatly determined the success of the students. Additionally, a study by Caupayan and Pogoy [50] established that, although deaf students faced challenges in online learning, the support they received from various stakeholders helped them to overcome them. From the related work, there is no study addressing online learning for deaf students in Saudi Arabia, which is the focus of the current study.

Table 1. Summary of systematic analysis studies for deaf and hard of hearing students in chronological order.

Study	Ye	Purpose	Method	Source of Info	Participants	Sample Size	Study Location
Long et al. [41]	2007	Understanding student perceptions of communication in blended learning courses	Survey	NTID	Students	908	United States
Slike et al. [42]	20	Investigating successes and challenges in offering online courses in a "virtual classroom" format to deaf hard of hearing	Online Synchronous Tool	University of Pennsylvania	Students	26	United States
Yoon and Kim [43]	2011	Capturing the effects of captions on deaf students' content comprehension, cognitive load, and motivation in online learning	Comprehension test & survey	Korean Nazarene University	Students	62	Korean
Burgstahler [44]	20	Identifying online learning practices make social inclusion possible for individuals with disabilities	Literature review	N/A	N/A	N/A	N/A
Alcazar et al. [38]	2016	Creating a supplementary English elearning system made for the Deaf	Survey	Philippine Institute of the Deaf	Students, Teachers	N/A	Philippines
McKeown [45]	20	Proposing a model which describes the three barriers deaf students might encounter in an online learning situation	Literature review	N/A	N/A	N/A	N/A
Batanero et al. [39]	2019	Testing a redesign of the Moodle platform on deaf and deaf-blind students	Empirical study	Moodle platform	Students	23	N/A
Counselman et al. [46]	20	Exploring current trends in online higher education, data on the experience of Deaf/deaf/Hard of Hearing students and current options for improving inclusively in the online classroom	Literature review	N/A	N/A	N/A	N/A
Fernandes et al. [33]	2020	Examining how the education of voters for deaf people	Interview	GERKATIN	Students	33	Indonesia
Lynn et al. [34]	20	Identifying Successes and challenges in teaching chemistry	Author's insights	NTID	N/A	N/A	United States
Tomasuolo et al. [37]	2020	Exploring the impacts of the recent pandemic crisis	Exploratory research	Literature review	N/A	N/A	Italy
Smith and Colton [30]	20	Developing a YouTube channel that focuses on providing	Literature review	Author's experience	N/A	N/A	United States
Alsadoon and Turkestani [4]	2020	Identifying the lecturers' obstacles during virtual classroom	Interview	King Saud University	lecturers	11	Saudi Arabia
Kritzer and Smith [29]	20	Recommending parents about educating DHH children	Survey	United States	Parents	133	United States
Swanwick et al. [35]	2020	Investigating the impact on deaf adults, children and their families, focusing on issues of inclusion	Interview	Ghana	Teachers, leaders, Students	6	Ghana
Lazzari and Baroni [32]	20	Presenting the remote teaching experience	Survey	Scuola Audiofonetica	Students	233	Italy
Paatsch and Toe [36]	2020	Investigating pragmatic skills among deaf children	Literature review	Existing evidence	N/A	N/A	Australia
Krishnan et al. [51]	20	Identify the Challenges Faced by hearing impairment	Survey	MySkill Foundation	Students	10	Malaysia
Halley Sutton [31]	2020	Suggesting best practices if courses shift to online learning	Literature review	Existing evidence	N/A	N/A	United States
Kylie Sommer [52]	20	Identify the Effect on deaf and hard of hearing	Survey	Lee University	Students	36	United States

Table 1. *Cont.*

Study	Ye	Purpose	Method	Source of Info	Participants	Sample Size	Study Location
Mantzikos and Lappa [53]	2020	Analyzing the difficulties and barriers individuals deaf	Literature review	Existing evidence	N/A	N/A	Greece
Mohammed [47]	20	Investigating how an emergent system of e-learning that started during crisis conditions affects the linguistic access of deaf students	Interview	Primary school & secondary school	Students, teachers, interpreters, parents	N/A	Trinidad and Tobago
Batanero-Ocha et al. [40]	2021	Analyzing the difficulties and barriers individuals deaf	Empirical study	Moodle platform	Students	23	N/A
Musyoka and Smith [48]	20	Identifying language barriers and academic performance when discussing mainstreamed D/HH students' online teaching	Literature review	Existing evidence	N/A	N/A	United States
Long et al. [49]	2021	Understanding the factors contributing to the academic achievement and the interaction of students in online learning	Survey	RIT	Students	88	United States
Caupayan and Pogoy [50]	20	examining and interpreting the lived experiences of 14 purposively selected deaf students who chose online modality for their education	Interview	La Salle University	Students	14	Philippines
This work	**2021**	**Investigating the challenging and concerns of deaf students**	**Interview & Survey**	**TVTC**	**Students**	**65**	**Saudi Arabia**

3.4. Accessibility with Deaf Students Studies

Several studies have addressed the topic of accessibility with deaf students. For example, a study by Sommer [52] in the US utilized a survey method to demonstrate how access to information by DHH students has been hampered by the COVID-19 pandemic, which has had emotional effects on them. Another study by Mantzikos and Lappa [53] reviewed existing evidence on overcoming difficulties and barriers to deaf education. It established the use of media, such as educational TV programs, helped improve access to information, although it was essential to improve new principles and approaches that helped DHH students. Research by Krishnan et al. [51] in Malaysia used a survey method to investigate students' challenges during COVID-19 and found that accessibility by DHH students was hindered by a lack of familiarity to online devices, hearing devices, emotional effects of the pandemic, and disruptions to their education.

The current study deviates from those reviewed because it focuses on accessibility by deaf students in Saudi Arabia. Specifically, it focuses on TVTC in Saudi Arabia, which no other study has addressed. TVTC has adequate and trained faculty with a lot of experience, who offer more support for the deaf. This research also differs from the rest in terms of the methodology and because this study is a larger-scale research article in terms of the sample compared to the previous ones.

4. Materials and Methods

This section presents the approach of our study, information about the participants engaged in the study, the data collection process, details about the procedures that were followed in interviews and survey, and analyzes the data to address our research question.

4.1. Study Approach

This research was carried out in several stages as follows. Firstly, the survey and interview guides were created based on the research questions and a preliminary review of literature on the subject. Secondly, the survey was administered, and interviews were conducted by the researcher. Thirdly, the survey was analyzed, and transcripts were coded. Finally, thematic analysis was used to create a theme map, which was followed by the analysis of results.

To explore the e-Learning experiences of deaf students during the COVID-19 era at TVTC, a mixed-methods approach was taken. The specific methodologies used were case study and survey [54]. We considered two approaches to be appropriate for this study because of several reasons. The first reason is that the case study methodology allows us to investigate a particular phenomenon in its natural environment [55], which also applies to deaf students in the TVTC. Given that the COVID-19 situation is of a worldwide nature, we deemed it fit to use a survey in order to obtain the views of deaf students whose education had been disrupted by the pandemic. The survey technique was conducted using two data collection methods, namely survey and interviews.

The nature of the current study is that it is both descriptive and exploratory qualitative. The descriptive aspect provided observations on how deaf students are e-learning in the current pandemic, while the exploratory qualitative aspect sought to identify their experiences in the COVID-19 era [56,57]. In this study, we followed the case study guidelines by Runeson and Höst [57] and survey guidelines by Kitchenham and Pfleeger [58]. To analyze qualitative data, we combined our methods with a deductive thematic analysis [59–61]. The thematic analysis was selected for this research [61]. The reason for selecting thematic analysis was to enable the researcher to identify themes in the study that could help interpreting interviews and derive meanings. Various prior studies conducted on deaf and hard of hearing have found this method to be adequate [62,63].

One of the advantages of thematic analysis is flexibility, and it was selected in this study because it can follow a given theoretical framework, unlike grounded theory [64]. The theoretical framework [61] employed in this research is deaf and hard of hearing challenging (described in detail in Section 5) stages, meaning that the thematic analysis approach used will be deductive. The researchers assumed a connection between the respondents' replies and the meanings. Hence, the essentialist/realist thematic analysis approach was adopted [65]. The directions given by Braun and Clarke [61] guided the thematic analysis technique in this paper.

4.2. Data Collection

This study's data were collected in two steps. First, we conducted interviews to collect preliminary insights, similar to the empirical approach of collecting evidence by surveys. The interview responses' patterns gave crucial insights on e-learning experiences for deaf students. Secondly, from the findings of the interviews, we designed a survey and distributed it to the deaf students. The reason for using the survey was to corroborate the data from the interviews with a higher sample size. We conducted a survey of deaf students in the TVTC. By conducting the survey, an in-depth investigation of the research question could be explored comprehensively and systematically.

4.3. Interviews

The researcher conducted interviews to explore the general experiences of deaf students learning at the TVTC during the pandemic. The following sections provide the interview protocol, participants, and analysis of the interview data.

4.3.1. Protocol

To ensure that researchers received both structured and unstructured responses, a semi-structured format was used in creating the interview schedules. The interviewer used the funnel method so that the interviews would look like conversations [66], as opposed to a question-and-answer format. Such an approach encouraged the interviewees to speak their minds freely, although the researcher ensured that the topics of interest in the discussion were addressed. The mentioned approach allowed the researcher to meet the exploratory and observational objectives of the study. To ensure validity of the interviews, investigator triangulation was conducted [67], where the questions were thoroughly discussed, and interviews were conducted by three researchers. It was generally agreed that the questions were sufficient in collecting information about the experiences of deaf students during the COVID-19 pandemic.

The interview consisted of 25 questions that asked various aspects that were in line with the objectives of this study. Given that a semi-structured approach was used, the interview questions acted as a guide for the researcher. The questions were used as conversation starters, after which the conversations flowed without disruptions. Table 2 presents the set of interviews questions. Interviews were conducted by the researcher via the Zoom platform using the Arabic language. All the respondents were native Arabic speakers; hence, the choice for the interviewing language was made. Given that Arabic is the first language in Saudi Arabia, it enabled the researcher to easily interact with the interviewees and obtain more insight from them. It is crucial to mention that the students were speaking sign language, and an interpreter translated the signed language to the Arabic spoken language. We considered this accommodation vital for the smooth running of the interviews, and since none of the researchers was conversant with sign language, we hired an interpreter.

4.3.2. Participants

The voluntary response sampling method explained by Murairwa [68] was used because the researcher wanted to include only those deaf students that were willing to share their experiences. Therefore, out of all the participants that were willing to take part in the research, only those who volunteered were interviewed. The interview stage was exploratory, and therefore, the researcher was not concerned about non-generalizability of results because of using the voluntary response sampling method.

The number of interviewees that agreed to take part were 8, out of a population of 80 deaf students that had been contacted. The interviewed students were all male because the college admits male students only. The individuals were contacted via the students' emails, and their responses towards the participation request were noted down. All of the 8 students were male, 4 in each of the 2 majors at TVTC (computer technology and business). Table 3 presents the demographic summary of the participants. The equal splitting between the two majors was conducted in order to have a good overview of each category. The interview duration was between 20 and 30 min. We compensated all participants with a $25 prepaid gift card.

Table 2. The set of interviews questions.

First **Background and Demographics**	*Fourth* **Challenges and Concerns**
Years of age, and study major	What were your distractions while you were learning online?
Do you have access to a device for learning online?	What were your most challenges during online learning?
What device did you use for online learning?	How was your learning environment at home?
Second **Generic Views**	How did you communicate with your teachers?
How would you describe your experience in learning online?	Were you able to access the class materials via Blackboard?
What type of device did you use for online learning?	How you ever encounter any barriers or issues communicating with your teachers or department?
How did you study for the class that needed hardware equipment?	Did all videos have subtitles?
Based on your experience in online learning, what do you prefer now?	Do you have a printed text transcript of audio content on the website?
Third **E-learning Tool**	*Fifth* **Students recommendations**
What is your perspective on Blackboard platforms?	What do you feel are the benefits of online courses, such as those provided during COVID-19?
Did you use any other e-learning tools? Why?	What are the things that you would like to change in online learning?
Did you train on Blackboard? if not, did teachers and department shared with you resources?	

Table 3. Demographics information. Each participant (P#) answered the interview questions.

Participant	Age	Major	Year	Derive Used	Received Support Yes/No	Prefer Learning Online Yes/No
P1	23	Computer Technology	3	Laptop	Yes	No
P2	22	Computer Technology	2	Laptop	No	No
P3	22	Business	2	Laptop	No	No
P4	21	Business	4	Mobile Phone	No	No
P5	24	Business	1	Mobile Phone	Yes	No
P6	20	Computer Technology	3	Desktop Computer	No	Yes
P7	22	Business	3	Mobile Phone	No	Yes
P8	23	Computer Technology	4	Desktop Computer	No	No

4.3.3. Data Analysis

The interviews were transcribed, which prepared them for the data analysis stage that was conducted through thematic analysis. The first stage of the thematic analysis method is reading the scripts in detail to facilitate coding the interviews in line with the research questions. In this study, codes were used to categorize the responses of the participants according to the selected topics. Subsequently, the codes were utilized in creating a theme map, which would illustrate the results of the study.

4.3.4. Transcript Coding

The interview responses given in the interviews were scanned in order to facilitate the coding process. The researcher assigned codes according to topics that expressed certain opinions, attitudes, and experiences that related to the research question. Given that the interviews were long, the researcher identified only the relevant responses to the current study. In the initial step, the researcher scrutinized the interview scripts and created a list of codes that emerged from the responses. The second step involved evaluating and investigating the codes to ensure that they were representative of the research questions. In the third step, the researcher revised the codes, which involved merging or dividing some of them.

4.3.5. Deducing Themes

The researcher categorized the generated codes into various themes. In this research, a theme is considered a pattern of responses that relate to a given research question. Thematic analysis involves constant revision of themes as the researcher investigates the interview text, which ultimately leads to the creation of a theme map [61]. In this study, a theme map demonstrated the insights derived from the interviews and their relationships. Such an approach ensured that detailed and in-depth descriptions of the research subject was conducted without interference from irrelevant data. Theme mapping was conducted and revised three times by the researcher. An illustration of the research findings of the theme map is given in Figure 1.

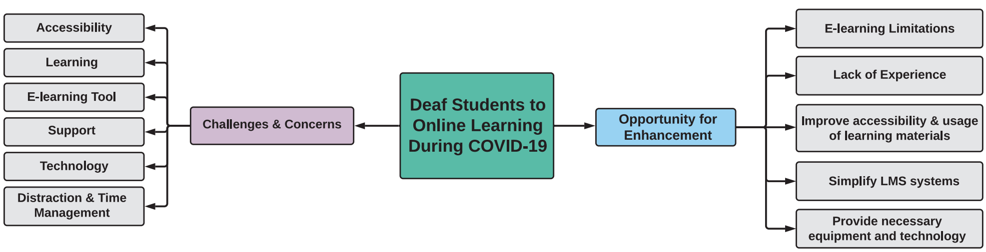

Figure 1. Thematic analysis findings in the form of a theme map.

4.4. Survey

After identifying the relevant topics from the interviews and considering the research questions, the survey was designed. The survey was created to corroborate the interview findings, discover new insights, and estimate the prevalence of some aspects using a larger population.

4.4.1. Design

The designing of the survey began with generating 100 questions and statements that were developed by the author. The survey was divided into four sections according to the themes that had been generated in the interviews section. Time was taken to revise the questions in order to remove those that were considered ambiguous, irrelevant, repeated, or of a personal nature. The revision of the questions paved the way for reducing the questions from 100 to 72. To evaluate the survey's effectiveness and overall experience, a pilot study was conducted with five deaf students. The feedback was that the survey was very long, some of the questions were repeated, and that it was important to arrange the questions in a logical manner.

Based on that information, we reduced the number of questions from 72 to 42 and grouped them into 3 sections. Easier questions were given first to encourage the respondents to answer the questions. Demographic questions were also placed at the end of the paper so that they do not lead to no-response if placed at the beginning. The researcher included both closed-ended and open-ended questions in order to provide a chance for the respondents to give their personal insights without restrictions. For our final survey, we included 42 questions that can be broken down as follows: 18 Likert questions, 19 multi-choice questions, and 5 that were open-ended. The Likert questions used a 5-point scale that indicated the extent of interest, concurrence, or importance of an aspect. It was also deemed appropriate to make some of the questions optional so that the respondents do not feel pressure to answer them just for the sake of completing the survey. The survey were designed using Google Forms, which also helped in collecting the data. It is also important to state that the survey was created in the Arabic language, which is the first language in Saudi Arabia, to enable the respondents to understand the questions easily [69]. The survey and interviews were carefully translated into English by three authors. Subsequently, a three-stage process was conducted to check the translated responses for their correctness. In the three-stage process, each of the three authors reviewed the translations and certified that they were accurate. Our survey questions are available in both Arabic and English in [70].

4.4.2. Participants

The survey link was shared through the students' emails. Out of the initial targeted number of 80 respondents, the researcher received 65 responses (response rate = 81.25%), which is considered high [71] . All the respondents were male because the college has only male students. From the total number of participants, 26.2% majored in computer technology, while 73.8% majored in business. The respondents were in their first, second, and third years of study.

4.4.3. Data Analysis

The results of the survey were analyzed by first merging some of the responses. For instance, strongly agree and agree were combined to give the general agreement rate. A weighted average response was developed to simplify the recording and analysis of the responses. For example, the disagreement percentage was the proportion of the responses that strongly disagreed or disagreed with a certain question. Analysis of quantitative data was conducted using R Language, which is a statistical computing package.

To facilitate the understanding of the quantitative data, it was corroborated with qualitative data. Such an approach helped in providing explanations for support or opposition to some questions. Several quotes were also provided, which were retrieved by reviewing the themes and codes that had been generated in the thematic analysis stage.

4.4.4. Privacy and Data Protection

We considered several privacy and data protection aspects. For instance, we anonymized all responses in order to hide the identity of the respondents that participated in the study. Furthermore, all the research materials, including responses received from participants, were secured in the researcher's laptop using passwords. Prior to participation, we requested consent from all potential respondents, who allowed us to use their information for the research.

4.4.5. Rationale behind the Interview and Survey Questions

We grouped our questions into five sections, as follows: background and demographics, generic views, e-learning tools, challenges and concerns, and students' recommendations. We created the questions based on the insights that had been gained from the related studies on the perspectives of deaf students in various other places. The rationale of creating and framing the questions the way we did was to obtain a broad picture of the challenges of online students within our research context.

5. Study Results

This section presents the findings of our study.

RQ_1: What are the challenges and concerns that deaf and hard-of-hearing students are having with an online education during COVID-19 pandemic?

A survey and interviews were conducted in order to obtain both quantitative and qualitative data. We have grouped our findings into seven challenges that will be discussed in this section.

As shown in Figure 2, we report the main challenges faced by deaf and hard-of-hearing students with an online learning education. The majority of the students (62 respondents

(96.9%)) communicated that they were having network issues or unreliable internet access at home. Forty-two students (75.4%) revealed that they have no access to tools to help facilitating the study and the many type distractions at home, such as the distraction of smartphones and televisions in the same room. A moderate subset of 34 students (52.3%) were concerned about the difficulty of communicating with the instructors and the interactions were not feasible, whereas two students (3.1%) were concerned about the collaboration with their fellow students. Twenty-five students (38.5%) found that COVID-19 makes fast internet connections more critical. Twelve students (18.5 %) mentioned that the development of the COVID-19 pandemic has resulted in life-altering employment shifts across Saudi Arabia. Five students (7.7%) found that maintaining an unstructured work schedule can be difficult and hard to adjust to, whereas one of the students (1.5%) found that the challenge is centered around the lack of interactions and feelings of isolation.

In the rest of this subsection, we provide more in-depth analysis of these challenges.

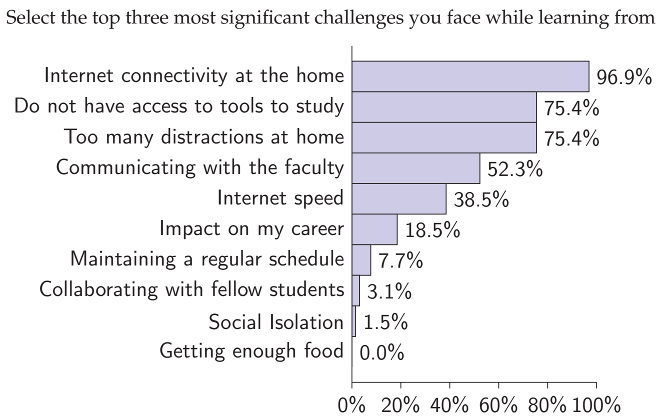

Figure 2. Presents the most challenges deaf students faced.

(1) Issues associated with accessibility:

In this section, we wanted to know whether students were accessing all the information on Blackboard, and our results are given in Figure 3. It was apparent that 47 students (72%) faced challenges in accessing information on the platform. **P8** noted that:

> *"at first, using Blackboard was extremely difficult and causing problems for getting course material and navigating the platform. Furthermore, there were different opinions because the department encourages us to use Blackboard, whereas the teachers encourage us to use different sites, so sharing class materials were very hard between the teacher and students. We ended up using social media application 'WhatsApp' to share the class materials."*

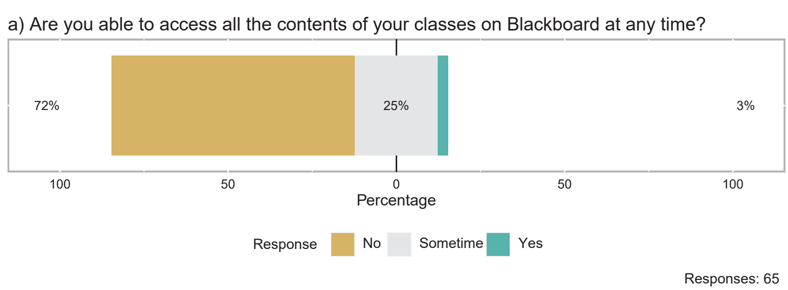

Figure 3. Accessibility of coursework materials.

We also wanted to know whether the coursework materials were accessible, and our results are given in Figure 4. We determined that most of the students indicated that the materials were not easily accessible. **P5** explained that:

> *"Blackboard was not friendly interface. I had an issue locating the exam component since there are a lot of headers and sub-headers in the navigation bar, and the font was very small hard to read."*

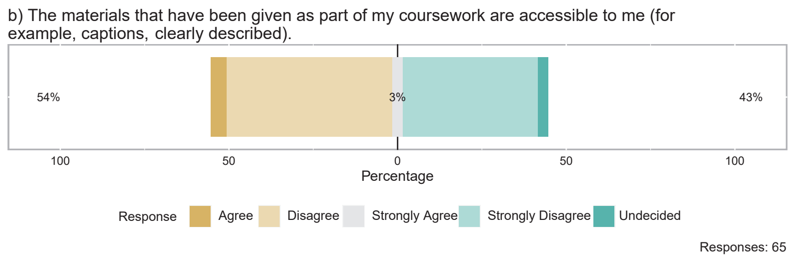

Figure 4. Accessibility of materials on Blackboard.

We also asked students whether the blackboard pages were easy to navigate, whether the videos had subtitles, whether they had enough time to complete the assignments, and whether the text sizes were easily seen. Our results are given in Figure 5, where a majority of the students indicated a lack of accessibility in all four aspects mentioned. **P3** explained that:

> *"Blackboard was in English interface, and it was hard for me to switch it to the Arabic language without any assistance. I missed many classes for this reason, and teachers were not recording the classes."*

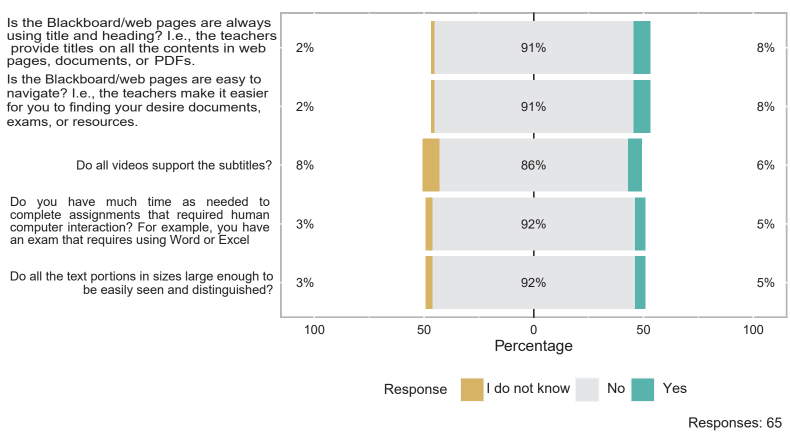

Figure 5. Responses to questions regarding to accessibility aspect.

(2) Learning problems:

In this sub-section, we wanted to identify the kind of learning challenges that the students faced during the pandemic. One of the questions we asked the respondents was whether the online learning was stressful during the pandemic, where 54 students (83%) noted that it was extremely stressful. The results are given in Figure 6.

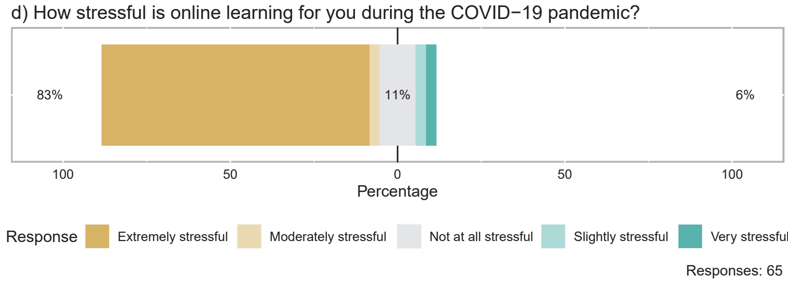

Figure 6. Stress in online learning during COVID-19 pandemic.

We also wanted to know whether online learning has been effective during COVID-19, and our results are presented in Figure 7. It was unfortunate that 40 (62%) of the respondents indicated that their learning was not effective at all during the pandemic.

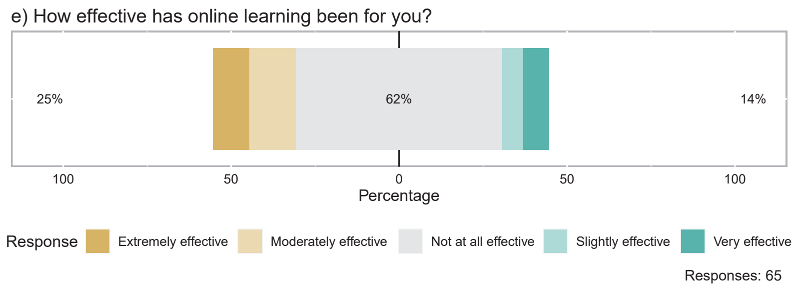

Figure 7. Effectiveness of online learning during the COVID-19 pandemic.

We also wanted to know how the educational performance of deaf students had been affected during COVID-19, and our results are given in Figure 8. Approximately 60 (92%) of the respondents were very worried about their performance during the period. Such outcomes were caused by teaching and learning challenges in learning that deaf students have faced in the pandemic. **P4** said that:

> *"Less than half of the materials were covered because the time was short, and we faced difficulties understanding the material. It has to be recorded for us to see it again, but there was nothing recorded."*

Such situations affected the educational performance of students.

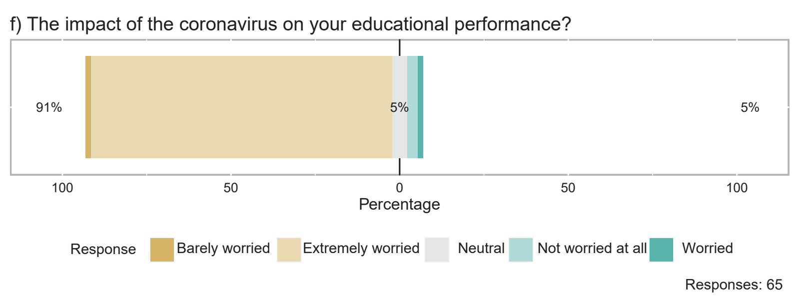

Figure 8. Impact of COVID-19 on educational performance.

(3) Challenges associated with e-learning tools:

Using online e-learning as a tool for teaching is one of the challenges and factors influencing the acceptance and use of e-learning tools, and these tools have become a key part of pandemic life. The rate of participants agreement on the usage of Google Meet, Zoom, and Backboard was 49 (75.4%), 13 (20%), and 3 (4.6%), respectively. From Figure 9, it is evident that Google Meet was the most preferred platform, followed by Zoom. A closer introspection reveals a shortcoming of Zoom and Blackboard over Google Meet that is the limitation of the visibility of the camera. We report samples of the participants' comments (**P2**) below to illustrate this challenge:

What is the most suitable e-learning platforms for you?

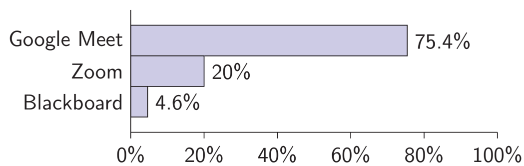

Figure 9. Presents the most suitable e-learning platforms students experienced.

> *"Zoom and google meet. Google meet was the best because all cameras were visible to us, whereas in Blackboard, we can only see four cameras."*

(4) Problems with communication:

In this section, we wanted to know how helpful deaf teachers were to their students. Most of the students indicated that the teachers have not been helpful. Our results are presented in Figure 10. For those students that found their teachers not very helpful, they gave their reasons. For example, **P3** said that:

> *"Communicate was my biggest issue, and there were difficulties in communicating with our teachers and the department. Some teachers take a while to respond, where others not responded at all."*

Other challenges were related to the congruence of the technology used on both the students and teachers. **P1** noted that:

> *"The teacher would call the student and sometimes presses on the name of the student or calls their name or waive at the student but in this case, the student cannot see, because the picture would be apparent only to the teacher but from the student view it was only visible for four students' camera, not all the class. So, the teacher would waive, but the student did not know because of the other four students, so it is always very late for the student to ask, and the teacher would answer: hold on, let me see which student needs me so I can show their camera."*

Hence, the communication challenge greatly affected the helpfulness of the teacher towards the students. We also wanted to identify the communication means that students used to communicate with their teachers, and our results are in Figure 11. It was established that 60 (93.8%) of the students used WhatsApp, while 13 (20.2%) used Zoom. **P5** said that:

> *"When the screen freezes, I take a picture and send it to the teachers via WhatsApp, and tell them I cannot log in."*

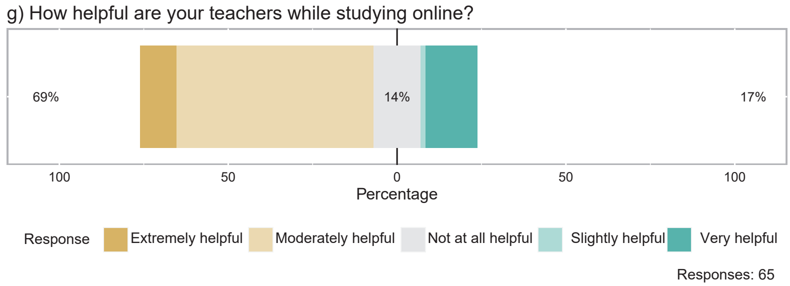

Figure 10. Teachers' helpfulness during the COVID-19 pandemic.

During your remote training, do you use any communication means, such as social media, video chat, etc. to help you communicate with your teachers or classmates? If yes, what is it?

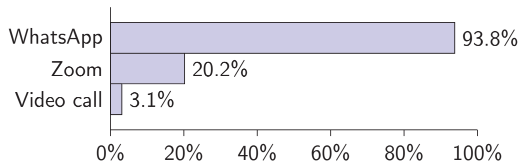

Figure 11. The communication means that students used to communicate with teachers and classmates.

(5) Inadequate support:

In most cases, deaf students require support in order to assist them in interpreting and understanding content from their teachers. Figure 12 shows the results that we obtained. A large majority of the students indicated that the level and kind of support that they received was not helpful. To interpret their suggestions, **P4** said that:

> *"We do not have an interpreter during COVID-19 as we used before the pandemic. The teacher should have a strong sign language for us to understand them. That is the most crucial thing the deaf needs in learning. The problem we encounter that some teachers sign language is weak. So as a deaf student, if the sign languages were inadequate, there isn't any benefit because the information isn't received correctly and isn't fair."*

Even when the interpreters and sign languages were provided, they were not effective in their roles. **P6** explained that:

> *"Teachers were very close to the device, and I will not be able to see their hands and signs."*

We concluded that the students did their best in trying to access the learning platforms but faced challenges due to lack of support. **P3** clarified that:

> *"Many times, we login into the correct lectures, but we cannot find the teacher."*

Support for deaf students is critical in the classroom and indispensable in virtual learning. Such students require a lot of assistance, which has not been forthcoming during the COVID-19 pandemic. Even when offered, it has not been adequate.

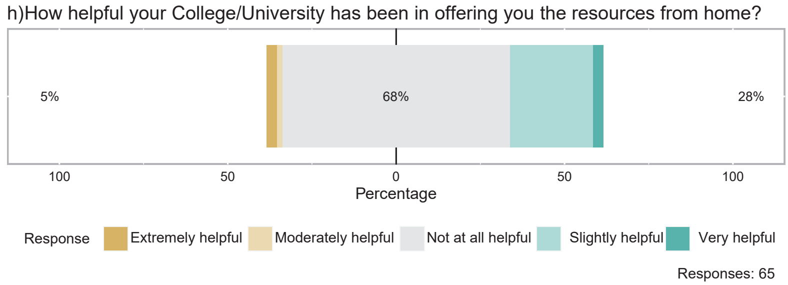

Figure 12. Institute support provided to deaf students.

(6) Technology problems:

We also wanted to know whether students were satisfied with the software that they were using for learning. Figure 13 shows the results that we obtained. We were surprised that 59 (91%) of the respondents were not satisfied with their online learning, while only 3% expressed satisfaction. To explain the situation, **P2** said that:

> *"When I encounter problems with the laptop, I switch to access the class through the phone because the internet signal was stronger on my phone than the laptop. When a teacher sends a file during the class, it was not easy to see it through a phone, so I switched back to the laptop. Then, I still struggle to get the file due to the weak internet signal."*

The COVID-19 pandemic has created a sudden shift from face-to-face learning to virtual learning, and it seems that many institutions, teachers, and their students were not ready for the change. The challenges have been especially worse for deaf students who require a lot of instructional support in their learning. Such a situation may explain the technological difficulties that they have faced.

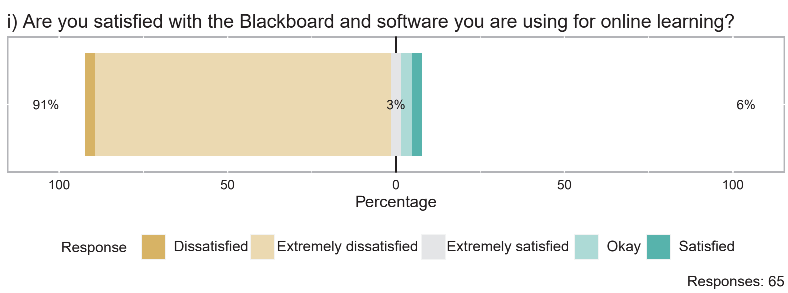

Figure 13. Students satisfaction on Blackboard platform.

(7) Distractions and Time Management Challenge:

Most of the respondents suggested that their learning during the COVID-19 period was greatly affected by the environment at home. As shown in Figure 14, approximately 51 (78%) of the respondents did not have a peaceful time when studying, and the majority of them faced distractions. Such an inconducive environment greatly affected the learning of the respondents at home.

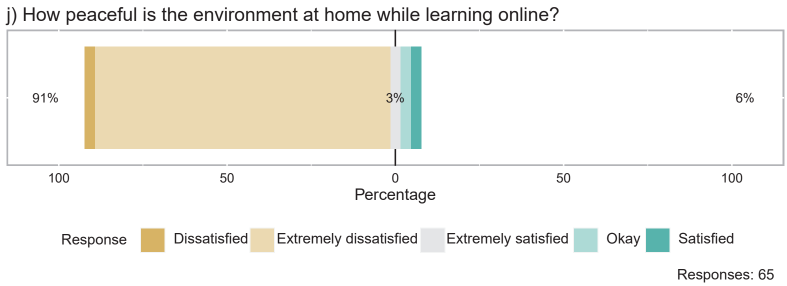

Figure 14. Students environment at home during COVID-19.

Having established that most of the students were distracted while studying from home due to the pandemic, we wanted to find out the types of distractions that they faced. In Figure 15, 56 (86.2%) of the students were distracted by social media, which is a common issue that affects students' learning in the modern world. Another significant issue was disruption due to the people at home, which was reported by 47 (72.3%) of the respondents. **P1** said that:

> *"It was difficult to manage time at home, and I was anxious. I remember that there were problems between my dad and me, where he kept asking me to do stuff at home while I was trying to study for college. Another issue is that many children were playing around, so half of the time focused on lectures where the other half was being busy with family."*

Similar sentiments were also given by the other interviewees, who confirmed that family commitments, as well as disturbance from parents and siblings, also disrupted learning. It was evident that distractions and time management challenges greatly affected the respondents during their studies at home, as Figure 16 indicated 36 (55.40%) of the students had poor time management. We established that the environment was not conducive for them.

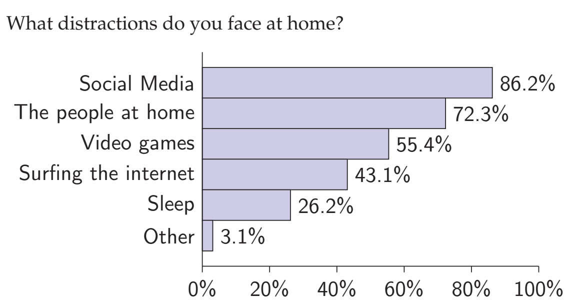

Figure 15. The distractions the deaf students faced.

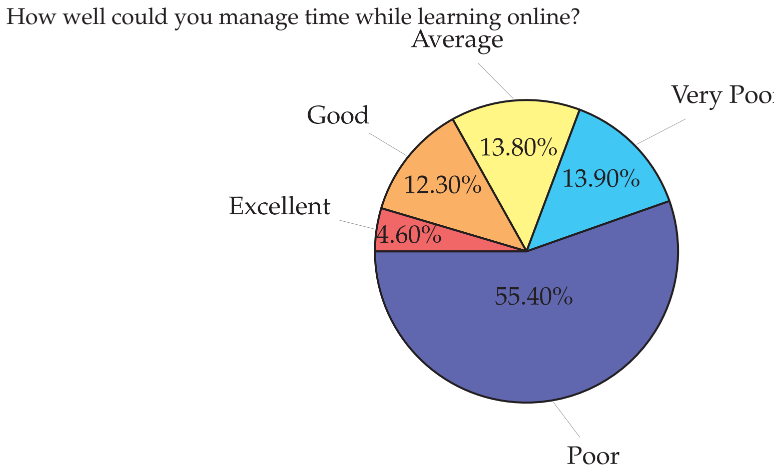

Figure 16. Distribution of student's time management during COVID-9.

6. Study Discussion

In this section, we provide the most important takeaways from our study. In total, five takeaways are discussed in the sub-sections below.

Takeaway 1: E-learning limitation. We found that the inadequacy of tools with limited cameras that can be visible to teachers and students posed great challenges to deaf education. The tools do not provide subtitles, and for Zoom, they provide a caption for the stream class, without supporting languages, such as Arabic. Such a finding greatly affected deaf students' learning because they cannot hear what is being said but depend on what they see on the screens. The importance of visual media in education is also indicated by Fernandes et al. [33] in Indonesia, who found that the effective use of videos greatly promoted education. Improvement of such aspects could greatly help in improving deaf education. Future researchers can compare the effectiveness of various e-learning tools to suggest which are more appropriate for deaf students.

Takeaway 2: Lack of experience. It was clear that teachers and students are not trained on the tools or do not even have good documentation to follow. Without such training, there were problems in how both students and teachers used the technology, leading to challenges in education. For deaf students, in particular, have not been trained to use the special tools needed to facilitate their education. Such findings corroborate a similar study by Krishnan et al. [51] in Malaysia that demonstrated issues in e-learning due to a lack of familiarity with technology. Other scholars can investigate the range of training programs, methods, and guidelines that would be useful in enlightening the population on how to undertake online education effectively.

Takeaway 3: Improve the accessibility and usage of learning materials. We noted that there were significant problems in accessibility and usage of learning materials due to reasons such as a lack of subtitles and captions on videos. The importance of improving accessibility for deaf students is confirmed by studies such as Sommer [52] in the US and Mantzikos and Lappa [53] in Greece. It is important to state that deaf students need such assistance in order to understand the content in videos. More research is needed on these accessibility issues in distance/remote education for deaf students to minimize access challenges in similar contexts.

Takeaway 4: Simplify LMS systems. Our findings showed that most students were facing problems navigating through the LMS systems, blackboard in particular. For instance, they did not know how to change languages, switch between content, obtain course materials, among others. The problem is worse for deaf students, who cannot follow audio directions on the systems. Such technical issues were also identified by Alsadoon and Turkestani [4] as significant barriers to e-learning for deaf students. It will be important for software engineers to investigate how LMS systems can be simplified for deaf students.

Takeaway 5: Provide necessary equipment and technology. We established that a lot of equipment was needed for students to communicate with their teachers and access materials from the online platforms. For instance, it is important for students to have computers, fast internet access, among other things. The need to provide such tools and technologies was emphasized in a previous study by Krishnan et al. [51]. It will be important to identify how such software and devices can be availed to students.

7. Limitations and Future Work

Given the range of effort, direct instruction, and mainstream environments on TVTC, we collected data in order to understand the challenges faced by deaf students. The scope of the study was not to focus on recommendations on how deaf students can best be supported during COVID-19 restrictions or similar circumstances when in a distance learning environment. Future researchers can study the long-term effects of the COVID-19 pandemic and work on coping with the current challenges mentioned in this study. For instance, an organization can set high standards for access to information and monitor educational access for deaf learners. As with every case study, the results may not generalize to other institutions. However, extending this survey with the teachers is part of our future investigation to study the challenges faced by the instructors as well, so technology could be better prepared for the next disaster.

8. Conclusions

Understanding the challenges that deaf students faced during the COVID-19 period is of paramount importance to the deaf community. In this work, we aimed to investigate the e-learning experience of 65 deaf students at the Technical and Vocational Training Corporation (TVTC) in Saudi Arabia. Due to the closure of physical classes, online learning using several devices in synchronous (live) and asynchronous (pre-recorded) environments has become an alternative learning method. However, this alternative learning method becomes challenging to deaf students due to the limited resources and accessibility to online learning. In summary, we found that: (1) Blackboard as well as the course material are not easily accessible to the deaf students; (2) deaf students find that learning is extremely stressful during the pandemic; (3) Google Meet is the preferable e-learning tool; (4) communication between deaf students and teachers is ineffective, which impacts the learning outcomes; (5) a lack of support in terms of the provided interpreters hinder the learning process; (6) technology is not always enhanced for people who are deaf or hard of hearing; (7) students who were deaf or hard of hearing had difficulty managing their time due to different types of distractions.

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Informed Consent Statement: For the online survey in this study, a specific section regarding the participants' consent was included. No personal data were collected, and all the data in the survey were anonymized.

Data Availability Statement: Not applicable.

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Article

A Case Study Investigating Mental Wellbeing of University Academics during the COVID-19 Pandemic

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Abstract: COVID-19 has impacted Higher Education worldwide. While several studies have examined the effects of the pandemic on students, few have addressed its impact on academic staff. Here, we present both survey (n = 89) and interview (n = 12) data highlighting the pandemic-induced effects on academics from various disciplines and career stages. Data was collected between May and September 2020, aiming to capture and understand the immediate effects of the U.K. lockdown on the academics examining demographic and employment factors, digital abilities and confidence, and mental wellbeing. Analyses revealed that most academics were satisfied with the support they received from the university and colleagues, and they had adequate equipment and space at home to work. However, half incurred additional financial costs to maintain access to technology and many felt an altered relationship with the university. There were discrepancies in digital abilities and confidence according to employment status, age, faculty, and social identity as an academic. Teaching workload did not increase across the board, rather seniority predicted increases. Levels of wellbeing were low but were not significantly predicted by workload increase or abilities and confidence in working digitally as might have been expected. Stronger social identity as an academic may predict higher mental wellbeing with qualitative data suggesting teamwork and collegiate activities helped. Furthermore, interviewees identified several positive aspects to working remotely. These findings suggest universities should consider carefully how to support all staff to work digitally and consider flexible working post-pandemic.

Keywords: digital capabilities; online teaching; social identity; wellbeing

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1. Introduction

COVID-19 has deeply impacted Higher Education [1]. While research has considered the effects of the pandemic on students [2–8], few studies have considered the impact on academics [9,10]. This gap is problematic because university academics not only provide education but are also at the forefront of the pastoral and academic support provision for students. Moreover, even prior to the pandemic, concerns had been raised about academic staff wellbeing, with many reported as being at risk of burnout [11] and a recent survey finding that 43% of academic staff exhibited symptoms of at least a mild mental disorder; this is almost twice the figure for the general population [12]. The pandemic induced sudden changes in the mode of working, switching to online education and homeworking, affecting both the personal and professional lives of the academics has the potential to have worsened the situation further.

Anecdotal evidence suggests that the abrupt transition to online education increased teaching workloads for academics. In the U.K. there were two critical periods in 2020—the period following the closure of universities' premises (March–April 2020) and the summer period (July–August 2020). During the former, academics were forced to respond quickly to the pandemic and offer prompt alternatives for face-to-face teaching and assessment. Thus, academics were required to provide timely solutions while they experienced a loss of usual resources and support provided through campus services (e.g., IT support) and other key support, such as childcare. In the latter period, academics focused on developing teaching suitable for the online delivery for the next academic year (2020/2021) when it became apparent a return to face-to-face teaching was not viable.

Online education is not new, but the accelerated shift to a fully online provision requires significant adjustment of teaching. Online teaching demands specific pedagogical knowledge and involves redesigning and reorganizing the teaching content to make it suitable for a different environment [13]. While motivation to use digital technology in teaching is high, few academics feel that they have the time to develop the necessary digital skills which underpin online education [14]. Further, the constraints experienced by students in using digital technology, such as challenges with digital devices and internet connectivity, would be equally applicable to academics when preparing for and delivering online learning without access to campus facilities [15]. In this context, the shift online might be expected to have been a source of considerable stress for academics.

It is also likely that the distress experienced by students, due to the pandemic, would have had a knock-on effect on the workload and emotional strain for some academics. Academics are often the first to respond to students' mental health concerns [16,17]. Despite this, research suggests that the emotional investment and time spent in supporting student mental health is not adequately recognized by universities and support for academics is limited [16,18]. Notably, in providing support to the students, the mental health and wellbeing of academics is often ignored [19]. Usually, the time spent in supporting students is unaccounted for and comes at a cost to other responsibilities, including research, which are assessed in performance reviews and count towards academic promotion [20]. This impact is greater for female academics than their male counterparts [21].

Teaching and other student-facing responsibilities were not the only activities impacted by the pandemic; some academics were involved in COVID-related research whilst others experienced a suspension of research activities, resulting in a loss of research funding or forcing plans to be re-arranged and affecting outputs that are essential for promotion and other forms of recognition. Disruption to these core activities of academics is likely to have impacted on their professional identity, which is known to be affected by multiple identities (e.g., as a teacher, researcher, discipline expert, gender, and personal roles such as parent [22]). Furthermore, professional identity in academics contributes to their sense of belonging [23], which could also be disrupted by drastic changes in work activities. Homeworking can create challenges for organizational belonging [24]. Both social identity [25,26] and sense of belonging [27] can impact on mental wellbeing indicating that these changes to academic working could affect mental wellbeing in staff.

Given the previous concerns raised about staff wellbeing prior to the pandemic and the clear potential for COVID-induced changes to academic roles and responsibilities to negatively impact on staff mental wellbeing, we aimed to better understand the impact of COVID on staff using a combination of quantitative and qualitative research. Specifically, we aimed to better understand what factors contributed to (i) digital capabilities, (ii) increased workload, and (iii) mental wellbeing.

2. Materials and Methods

2.1. Design and Procedure

This study adopted a mixed methods approach, with two phases of data collection. During the first phase (12 May–23 June 2020) data was collected from academic staff at a large Russell group London-based university using an anonymous online survey. The survey was advertised via institutional research recruitment circulars, the university's virtual learning environment and through program administrators. It took approximately 25 min to complete, and participants were asked to provide an email address at the end, held separately from their survey data, if they would be willing to be interviewed about online education during the pandemic. The interviews formed the second phase of data collection and were held in August and September 2020. Interviews were approximately 40 min. All participants completing the survey had the option of being entered into a prize draw for £50 vouchers and those completing interviews were given a £10 voucher honorarium. This research was approved by the institutional ethical review committee (MRA-19/20-18209).

2.2. Survey Measures

2.2.1. Demographic Factors

To characterize the sample and understand what demographic factors might impact workload and wellbeing the first part of the survey assessed age, gender, ethnicity, and disability. Given that one of the major challenges facing all workforces during the pandemic was the closure of school and childcare facilities, we also assessed caring responsibilities. Staff were asked to indicate if they had caring responsibilities and for whom (e.g., pre-school age child). They were then asked to indicate if these responsibilities had increased during COVID and whether any increase had impacted negatively on their work. They were also asked to indicate the how many hours were spent caring in a day. A final open question on caring asked staff to explain how their work has been affected by the increased caring responsibilities. Demographic characteristics of the sample are shown in Table 1.

Table 1. Teaching staff demographic information.

Demographic	Survey (%)	Interview (%)
Age range (years)		-
26–35	17 (19)	-
36–45	32 (36)	-
46–55	20 (23)	-
56–70	19 (22)	-
Gender		
Female	56 (64)	6 (50)
Male	32 (36)	6 (50)
Ethnicity		
White British	45 (51)	-
White non-British	34 (39)	-
BAME †	9 (10)	-
Disability		-
No	63 (75)	-
Yes	21 (25)	
Caring Responsibilities		
NoYes	50 (56)	-
	39 (44)	-

† Including Black or Black British, Asian or Asian British, Chinese or Chinese British, and mixed background ethnicities.

2.2.2. Employment Factors

Details of employment were also collected with staff indicating the following about their current employment: (i) status as full or part time (with full-time equivalent); (ii) seniority of academic position (e.g., teaching fellow, professor); (iii) faculty and type of program they teach on (e.g., natural science and undergraduate); (iv) contract type (e.g., fixed term). Table 2 provides a summary of the employment characteristics of the sample.

Table 2. Staff employment information.

Employment	Survey (n = 89)	Interview (n = 12)
Employment status		
Full-time	67 (75)	-
Part-time	22 (25)	-
Contract type		
Fixed term	20 (23)	-
Open-ended	67 (76)	-
Casual †	1 (1)	-
Seniority		
Teaching Fellow	18 (21)	3 (27)
Lecturer	27 (32)	4 (36)
Senior Lecturer	17 (20)	0
Reader	11 (13)	2 (18)
Professor	11 (13)	2 (18)
Teaching level		
Undergraduate	60 (68)	-
Taught postgraduate	28 (32)	-
Faculty		
Arts & Humanities	9 (10)	1 (8)
Social Sciences & Economics	23 (26)	4 (33)
Medicine & Allied healthcare subjects	47 (53)	5 (42)
Natural & Mathematical Sciences	9 (10)	2 (17)

† Omitted from further group analysis.

Table 3 indicates the employment characteristics of staff indicating a range of staff contributed to the dataset.

Table 3. Regression coefficients for overall digital confidence and ability.

IVs	Digital Confidence				Digital Ability			
	b	95% CI		Sig	b	95% CI		Sig
Gender	0.90	−50.89	27.06	0.873	−0.03	−11.12	11.06	0.996
White non-British [1]	−1.65	−10.32	12.11	0.746	0.76	−9.35	10.87	0.881
BAME [1]	−7.12	−11.82	8.51	0.287	−4.57	−18.55	9.42	0.516
Age	−7.21	−20.38	6.15	<0.01	−5.41	−10.42	−0.40	<0.05
Disability	6.38	−11.98	−2.44	0.242	8.05	−3.13	19.23	0.155
Caring	2.09	−4.43	17.19	0.649	−3.59	−13.05	5.88	0.451
Status	14.29	−7.08	11.26	<0.05	4.80	−7.54	17.15	0.439
Contract type	−1.84	2.61	25.98	0.743	−0.70	−12.53	11.13	0.906
Seniority	1.19	−13.06	9.37	0.532	3.22	−0.81	7.24	0.115
Teaching level	9.82	−2.61	4.99	0.039	4.11	−5.56	13.78	0.398
Arts/Humanities [2]	12.09	0.53	19.11	0.137	8.74	−8.22	25.71	0.306
Social Sci.&Econ. [2]	0.71	−3.95	28.13	0.891	5.88	−4.92	16.68	0.280
Natural/Maths Sci. [2]	21.58	−9.67	11.09	≤0.01	17.36	1.39	33.32	<0.05
Social identity	0.72	5.63	37.54	≤0.001	0.57	0.13	1.01	<0.05
Safe space to work	3.57	0.30	1.14	0.553	0.31	−12.13	12.75	0.960
Equipped space	1.92	−8.41	15.55	0.722	0.27	−10.32	10.86	0.959

Digital confidence: R2 = 0.52, F(16, 55) = 3.69, $p < 0.001$; Digital ability: R2 = 0.37, F(16, 57) = 2.10, $p = 0.021$. [1] Reference value, White British; [2] Reference value, Medical Sciences.

Related to employment, the 11-item Social Identity scale [28] was used to measure how much of the participants' perceived identity was linked to them being academic at the specific university to access constructs around identity and belonging. Items, such as "In a group of people at my university, I really feel that I belong", were positively worded and were ranked on a 7-point Likert scale (strongly disagree–strongly agree). Items were summed to calculate a total score (range 11–77). Higher scores indicate a closer link between social identity and being an academic at the specific university. This scale showed excellent reliability (α = 0.87). Staff were also asked to indicate whether their relationship with the university had changed since the pandemic begun (Y/N), followed by an open question asking them to elaborate on their response to the Y/N question.

2.2.3. Technology and Digital Capabilities

Given the extensive reliance on digital tools and remote working, staff were asked about access to software and hardware prior to the pandemic and during it. They were also asked about whether they had incurred additional financial costs for work-based activities (e.g., purchasing of devices or internet costs). Workspace was also investigated by asking about whether staff had a safe space to work at home relatively undisturbed and whether they had an adequately equipped space at home. Finally, they were asked whether the university had offered to provide any necessary devices or software. The JISC digital capabilities tool was used to assess digital abilities and digital confidence. Six digital capabilities domains were assessed: (i) digital proficiency, (ii) information, data and media literacies, (iii) digital communication, collaboration and participation, (iv) digital creation, problem-solving and innovation, (v) digital learning and development, (vi) digital identity and wellbeing. For each domain, participants ticked off their abilities from a pre-defined list. Each domain is composed of 10 items except for the 'Digital communication, collaboration and participation' which has 9 items. Six ability scores were calculated, scaling to obtain a percentage from 1% to 98.6%, as advised by JISC. Digital confidence was assessed within each domain using a 0–100% scale.

2.2.4. COVID-Related Education Changes

To provide some context to the findings, the survey asked questions about the shift to online learning. Staff were asked to indicate from a list (with an 'other' option) the changes to teaching that they have experienced, e.g., I have made my small group teaching available online (e.g., using MS Teams or Zoom). This was followed by an open question asking staff to indicate the most and least effective approaches and explain their reasoning. They were also asked to identify changes to assessment types (e.g., change to exam format) and respond to an open question about the support that was made available to them to set up alternative assessment. Two further open questions were asked about the most positive and most challenging aspects of teaching during COVID. Finally, to provide an indication of workload changes relating to teaching, staff were asked to indicate the proportion of their time dedicated to teaching prior to and during COVID-19.

2.2.5. Mental Wellbeing

The 7-item Short Warwick-Edinburgh Mental Wellbeing Scale (SWEMWBS) was used to measure mental wellbeing (Stewart-Brown et al., 2009). Items were positively worded and were scored on a 5-point Likert scale. Total raw scores were calculated by summing all items. Raw scores were then converted to metric scores (range 7–35; Stewart-Brown et al., 2009). This scale showed good reliability (α = 0.79).

2.3. Interview Schedule

Semi-structured interviews were completed with a subsample (n = 12) to further understand how academics had coped and were coping with the pandemic-induced sudden transition to online teaching. We aimed to understand whether the academics had an adequate environment for working, whether they had received adequate support from their line managers, their departments or the university, and note their experiences with online teaching and online assessment. In addition, we wanted to understand if and how their mental wellbeing had been affected during the pandemic and whether the pandemic had forced them to change their career plans. Interview questions were initially developed by four teaching academics, who themselves had experienced the rapid transition to online learning. In addition, following the preliminary analyses of the quantitative data, we added several questions on digital skills to understand the skills the academics used and developed when switching to the online teaching and learning mode. The final interview schedule was divided into four sections: their working environment during the pandemic (e.g., space, equipment, and challenges); teaching and assessment experiences during the pandemic including digital needs; and support and wellbeing.

2.4. Data Analysis

Quantitative survey data were analyzed using SPSS. Demographic and employment factors, as well as digital capabilities and mental wellbeing constructs were examined via descriptive statistics. Additionally, based on previous research or anecdotal reports during the pandemic several planned exploratory analyses were conducted. Caring responsibilities were compared between demographic groups using Pearson's Chi-Square. Social identity was compared between different employment and demographic groups using either independent t-tests or One-Way ANOVAs. Linear regression analysis was used to ascertain whether demographic, employment factors or home working arrangements predicted digital abilities and confidence. Similarly, linear regression was used to examine whether demographic, employment factors, home working arrangements, digital abilities and confidence predicted change in workload during the pandemic. Finally, linear regression was used to determine whether social identity, workload change, digital ability and confidence could predict mental wellbeing.

The free-text answers from the eight open questions, which were answered by between 60% and 100% of survey respondents, and the interview data were initially analyzed separately. Thematic analysis was completed by three researchers. Survey responses were reviewed and coded independently by two researchers. This coding was reviewed by a third coder. Interviews were transcribed automatically using Microsoft Stream, checked, and corrected by two researchers. One interview was coded independently by three researchers. The remaining 11 interviews were double coded by two of these researchers. Finally, reviewing codes from the survey and interviews in parallel, themes from these two avenues were integrated. The analysis took a realist approach and was completed at a semantic level, with themes identified from the explicit meanings of the participants' responses [29]. An inductive, bottom-up approach was adopted to identify themes and patterns within the dataset. Coding was discussed between the team at multiple points to clarify themes and avoid individual biases [30].

3. Results

Given the mixed methods approach and the common analysis adopted for both open survey responses and interview data, the results are divided into quantitative and qualitative findings.

3.1. Demographic and Employment Characterization

The demographic and employment characteristics of the participants are detailed in Tables 1 and 2, respectively.

In terms of caring responsibility, almost half (44%) of the participants reported having to provide care, with most reporting caring for children (26% pre-school age, 33% primary school age, 31% secondary school age), while 26% stated they cared for other dependent family members and 8% cared for someone else. Data from these 39 individuals exceeds 100%, indicating that in some cases, people had caring responsibilities to more than one person. The amount of time spent engaged in caring responsibilities in a typical day ranged from up to 1 h to more than 12 h with the most commonly reported duration 3–4 h (22.5%), followed by 1–2 h (17.5%) or more than 12 h (17.5%). All of those with caring responsibilities reported that these increased due to the pandemic. More than a quarter of staff members with caring responsibilities (30%) indicated that this increase impacted their work negatively. There was no association between caring responsibility and gender (χ^2 (1) = 0.95, p = 0.378), ethnicity (χ^2 (2) = 1.79, p = 0.408) or disability (χ^2 (1) = 0.26, p = 0.611). However, there was an associated between caring and age (χ^2 (3) = 20.06,

$p < 0.001$). Younger (26–35 years) and older (56–70 years) group individuals were less likely to have caring responsibilities whereas this was more common in 36–45 years and 46–56 years of age.

The mean social identity score of 53.51 (SD = 10.81) indicated that being an academic at the university was a moderately strong factor in their social identity. This did not differ significantly between any of the different employment groups: full vs. part time; fixed term vs. open-ended (noting casual employment status was excluded from analysis due to low sample size); seniority; teaching level and faculty. Furthermore, social identity scores were not significantly different between genders, age groups, ethnic groups, disability status, or caring role.

3.2. Technology and Digital Capabilities

Prior to the lockdown, most teaching staff (81%) had access to university PCs or laptops. Following the lockdown and closure of university's campuses, only half (48%) of academics stated that the university provided them with the necessary equipment to continue their work from home. While access to generic software remained largely unchanged, there was a 32% decrease in the number of respondents with access to specialist research software. Most academics had adequate equipment (56%) and space (78%) to work from but almost half (48%) encountered additional financial costs to achieve this. Figure 1 shows a breakdown of academics' digital abilities and digital confidence as percentages. The overall ability score was 50% and the overall confidence score was 57%. This indicates that digital confidence was almost on par with the actual digital skills.

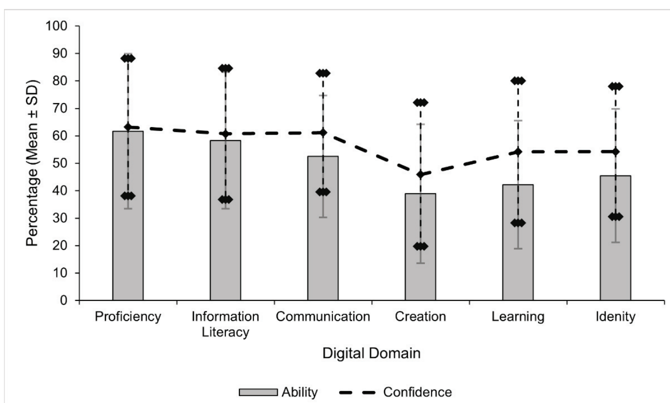

Figure 1. Academics' digital abilities and digital confidence. Error bars represent the standard deviation of the measure (grey line = ability; black diamond = confidence).

Given the importance of digital capabilities in designing and delivering online education we examined whether overall digital confidence and ability were predicted by demographic and employment factors. As summarized in Table 3, regression analysis reveals several significant predictors of digital confidence. Firstly, older age groups had less digital confidence. Secondly, full time staff are more confident than part time staff. Staff within the natural and mathematical science faculty also had greater confidence. Finally, greater social identity as an academic was associated with greater confidence. For digital ability, age, faculty, and social identity predictions remain significant.

3.3. Online Education Experiences and Workload

Most staff reported using synchronous online activities to replace face-to-face teaching (85%), shifting to online video calling platforms. Many also used asynchronous online activities (71%), such as lecture capture. For assessment, the most frequent alternative was written coursework (76%), followed by online exams (69%). Time dedicated to teaching changed during the pandemic; prior to COVID-19, the most reported duration spent teaching was 21–40% of their time (31%), followed by 41–60% (23%). However, during the pandemic the mode response was over 80% of their time (27%), followed by 61–80% (24%). Despite this, 47.5% did not report a change in the amount of teaching, and a further 20.0% reported a decrease in teaching. The remaining 32.5% reported an increase, demonstrating that increased workload was not equally distributed across staff. Workload change was calculated by subtracting post-COVID workload level from pre-COVID workload, such that a positive value indicates a decrease in workload during COVID. As summarized in Table 4, the only significant predictor of workload changes was academic role or seniority, such that more senior staff had greater increases in workload, although the overall regression model was non-significant.

Table 4. Regression coefficients for predicting pandemic induced workload-changes.

IVs	Workload Changes			
	b	95% CI		Sig
Gender	−0.03	−0.94	0.89	0.951
White non-British [1]	−0.54	−1.36	0.28	0.194
BAME [1]	−0.37	−1.38	0.65	0.470
Age	0.11	−0.29	0.51	0.580
Disability	0.17	−0.70	1.04	0.696
Caring	−0.30	−1.05	0.45	0.420
Status	−0.03	−0.98	0.93	0.953
Contract type	−0.11	−0.98	0.76	0.800
Seniority	−0.40	−0.72	−0.07	<0.05
Teaching level	−0.32	−1.05	0.42	0.392
Arts/Humanities [2]	0.28	−1.10	1.65	0.685
Social Sci.&Econ. [2]	0.27	−0.61	1.14	0.543
Natural/Maths Sci. [2]	−0.74	−2.00	0.51	0.240
Social identity	−0.00	−0.04	0.03	0.819
Safe space to work	−0.07	−1.00	0.85	0.870
Equipped space	−0.23	−1.09	0.62	0.587
Digital abilities	−0.00	−0.03	0.03	0.930
Digital confidence	−0.00	−0.03	0.03	0.922

Model: R2 = 0.36, F(18,45) = 1.41, p = 0.173. [1] Reference value, White British; [2] Reference value, Medical Sciences.

3.4. Predicting Mental Wellbeing

Respondents had relatively low levels of mental wellbeing; mean SWEMWBS score was 20.10 (SD = 3.19). This is 3.5, 95% CI (2.69, 4.33), points below the normative measure for the general population pre-COVID [31]. As summarized in Table 5, the factors predicting mental wellbeing were assessed in a multiple regression analysis. Although the overall model was significant, no single predictor reached significance, although there was a trend towards this for social identity.

Table 5. Regression coefficients for mental wellbeing.

IVs	Mental Wellbeing			
	b	95% CI		Sig
Social Identity	0.07	−0.00	0.14	0.064
Workload change	0.28	−0.31	0.87	0.344
Digital ability	0.01	−0.05	0.08	0.700
Digital capability	0.03	−0.04	0.09	0.410

Model: R2 = 0.16, F(4,71) = 3.286, p = 0.016.

3.5. Qualitative Themes

Four themes and subthemes were identified which are elaborated below: remote working, transition to online teaching, experiences of online assessment, and technological support and challenge.

3.5.1. Remote Working

Six sub-themes were identified under the remote working theme: home office, distractions, work-life balance, motivation, monotony, and university support.

Home office: In terms of space to work at home, responses indicated staff were working in a range of spaces. For example, some academics reported having their own private workspace at home: "*I am lucky enough to have a fairly big home, where I can have my own study, [and] where my partner can have her own study*" (Interview 9). Others reported having sub-optimal workspace: "*I live in a flat share, and the only place I can really work is my bedroom. So I'm spending a lot of time in that space*" (Interview 4).

A minority of respondents felt home-working was an improvement, with better scenery and access to natural light. Some respondents identified no change in their work environment or reflected that the changes had no impact on their ability to work. However, many identified problems related to the accessibility of resources and the ergonomics of home-working. Staff identified problems including not have fully functioning laptops, headphones, or printers at home. While a minority of these concerns were alleviated by university provided resources, most respondents were left to resolve these issues themselves, privately purchasing new equipment. Many were working in non-ergonomic spaces: "*I don't have a very good desk setup in terms of ergonomics*" (Interview 7).

Distractions: Although most respondents had a quiet place to study at home, distraction was something they talked about. For some distractions increased; parental responsibilities impacted the work of some academics: "*You can't be working full time and doing childcare. And you had a lockdown, the main issue was the closing down of child minders, nursery schools and so on. So that was the main factor*" (Interview 12). Others mentioned that remote working involved fewer distractions compared to the alternative, which for some meant shared offices: "*I think the silence has been helpful in that before I was working in a shared office space. So there was a lot of noise all the time, which was obviously quite distracting*" (Interview 4).

Work-life balance: Most respondents experienced some changes in how they managed their personal and work lives due to the pandemic. Some academics were able to spend more time with their partners or families, for example, due to the absence of time spent commuting: *"I feel like I have a lot more free time without commuting, which is so nice, you know, like being able to be in my workspace immediately, I feel like in some ways, my quality of life has improved because of that, because at the end of the day, at five o'clock, I can switch off my computer, and I'm home and I can already do the things that I want to spend my free time doing rather than sitting on the tube"* (Interview 1). Others had difficulties in separating work and home responsibilities when they happened within the same space. Parents were forced to balance full-time work and caring responsibilities, leading some to work unsociable hours. A minority said that they had fewer meetings. The combination of having more time and fewer meetings led to more flexibility around starting times and breaks, and for some, this increased productivity.

Motivation: Motivation fluctuated for most respondents. Some felt demotivated in the absence of varied activities and time off: "I think at the beginning, I was feeling extremely motivated and productive. And I did lots of different additional projects. And then I feel that I had a little bit of a low. And maybe, I think, mainly because I haven't actually taken any proper holiday" (Interview 4). Motivation levels were also affected by teaching, which some described as impersonal and distant. However, a minority felt more motivated to be productive: "I've actually found probably being more productive or able to get through more" (Interview 6). This increased productivity related to ease of access to teaching materials from home, reduced distractions, and the ease of getting hold of colleagues via online video calling platforms.

Monotony: The monotony of remote working and restrictions was mentioned by some respondents. Monotony and the lack of recreational activities outside work were identified as deterrents to good mental health: "*It's not that I don't [. . .] enjoy myself being at home or relaxing with my partner or with my friends. We are locked down. I've been restricted at home, so it's not a direct effect of not being able to work [on] campus, but it's a general effect of the situation. I mean, at this point, I'm not even enjoying the walks in the park. I just got sick of it because there are no alternatives, [. . .] so I can't be much more positive about that, even though I would love to*" (Interview 2). The absence of casual interactions at work was also a factor that used to break up the workday in the office. Some academics arranged meetings that were not related to work to facilitate casual interactions.

University Support: Support consisted of efficient communication, acknowledgement, and regular drop-in sessions where they could share their worries and receive support from others. Most respondents felt adequately supported by their immediate department and the university, which helped them navigate the abrupt changes: "*I felt very well supported all across. And I think that helped me a lot, trying to manage the stress and the change*" (Interview 5). However, several academics mentioned that communication from the leadership could have been improved, while some were not included in some decisions which directly involved them, such as assessment arrangements. One academic mentioned that junior staff could be better supported: "*as a more junior member of staff, I feel like that could have been greater as support in places. Even just kind of checking in to see if you're okay, and like just, you know, how your workload is,* etc. *And I don't feel there's been a huge amount of that*" (Interview 4). Administrative support was also mentioned, with one interviewee pointing towards the lack of administrative support, a deficiency described as "*really stressful. Deadlines are approaching and nobody comes back to you, HR doesn't work, library services don't work*" (Interview 5).

Parents and carers felt acknowledged by the university and were encouraged to take a flexible approach in balancing caring responsibilities and full-time work. Despite this support, some noted that their workloads remained difficult to manage and that work had to be completed regardless. One interviewee managed this by working unsociable hours to balance home responsibilities and work: "*especially at the beginning, I don't remember having weekends at all, there was not a chance [. . .] I had maybe six hours a day and then I had to work it out in the weekends just to make it up*" (Interview 5).

Some respondents mentioned the importance of informal support, such as coffee mornings, in reducing loneliness, conserving normalcy, and mimicking the pre-pandemic interactions. Academics also mentioned that the newness of the situation facilitated interaction between colleagues, either by helping or receiving digital help from others.

3.5.2. Transition to Online Teaching

Two sub-themes were identified: redesigning teaching materials and interactions with students.

Redesigning teaching materials: Academics noted that creating materials for online teaching involved a lot of work: "A module that is prepared to be taught fully online is very different from the online version of a module that is meant to be face-to-face. Now what I'm saying is fairly trivial and may appear obvious, but there is a fundamental difference because the way you prepare the material before and for a fully online module" (Interview 9). This increased work, left academics feeling overwhelmed: "There's been a massive increase in workload. So I feel like I'm working at, you know, 150%. But there's still just an endless to do list" (Interview 4). The switch to online education also meant staff spent time engaging in digital skills training or supporting colleagues to develop these skills, including the ability to use video calling platforms (e.g., Microsoft Teams) for setting up and attending meetings and recording software (e.g., Kaltura) to create teaching materials. Despite the workload and need to upskill, some positive aspects were reported, including the opportunity to improve teaching materials and work collaboratively with colleagues towards a common goal.

Interactions with students: Experiences around student engagement varied. Some reported decreased student attendance and participation and limited feedback on online teaching: "*it was quite hard not being able to see the students because most, I think everybody had their camera off. You can't hear them, because the microphones are also off. So, you know, it's like talking into it into the void. You don't know if anybody's there*" (Interview 10). Some respondents felt frustrated about the lack of information they had about assessments at the beginning of the pandemic, as they could not answer students' questions. Nonetheless, some respondents reported increased interactions and remarked that students quickly adapted to online teaching: "*it feels a lot more settled now in terms of just being able to deliver the classes and know that my students are going to be there on the other side of the screen, and I'm not just going to be talking to 20 little black boxes*" (Interview 1).

3.5.3. Experiences of Online Assessment

Three sub-themes were identified: marking and feedback, integrity, and assessment guidelines.

Marking and feedback: The use of online assessment where previous forms were on paper or in person received mixed support from staff. Most respondents found online marking to be more efficient because it was easier to read: "*I think it'd be nice to keep doing online assessment, [. . .] I think it does work better, [. . .] you don't have to worry about students' handwriting or that you've missed a page that a student's written on*" (Interview 11). However, others felt that it was more time-consuming because students expected more thorough feedback. Additionally, use of some online tools such as audio feedback created difficulties: "*I find it laborious; I find it far harder to mark exam scripts, and far harder to mark coursework than having a printed version*" (Interview 8). One interviewee noted that online marking worked particularly well for online presentations, due to higher attendance from members of the teaching team and greater level of feedback: "*if we're doing student presentations, and you can get seven other academics in the call with you, you've got a much better chance of getting a much better assessment. So it's been really nice to have more colleagues involved in those assessments. Normally, it's just two of us in a room with students, it's been lovely to have more colleagues*" (Interview 8).

Integrity of assessment: Most respondents raised concerns about the integrity of online assessments, which they felt was compromised. These concerns were particularly notable for STEM subjects where limited correct answers would make it harder to identify any collusion or other forms of cheating: "*in maths, physics, chemistry, and some extent in computer science, where the answers are just facts. Two correct answers will look very much the same*" (Interview 10). Despite this, most agreed that this related to the time available to prepare the online assessment rather than an issue intrinsic to this form of assessment.

Assessment guidelines: Most respondents noted a lack of clear and consistent guidelines around assessment. Constant changes regarding assessment, marking and feedback were mentioned. Due to these changes, academics often doubted whether the received information was definitive: "*just get the record straight, come back to me with just one final answer. And then I'll just generate the material as you request it*" (Interview 5). This put academics in a difficult position as students were demanding clarifications. Nonetheless, a minority of academics noted that their departments gave clear guidelines and thus adjusted to the transition to online learning quickly.

3.5.4. Technological Support and Challenges

Three sub-themes were identified under technical support and challenges: access and connectivity, digital training and support, and digital working.

Access and connectivity: Academics questioned whether they had adequate provision of hardware and software. Two interviewees said that they have had to work with what they had, while one mentioned that they had been offered a tablet. Several academics mentioned that they had incurred additional financial costs to equip their home offices. These costs ranged from office equipment to more costly recording equipment meant to enhance the quality of teaching materials: "*It's been a considerable financial investment for me. I've, you know, bought desks and chairs and new speaker systems and a new monitor and microphones and all that kind of stuff*" (Interview 8). Many also experienced internet connection problems, particularly in instances where they shared the internet with household members. Several academics noted that they incurred additional costs for upgrading their home broadband and one academic affirmed that the university's "*reliance on home broadband for teaching is going to be really a very weak point*" (Interview 10).

Digital training and support: While digital training and support were provided, the timing, format and content of the training materials could have been improved. Academics stated a preference for simple training and technology. This did not align with the experience of all; "*[I feel] slightly overwhelmed with the amount of different software and technology that we're told about. So it's just difficult to have the time to … get into it and learn about it.*" (Interview 4). One solution to the information overload was to create training materials that are short and easy to access: "*And then up to the point that in one of the meetings, I told them, I feel overwhelmed by the amount of information. Can we distil it into, you know, a couple of one pagers that people can use […].These one pagers are fantastic because you know, even if you have not engaged so far as an academic or as a professional services, […], you can just download this one pager and there is there are instructions on what you should be doing*" (Interview 9). Despite the high volume of information, a few respondents believed that digital support was basic and advocated for more detailed training sessions.

Several academics noted their digital training was partly provided by their tech-savvy colleagues. One respondent believed they were "*better than the ones that are on the official university sites*" (Interview 6). One academic involved in creating the extra digital content admitted that they "*personally really enjoy and thrive on giving support to my colleagues*" and that once the pandemic hit, they "*started producing a whole load of tutorial videos for my colleagues to help them teach online. So I've produced about 60 videos, which are all up on YouTube and the college stream site where people can drop in and learn how to set up a meeting in teams or learn how to deliver a lecture online, learn how to record a PowerPoint presentation, learn how to edit and do all this other stuff. So for me, it's been very positive in that I've had the opportunity now to really show what we can do as staff to support each other and showcase what we're capable of as a staff, which has been brilliant. You know, it's nice to have that opportunity to do something positive for the community as well as my own career*" (Interview 8). Nonetheless, these materials were added to the usual workload and the academics involved did not receive any additional pay. In fact, one interviewee pointed out: "*I see lots of people's digital efforts, and none of it was gonna be paid extra and stuff. A lot of it's just kind of good citizen type behaviour*" (Interview 12).

Several academics highlighted the need for far bigger technological changes, such as rethinking the university's IT infrastructure to optimize it for online teaching and assessment. One academic highlighted the need to consult experts in online security in the context on delivering online education

Digital working: Academics identified both advantages and disadvantages to working online. Online meetings between academics increased flexibility, were time-effective and increased attendance to research meetings, contributing positively to learning and development. Several academics considered that online hosted meetings and conferences can widen participation and improve access. Many said they would like to continue meeting online even when face-to-face teaching resumes: "*I definitely hadn't used [Microsoft] Teams before, and things like that. […] And it was actually really useful. I think, even going forward, if we were, you know, to return to do things the way we did before, I think those are things that I will carry on using*" (Interview 11). However, for some, the frequency of online meetings was burdensome. One interviewee said there was an "*overabundance of online meetings, probably to compensate for the fact we are not able to meet face-to-face anymore […] which meant that there was very little time to do anything else but participate in the meetings*" (Interview 9).

4. Discussion

The pandemic affected academics on multiple fronts. On a practical level, most academics had a space to work from at home, although this was not always optimal and some incurred additional costs, including paying for internet upgrades, and equipment for teaching. Remote working was also associated with difficulties in work-life balance and distractions for some. Almost half of the academics surveyed had caring responsibilities and all reported that these had increased during the pandemic. A quarter indicated this increase had impacted negatively on their work. Qualitative data indicates that this was in part due to the difficulty juggling childcare and work and the interruptions to work that result from this. Interestingly, despite previous work indicating that females are more likely to have caring responsibilities [32], our data did not support this. We did however, find that those in middle age were most likely to be caring, in line with previous research [33].

As well as switching to remote working, the pandemic required a rapid switch to online education delivery, including assessment. Anecdotal evidence suggested this resulted in significant increases in workload for academics. Our data support this to some extent, in that around 30% reported an increase in their teaching workload, in contrast to around 50% having the same teaching load and the remainder seeing a decrease. The only factor that predicted increased workload was seniority. The senior academics who saw an increase in their workload were also likely to be spending substantive amounts of time in meetings, developing plans to manage the impact of the pandemic, making this group arguably most vulnerable to burnout, which is thought to have been widespread in academia during the pandemic [34]. Increased teaching time for senior academics is also likely to have knock-on effects elsewhere. For example, interviews highlighted that junior staff felt a lack of acknowledgement and support, which would typically come from more senior staff. Not surprisingly, many academics interviewed reported working longer hours and some highlighted that the excessive teaching workload prevented them taking time off, especially in cases where they were also juggling caring responsibilities. Furthermore, although most found the university supportive and were able to work flexibly, the work still needed to be done by them, meaning the benefits of support were limited. The dominance of teaching reported here, aligns with data from a report conducted in May and October 2020 in a sample of over 1000 academics from Europe, Asia and the Americas, which found that 53% of their sample were busier in October 2020 compared to before the pandemic and 48% of those involved in primary research were producing fewer outputs [35], suggesting an increase in non-research related activities.

The switch to online education, despite its associated workload, was viewed positively by some as an opportunity to work in teams and improve on previous teaching, although there was a sense of frustration about initial interactions with students. More concern was raised about assessment. This included meeting the expectations of students, a point previously noted in the literature [36]. The issue of ensuring integrity in assessment was also raised when assessments moved online. This has been identified prior to the pandemic for online courses and evidence suggests that, contrary to popular opinion, cheating is no more prevalent online than it is in other formats [37]. Nonetheless, staff in the present study noted that these concerns related to expectations and timescales which could be addressed in a non-emergency situation.

Both the transition to online education and remote working are likely to rely on digital abilities and confidence. Our data indicate that older age groups were less able and confident with digital skills. Previous research has indicated that older adults are less digitally-able than their younger counterparts and it has been noted that support for developing skills in these individuals may require a bespoke approach [38]. For example, older adults may benefit from a mentoring-style approach and support between any synchronous sessions [38]. We also found that those in natural and mathematical sciences were more able and confident than other faculties. A stronger social identity as an academic was associated with stronger ability and greater confidence. Employment status also predicted confidence with full time staff more confident than part time staff. Killen

(2020) [14] reported that most academics, while eager to develop their digital skills, do not have the time required to do so. Time constraints may explain some of the findings here. For example, part time staff and those in more junior positions, irrespective of age, might be more likely to be overburdened with other tasks such as pastoral care and administrative tasks. These factors need further consideration in future research. The relationship with social identity is harder to interpret. It is possible that a stronger social identity could have arisen due to better skills in this area or due to participation in more training. Qualitative data did not contribute any further information here, and therefore, this is an area that warrants further investigation in future.

Despite increasingly high expectations of academics [19], the mental wellbeing of this group has received relatively little attention. Prior to the pandemic, Kinman and Johnson (2019) [39] noted that academics were having to fulfil numerous additional roles at the same time as role clarity, autonomy and collegiality were declining, contributing to an increased volume and intensity of work. Reports had also shown high levels of burnout and mental disorders [11,12]. The pandemic has accentuated these concerns. Given the increased workload, reliance on digital skills, and the possible changes to social identity due to the different work activities, we expected that these factors may predict mental wellbeing. Overall, our findings support low levels of wellbeing, but this was not predicted by the hypothesized factors in our quantitative analysis. Our data revealed a trend towards significance for stronger social identity being associated with better mental wellbeing only.

The interview data does, however, strengthen this finding in that academics admitted that supportive departments and colleagues helped them navigate the abrupt transition to online education. Furthermore, many mentioned that the pandemic created a strong sense of collegiality and team spirit which acted as motivators and likely contributed positively to social identity as an academic and wellbeing. Encouragingly, most respondents agreed that they received adequate support throughout the pandemic, which might have had similar effects. Despite those positives, the relationship between academics and the university changed during the pandemic. This is not surprising considering that work shifted from the office to the home environment and that interactions with colleagues and students had to be moved online. In fact, the majority mentioned that they longed for casual interactions with colleagues and that some activities were more difficult to fulfil from home. Furthermore, the strained relationship between academics and the university is likely to impact on academic roles and the academic identity, which could then impact wellbeing. Nonetheless, the interviews helped identify some benefits of working from home; namely, many respondents believed that online meetings increased access to research meetings and conferences. These findings suggest that mental wellbeing in academia is likely multifactorial; while strong social identity as an academic may be a protective factor, being away from campus and colleagues can impact the manner in which academics perceive their relationship with the university.

This work has several strengths. First, we present quantitative and qualitative data from academics specializing in various fields, who routinely engage in teaching and whose activities were inevitably impacted by the abrupt transition to online education in Spring 2020. Second, data was captured at two key time points: quantitative data was collected in May–June 2020 when academics had experienced the emergency transition to online education, but uncertainty around the provision of teaching and assessment remained, whilst interviews were conducted in August–September 2020 when academics had more clarity regarding the approach that is required for distance learning. Nonetheless, our findings must be considered carefully in light of several limitations. First, the sample size is relatively small and there are concerns that the most burdened academics were the ones least likely to take part due to limited time and resources. While data collection was specifically planned to capture critical moments in the university, it is likely that these periods affected the academics' availability to engage in voluntary activities such as research. Second, in relation to the university staff population in the UK, our survey sample overrepresented women and younger academics, and under-represented individuals from a BAME background [40]. Third, the timings of the online survey and subsequent interviews merely captured a snapshot of the academics' experience as the pandemic brought numerous dynamic changes that influenced their workloads and livelihoods. Lastly, we present data from a large London-based university that arguably had sufficient financial resources to provide digital skills training and equipment for its staff and that had a minimal technological infrastructure that served as a foundation for the provision of online education at the start of the pandemic. We recognize that these aspects can vary between universities and countries.

In summary, this mixed-methods study investigated the transition to online education during two key stages in the COVID-19 pandemic for the Higher Education sector. By showing that poorer digital abilities were more prevalent in older staff and those who are part-time lack digital confidence, we recommend that universities tailor their programs to support these groups. Many UK universities, including our own, offered rapid, just-in-time, training to staff during the pandemic which could be accessed online both synchronously and asynchronously. The rapidity with which the training was made available meant that it was not possible to tailor all training to specific groups who may need greater or different support. As we move beyond the pandemic there is an opportunity to build on this by offering more personalized training to support the needs of all staff. Increased teaching time and high workloads are two concerning findings of the current work. With the strong focus in recent years on improving the mental health of students, it is worrying that the wellbeing of academics, who are often the first point of contact and have pastoral duties, is neglected and even pushed to the limit during an international health emergency. On the positive note, this work shows that strong academic identity is associated with better digital abilities and confidence and may be a protective factor for mental wellbeing and that online meetings can facilitate communication and collaboration between colleagues, as well as widening participation in research activities. Many academics enjoyed working from home outside of the initial crisis and there were reports of increased productivity and time for activities outside academia. We therefore recommend that the Higher Education sector rethinks some of its structures before returning to the pre-pandemic conditions. Furthermore, the University Mental Health Charter [41] published in 2019 includes provision for staff mental health and wellbeing, suggesting that the sector is now primed to seriously consider staff and students. More recently in 2021, a Charter Award system has been introduced which will allow university to apply for the Charter Award by demonstrating they meet certain criteria. The findings presented here suggest areas which universities might focus on to improve wellbeing as part of this process.

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Article

Using Analytics to Identify When Course Materials Are Accessed Relative to Online Exams during Digital Education

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Abstract: Face-to-face education has changed to blended or distance teaching due to the COVID-19 pandemic. Since education took a digital format, it can be investigated when course materials are accessed relative to online exams: are they opened before exams or during them? Therefore, four subjects were chosen for investigation at the University of Pannonia: one theoretical, one practical, and two that are both theoretical and practical were selected. Two groups of non-repeater 2nd-semester students and two groups of non-repeater 5th-semester students attended these classes. Slides were uploaded to the university's Moodle system, while videos were uploaded to YouTube. Their analytics were used for the investigation. The analyses were conducted in five groups of days relative to the exam day. According to the results, students studied throughout the semester for the normal exam in most cases, while they studied a day before the supplementary one. For cheating, the 2nd-semester students used significantly more slides, while 5th-semester students used significantly more videos. Even with cheating, the students in their 2nd semester received significantly worse marks by 26.06% than those who were in their 5th semester.

Keywords: cheating; course materials; data analysis; education; learning; online; teaching

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1. Introduction

The COVID-19 pandemic has greatly impacted our lives, and as a result, a digital format was (and is still) used by most universities. Due to the pandemic and this format transition, managing and research became more difficult at institutions, while exams were either reformatted or postponed [1]. According to the previous survey, classroom teaching was replaced by online teaching and learning in African, American, Asia–Pacific, and European regions by 29%, 72%, 60%, and 85%, respectively. Clearly, the life of university staff and students became harder as many new challenges arose [2–5], mainly in medical education [6–9].

According to the results presented in [10], the lack of interactions with teachers and classmates was a major hindrance during online learning. As presented in a survey [11], students preferred face-to-face education because 88% of them considered it effective. Contrarily, online and hybrid types of education were only considered effective by 7% and 44%, respectively. Hybrid or blended types of education were preferred by educators [12]. Aboagye et al. concluded that blended learning should have ushered learners to complete online learning [13].

However, since students had diminished engagement due to the quick transition to digital education [14], course materials could be opened fewer times. They even became more accessible, resulting in cheating which also became a serious problem on online exams due to distance education and negative feelings. The former is considered ineffective [15]. Regarding the latter, it is concluded by the study of Abdelrahim that the pandemic causes depression, stress, and anxiety, which are the causes of cheating [16]. This fact is also strengthened by the study of Vargus [17].

According to the referenced study of [15], screen sharing and/or a camera should be used to mitigate cheating. Without a camera or an honor code, students are more likely to cheat [18]. Naturally, an honor code cannot avert students from cheating. It is a necessary but not sufficient condition. Screen sharing is also important, as students could use file-sharing websites without it [19], or some students could even log in to their friend's profiles to download their answer files [20]. Other strategies, such as higher-order thinking multiple choice questions and higher-order thinking short answer questions, are detailed in the literature to reduce cheating [21]. Even guidelines were created for online assessments to minimize cheating [22,23]. Moreover, the study of Balderas and Caballero-Hernández suggests that the students' works should be recorded to minimize cheating [24], while Sharma et al. and Jadi proposed convolutional neural network-based technologies to identify cheating [25,26]. Lee et al. also developed a system with multiple cameras to mitigate cheating [27]. Kharbat and Daabes proposed e-proctoring tools, but ultimately, students were worried about their privacy [28]. This may also raise the question: when is exam surveillance too much [29]? Ultimately, cheating can be mitigated but cannot be stopped completely [15].

As can be observed, several studies tackled the idea of cheating mitigation; therefore, the goal of this article is not to develop new methods to minimize or prevent it. In fact, the authors *explore* when course materials are accessed relative to exams: if the course materials are accessed during exams, that would mean cheating has occurred. Therefore, the online interaction with the course materials are investigated, and the authors set up five research questions (RQs):

- RQ1: Do students learn before online exams?
- RQ2: If they do, when do they access/learn the course materials?
- RQ3: If they learn before the exam, would they cheat if they had the chance?
- RQ4: Regarding cheating, does it matter whether a subject is theoretical or practical?
- RQ5: Is cheating influenced by which semester the students are in?

2. Materials and Methods

After the RQs were formulated, four subjects were selected for the investigation. Then, prerecorded videos were uploaded privately to YouTube, while slides were uploaded in a PDF format to the university's online Moodle system, both on a (mostly) weekly basis. Links to the videos were also placed in this system; therefore, only the students could access them. Sometimes a week was skipped due to other activities or breaks, but in those cases, two weeks' worth of educational material (slides and videos) were uploaded the following week. All materials were only accessible to the students and teachers. Since both prerecorded videos and slides were uploaded beforehand, these four university subjects were structured as follows: the students could read/watch the educational materials any time before each occasion, while they could ask questions during the online class hours. This way, there was a form of contact between the teachers and students.

As was mentioned earlier, four subjects were chosen for the investigation: artificial intelligence, computer architectures, data automation, and the fundamentals of programming. These subjects are called first, second, third, and fourth subjects, respectively, in this article. These four subjects are also independent of each other, meaning no subject was a prerequisite for another one. Critical information about these selected subjects is shown in Table 1.

Table 1. Overview of the investigated university subjects.

Subject	Type	Had Slides	Number of Students	Students' Semester	Education
First	Theoretical and practical	Yes	11	5th	Business informatics
Second	Mostly theoretical	Yes	14	2nd	Business informatics
Third	Practical	No	15	5th	Business informatics
Fourth	Theoretical and practical	Yes	21	2nd	Business informatics

Out of these four subjects, one was mostly theoretical. This means that the students learned definitions, methods, or ways to solve problems when attending them. Few practical examples and solutions were also taught in the last few weeks. These were contained in the uploaded slides and videos. The third subject was purely practical: no slides were uploaded. Exercises were uploaded instead of them. Videos that contained solutions to these exercises were also recorded and uploaded. The first and fourth subjects were both theoretical and practical. There were new definitions and exercises every week, and therefore, each slide contained many problems and solutions. These exercises were also explained and solved in the videos. Naturally, it was up to the students whether they practiced at home.

The advantage of both Moodle and YouTube is that the analytics are provided by them, which fits the General Data Protection Regulation (GDPR) that is used in Europe: they do not provide concise information about the students, respecting their anonymity. With Moodle, it is possible to see the number of clicks on the uploaded educational materials, while with YouTube, significantly more types of information can be accessed, although three were used in this investigation: the clicks on the videos, watch time, and average view duration.

The next step was to create groups of days. After examining both Moodle and YouTube analytics, five groups of them were made that were relative to the day of the exam: "at least 4 days before", "3 days before", "2 days before", "1 day before", and lastly, "Exam day". The analytics were placed in these groups in the case of each subject. These groups were created simply due to student interaction: after the slides/videos were uploaded, interaction with them quickly dwindled over the days. However, it increased when the exams' date became closer (usually 3 or 2 days before the exam).

The online exams were structured as follows: the virtual rooms were hosted by the teachers on the university's online platform, then the students could log in. They had to be logged in throughout the exam. If they encountered a problem or had a question, they could mention it at any minute, and the teacher could answer them. Afterward, their identity was checked through their cameras, and then the password was provided so the PDF files of the questions could be downloaded from the Moodle system. Then, the students were given 90 min to solve the questions. After they solved them, they could upload the answer files to the Moodle system. Naturally, after they successfully uploaded them, they were allowed to log out. The exams were constructed as follows:

- First subject: Students received random test questions in the Moodle system, and they had to select answers. They received 16 theoretical questions and 3 practical ones, all about artificial intelligence. Students could reach 50 points overall;
- Second subject: There were eight questions regarding computer architectures, such as "Define and explain the Neumann-architecture". After seeing the PDFs of questions, students had to write their answers on paper (by hand). In the end, they had to take photos of their answers and upload them to the Moodle system. Forty points could be reached overall;
- Third subject: The first exam had to be solved using Microsoft Excel. Students had to use functions, macros, and forms to solve 19 small problems that were defined in the exam PDF. The second exam had to be solved with RStudio: there were 14 questions, which included creating matrices, data frames, distribution analyses, correlation tests, and searching for significant differences among data using the right tests. After each exam, the respective Excel/R files had to be uploaded. Overall, 59 points could be reached;
- The fourth subject also contained small exams: these were online tests in Moodle, where the students had to select answers. They had 1 min for one question. The normal exam consisted of two parts: theoretical and practical parts. All were randomized by Moodle: each student received 20 theoretical questions and 1 practical question. In the former, program codes had to be extended by selecting correct functions from a dropdown list, while the former asked the students to code a certain problem (e.g.,

whether a number is even or odd) in C as well as write its pseudocode and draw its flowchart. Students had to upload their codes and drawings into the Moodle system. One hundred points could be reached overall.

One thing should be noted: the teachers told the students not to cheat or talk about the answers because they would instantly fail the exam. However, based on the results that are presented later, it is possible that they did not talk to each other about the answers because their solutions to the problems were clearly different from each other.

It should also be mentioned that since the grading systems are different around the world, the authors would like to present their version that was used during grading. This version is detailed in Table 2 and is based on the Hungarian grading system. This means that "1" is the worst mark, while "5" is the best one. In Table 2, the points of students are symbolized with x.

Table 2. The used grading system.

Percentage of Achieved Points	Mark
$x \leq 49\%$	1
$50\% \leq x \leq 62\%$	2
$63\% \leq x \leq 75\%$	3
$76\% \leq x \leq 87\%$	4
$88\% \leq x$	5

It should be noted that at the university, it is possible to hold a supplementary exam at the end of the semester for those who failed the normal exam. However, the mark received on the supplementary exam is considered final even if it is worse than what is received on the normal exam. It is not mandatory for the teacher to hold a supplementary exam.

Lastly, when all data were gathered after the exams were over, they were evaluated in the statistical program package R. In every case, the distributions of data were carefully analyzed with the Shapiro–Wilk normality test and quantile–quantile plots. Depending on the results of these mentioned normality analyses, either Welch Two Sample *t*-tests or Wilcoxon Rank Sum tests were used to compare the data. The former was used when the data was normal; otherwise, the latter was used. The results of the investigation are presented in the next section.

3. Results

This section is split into five subsections. The first four of them correspond to a subject at the university and have different evaluation methods. The last subsection examines the students' results.

3.1. The First Subject

Eleven non-repeater 5th-semester business informatics students had a theoretical and practical subject. The requirement of this subject was to successfully ($\geq$50%) complete an exam at the end of the semester. No supplementary exams were provided to the students to correct their mistakes. The slides and videos were not taken down prior to the exam. First, the clicks on the slides were investigated. They are detailed in Table 3.

As can be seen in Table 3, the slides were viewed throughout the semester. Almost every new slide is opened fewer times than before. This phenomenon happens until the exercises are uploaded a week before the exam. Afterward, the exercises' slides became the most clicked ones during the semester, although the solutions are not as viewed as the problems themselves. It should be noted, however, that the solutions were presented in the last lesson before the exam. As was suspected, great significant differences exist in most cases, but no significant differences can be observed among "2 days before" and "1 day before" (p = 0.4881) as well as "1 day before" and "Exam day" (p = 0.1212).

Table 3. The number of clicks on the slides before and on the exam day.

Slide	At Least 4 Days before	3 Days before	2 Days before	1 Day before	Exam Day
Week 2	35	0	1	1	2
Week 3–4	21	0	2	1	3
Week 5	27	0	1	1	4
Week 6	17	0	1	1	4
Week 8	16	0	1	1	2
Week 9	19	0	1	1	1
Week 10 (problems)	48	2	1	4	3
Week 10 (solutions)	21	1	1	5	4

The next to investigate was the YouTube analytics regarding this university subject. Nine prerecorded videos were uploaded (one every week). These weekly videos are represented by various shades of grey in Figure 1. The darkest one is the oldest video, while the brightest one is the newest.

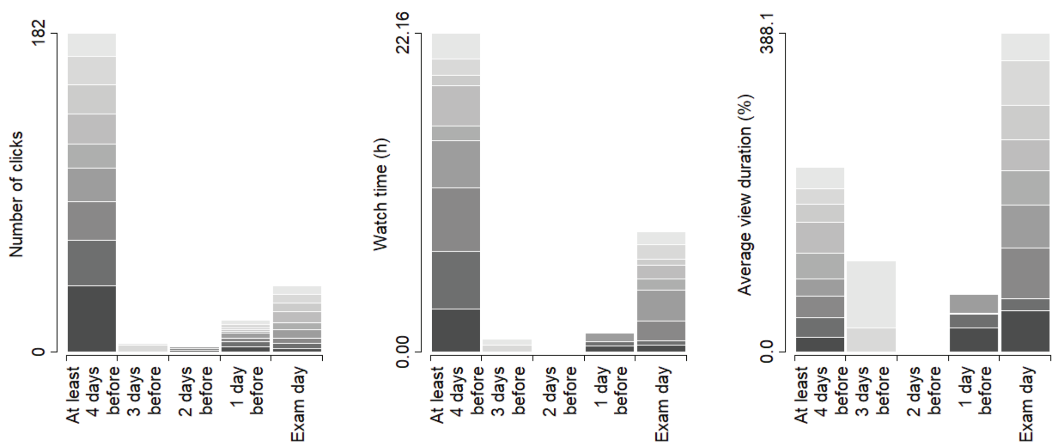

Figure 1. The number of clicks (**left**), watch time (**middle**), and average view duration (**right**) regarding the first subject's videos.

It is shown in Figure 1 that the clicks on the videos are quite similar to the clicks on the slides. The significant differences are between the same groups of days as in the case of the slides. However, are there significant differences among the clicks on videos and slides? According to the results, there is only one significant difference, which is between the clicks in "2 days before" (p = 0.005627): the slides were more viewed by 200% than the videos. The remaining pairs are not significantly different.

Next, the view times were compared. The following significant differences were found:

- "At least 4 days before" and "3 days before" (p = 0.0002739);
- "At least 4 days before" and "2 days before" (p = 0.0002191);
- "At least 4 days before" and "1 day before" (p = 0.0003582);
- "At least 4 days before" and "Exam day" (p = 0.01061);
- "3 days before" and "Exam day" (p = 0.001233);
- "2 days before" and "Exam day" (p = 0.0002191);
- "1 day before" and "Exam day" (p = 0.002415).

It is noticeable that the "At least 4 days before" group is always significantly different when paired with another one; however, a similar case can be observed with "Exam day". This means that the videos were the second most-watched on the day of the exam.

Even though the watch time is longer in the first group, it can be observed in Figure 1 that the average view duration is different. By analyzing the latter, it can also be concluded that it is the largest on the day of the exam: the increase in average view duration on the exam day is 72.03% compared to "at least 4 days before" the exam. This increase is also significant (p = 0.004196). This means that the students were searching for the solutions inside the videos. It should be noted that every group is significantly different from each other, except the pair of "3 days before" and "2 days before" (p = 0.9109).

3.2. The Second Subject

This mostly theoretical subject was attended by 14 non-repeater 2nd-semester business informatics students. Similarly, the requirement was to successfully (≥50%) complete an exam at the end of the semester. However, a supplementary exam was provided to the students to correct their mistakes. As with the first subject, the slides and videos were not taken down prior to the exams. First, the clicks on the slides were investigated both before the normal exam and supplementary exam. This can be seen in Table 4.

Table 4. The number of clicks on slides before and on both the normal and supplementary exam day.

Exam Type	Slide	At Least 4 Days before	3 Days before	2 Days before	1 Day before	Exam Day
Normal	Week 1	20	3	0	2	11
	Week 2	10	1	0	2	13
	Week 3	8	1	0	1	24
	Week 4	6	1	0	0	24
	Week 5	1	2	0	1	13
	Week 6	3	0	0	0	13
	Week 7	3	0	0	0	16
	Week 8	3	0	0	1	19
	Week 9	2	0	0	1	22
	Week 10	1	0	0	1	18
	Week 11	3	2	0	1	13
Supplementary	Week 1	1	1	1	2	7
	Week 2	0	0	1	1	6
	Week 3	2	0	1	3	13
	Week 4	2	0	0	1	16
	Week 5	1	0	0	1	7
	Week 6	1	0	0	1	8
	Week 7	1	0	0	1	7
	Week 8	1	0	0	1	13
	Week 9	1	0	0	1	11
	Week 10	1	0	0	1	15
	Week 11	1	0	0	2	11

According to the results of the investigation, great significant differences exist between almost all pairs, except among "3 days before" and "1 day before" (p = 0.8604). The results also show that the slides were most clicked on the day of the exam: it is a 210% increase compared to "at least 4 days before" (which means almost the whole semester). Clearly, the students cheated on the exam. As can also be observed, the students rarely opened the slides between the two exams. Even the "at least 4 days before" groups are significantly different from each other (p = 0.001133). "Exam day" groups are also significantly different (p = 0.001804): the slides were averagely more viewed by 63.15% on the normal exam than on the supplementary one. Those who decided to take the supplementary exam either did not attend the normal one or received a "1" mark. Five people took the supplementary exam, as two did not attend. It is suggested by the bottom half of Table 4 that they also cheated.

Next, the data regarding the videos were analyzed. Similarly to before, the number of clicks, watch time, and average view duration were investigated. These data can be observed in Figure 2. NE stands for normal exam, while SE means supplementary exam.

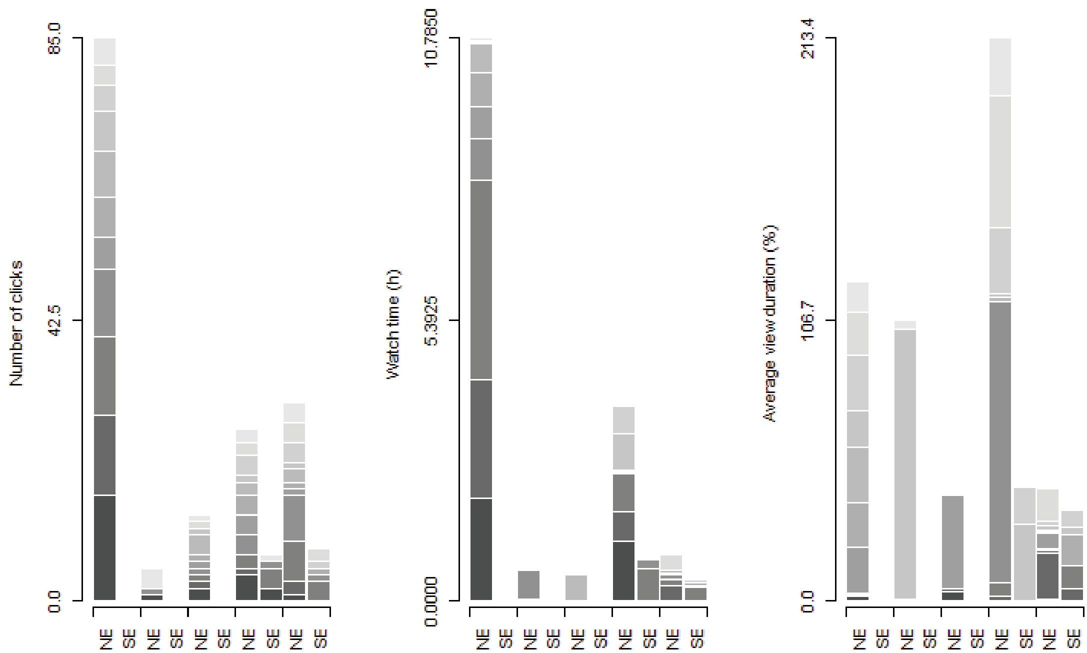

Figure 2. The number of clicks (**left**), watch time (**middle**), and average view duration (**right**) regarding the second subject's videos. The groups from left to right in each case: "at least 4 days before", "3 days before", "2 days before", "1 day before", and "exam day".

When comparing the clicks on the slides and videos to each other, the following conclusions were made (Table 5):

Table 5. The *p*-values when the clicks on the slides and videos are compared.

Exam Type	At Least 4 Days before	3 Days before	2 Days before	1 Day before	Exam Day
Normal	0.06872	0.2205	5.73×10^{-5}	0.001685	7.213×10^{-5}
Supplementary	5.695×10^{-5}	0.3633	0.07744	0.02232	6.581×10^{-5}

According to the data presented in Table 5, significant differences exist between the clicks on the slides and videos in "2 days before", "1 day before", and "Exam day" groups regarding the normal exam, with $p = 5.73 \times 10^{-5}$, $p = 0.001685$, and $p = 7.213 \times 10^{-5}$, respectively. Similarly, significant differences regarding the supplementary exam can be observed in "at least 4 days before", "1 day before", and "Exam day" groups, with $p = 5.695 \times 10^{-5}$, $p = 0.02232$, and $p = 6.581 \times 10^{-5}$, respectively.

At least 4 days before the normal exam, the videos were more opened by 41.66% than the slides. However, at least 4 days before the supplementary exam, no videos were clicked on, while there were 12 clicks on the slides. Contrarily, on the day of the normal exam, the slides were more clicked on by 520% than the videos, while the number of clicks on slides was 1325% more than on videos during the supplementary exam day. This suggests that the slides are easier to cheat from than the videos in the case of (mostly) theoretical subjects.

When analyzing watch times, the following conclusions are made: the students watched significantly more of the videos before the normal exam. The group of "at least 4 days before" is significantly different than almost every other one, except "1 day before" ($p = 0.1145$). While the watch time in "1 day before" is greater by 313.73% than on the day of the exam, they are not significantly different from each other ($p = 0.4489$). Regarding the videos before the supplementary exam, they were only watched one day before and on the exam day. There is still no significant difference between them (p = 0.7126), but more time is watched by 72.82% on the day before the supplementary exam.

In the case of the average view duration, the "1 day before" group is the largest regarding both exams. Regarding the normal exam, there are significant differences in average view duration among the following categories:

- "At least 4 days before" and "3 days before" (p = 0.004705);
- "At least 4 days before" and "2 days before" (p = 0.01241);
- "3 days before" and "1 day before" (p = 0.02287);
- "3 days before" and "Exam day" (p = 0.01537);
- "2 days before" and "Exam day" (p = 0.04465).

Regarding the supplementary exam, there are significant differences in average view duration among the following categories:

- "At least 4 days before" and "1 day before" (p = 0.03591);
- "At least 4 days before" and "Exam day" (p = 0.01576);
- "3 days before" and "1 day before" (p = 0.03591);
- "3 days before" and "Exam day" (p = 0.01576);
- "2 days before" and "1 day before" (p = 0.03591);
- "2 days before" and "Exam day" (p = 0.01576).

The average watch duration among the two exams was also compared, but only in the "1 day before" and "Exam day" groups. A significant difference exists in the former (p = 0.02953): the average view duration was 386.10% larger before the normal exam than before the supplementary one. While the average view duration was larger by 25.14% on the normal exam day than on the additional ones, it was not significant (p = 0.2593).

3.3. The Third Subject

This subject was purely practical. This means that no theoretical slides were uploaded. Instead, only exercises were uploaded. They were not solved by default, meaning that the students had to solve them based on the uploaded videos. Fifteen non-repeater 5th-semester business informatics students attended this subject. The requirement of this subject was to successfully complete two normal exams (≥50% on each). A supplementary exam was provided on the last week of the semester to correct mistakes. The practical problems and videos were not taken down prior to the exam. First, the clicks on the practical problems were investigated, and the results can be seen in Table 6. It should be noted that practical examples were only uploaded before the first normal exam. Students had to follow the videos in the next half of the semester.

Table 6. The number of clicks on slides before and on the first normal and supplementary exam day.

Exam Type	Slide	At Least 4 Days before	3 Days before	2 Days before	1 Day before	Exam Day
Normal	Week 2	12	1	2	3	1
	Week 3	10	1	3	2	1
	Week 4	10	1	2	5	1
	Week 5	9	1	2	0	6
	Week 6	7	1	3	0	3
Supplementary	Week 2	0	0	0	0	1
	Week 3	0	0	0	0	0
	Week 4	0	0	0	1	1
	Week 5	0	0	0	1	1
	Week 6	0	0	0	1	1

According to the results, significant differences exist among all pairs that contain "at least 4 days before", and between the pair of "3 days before" and "2 days before". The differences among all other pairs are insignificant. It should be pointed out that these files only contain exercises, meaning that their solutions are not included. Therefore, the fact that some students downloaded them on the day of the exam is quite interesting. Perhaps, they were those students who did not learn beforehand, wanted to cheat, but in the end, they failed the first normal exam. There were seven of those students.

At the end of the semester, a supplementary exam was held. As seen in Table 6, the exercises were downloaded fewer times. The number of downloads between the normal exam "Exam day" and the supplementary exam "Exam day" groups is not significantly different ($p = 0.1231$). The same case applies to the "1 day before" categories ($p = 0.3824$).

Since no slides existed in the case of this subject, the clicks between them and the videos were not compared. Therefore, this part of the investigation was omitted. Afterward, the data from YouTube was analyzed. Videos of weeks 1–6 were part of the first normal exam. Contrarily to before, these videos were uploaded in 20 smaller parts due to editing problems. Videos of weeks 7–10 were part of the second normal exam. These were also uploaded in five parts due to similar problems. The supplementary exam consisted of all uploaded videos. The video analytics are shown in Figure 3. Three abbreviations are used in this case: first normal exam (FNE), second normal exam (SNE), and supplementary exam (SE).

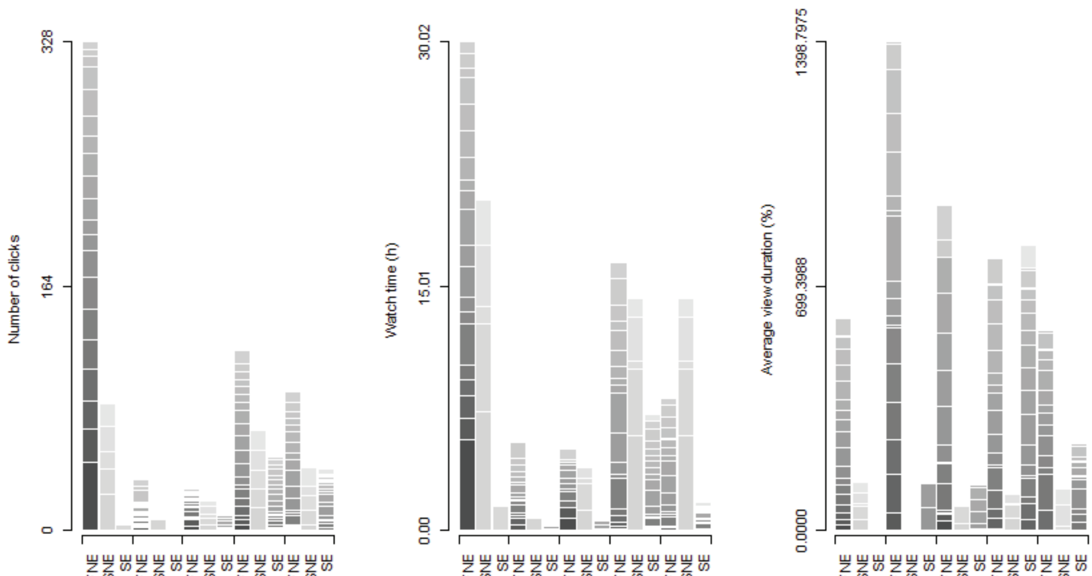

Figure 3. The number of clicks (**left**), watch time (**middle**), and average view duration (**right**) regarding the third subject's videos. The groups from left to right in each case: "at least 4 days before", "3 days before", "2 days before", "1 day before", and "exam day".

First, the clicks on the videos were analyzed. Regarding the videos before the first normal exam: there are great significant differences among almost all possible pairs of groups, except among "3 days before" and "2 days before" as well as between "1 day before" and "Exam day" ($p = 0.6879$ and $p = 0.1041$, respectively). Regarding the videos before the second normal exam, almost every possible pairs are significantly different from each other, except between "at least 4 days before" and "1 day before" as well as among "3 days before" and "2 days before" ($p = 0.1439$ and $p = 0.1264$, respectively). Regarding the videos before the supplementary exam: significant differences exist among all possible pairs, except among "at least 4 days before" and "3 days before" as well as between "1 day before" and "Exam day" ($p = 0.3427$ and $p = 0.2799$, respectively). According to Figure 3 and these facts, it can be concluded that the videos before the two normal exams were more viewed at least 4 days before them. This is not the case regarding the videos before the supplementary exam: they were most clicked on 1 day before it. Based on the clicks alone, students studied for the supplementary exam a day before. This fact is also strengthened by the watch time: it is also the largest on the day before the supplementary exam, and it is significantly different from the other groups. Moreover, it is the second largest on a day before the two normal exams. Regarding the first normal exam, the watch time on "1 day before" is significantly different from the other groups. Regarding the second normal exam, the only significant difference in watch times is among "3 days before" and "1 day before" groups.

When the average view duration is analyzed, it also suggests that the students significantly studied more one day before the supplementary exam (p = 0.008112). If the first normal exam is investigated, it can be concluded that the average view duration of videos is significantly larger in the category of "3 days before" than the category of "Exam day" (p = 0.01015). If the second normal exam is investigated, neither average view duration groups differ significantly from "Exam day".

3.4. The Fourth Subject

This subject was both theoretical and practical: both the uploaded slides and videos contained practical examples. As in the subsection before, the problems were not solved by default; therefore, the students had to solve them based on the uploaded videos. This subject was attended by 21 non-repeater 2nd-semester business informatics students. The requirement of this subject was more complex than the others: the students had to complete three small assignments, two small exams, and a large exam. The large exam consisted of two parts: a practical and a theoretical one. Their points were summed, and they had to reach ≥50% of all the points. A supplementary exam was provided on the last week of the semester to correct mistakes; however, only the practical part of the large exam could be corrected. As before, the practical problems and videos were not taken down prior to the exams. First, the clicks on the slides were investigated, and the results can be observed in Table 7.

Table 7. The number of clicks on the slides before and on all the exam days.

Exam Type	Slide	At Least 4 Days before	3 Days before	2 Days before	1 Day before	Exam Day
1st small	Week 2	66	1	1	4	20
	Week 3	69	2	5	6	20
	Week 5	25	1	5	5	19
	Week 6	15	0	5	7	25
	Week 9 [1]	NA	NA	NA	NA	NA
2nd small	Week 2	2	0	0	0	15
	Week 3	0	0	0	0	8
	Week 5	0	0	0	1	8
	Week 6	0	0	0	0	10
	Week 9	2	0	3	5	28
Normal	Week 2	0	0	1	1	18
	Week 3	0	0	1	1	27
	Week 5	0	0	1	1	18
	Week 6	0	0	2	1	18
	Week 9	0	0	5	2	25
Supplementary	Week 2	9	1	1	1	2
	Week 3	1	0	1	0	1
	Week 5	1	0	0	0	1
	Week 6	1	0	0	0	0
	Week 9	1	0	0	0	0

[1] This slide was uploaded after this small exam (and was not part of it).

According to the clicks presented in Table 7, the students studied at least 4 days before the first small exam. However, many slides were opened on the first small exam day. These numbers changed regarding the second small exam. As can be seen, after experiencing the first small exam, the students (almost) only opened the slides on the second small exam day. Their behavior remained the same on the normal exam day: they mostly only opened the slides on the normal exam day. However, something changed after this exam: the students opened the slides before the supplementary exam day. Naturally, the number of clicks was not that many as in the case of previous exams because only five students participated in the supplementary exam.

Next, the data regarding the videos were analyzed. Similarly to before, the number of clicks, watch time, and average view duration were investigated. These data can be seen in Figure 4. Four abbreviations are used in this case: first small exam (FSE), second small exam (SSE), normal exam (NE), and supplementary exam (SE).

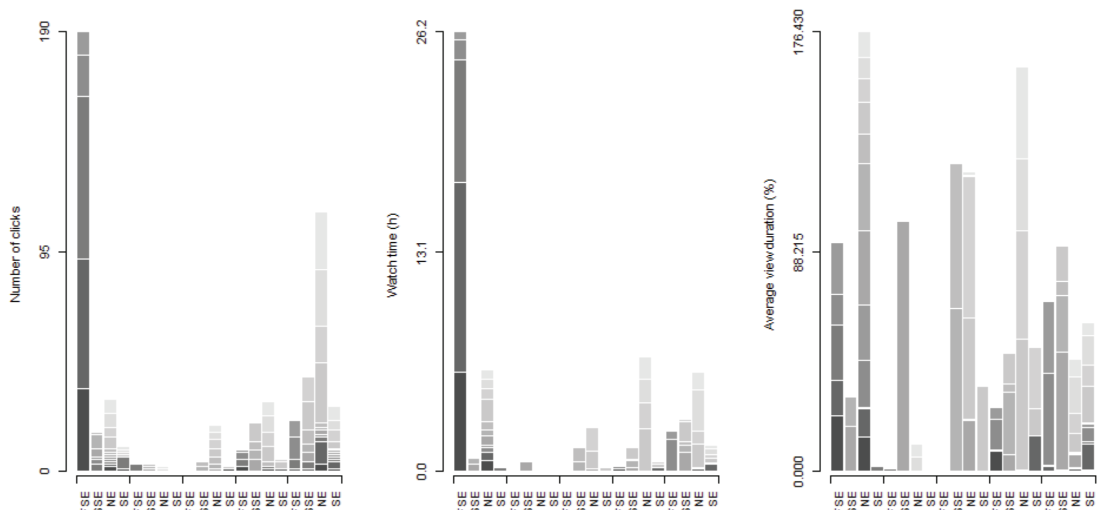

Figure 4. The number of clicks (**left**), watch time (**middle**), and average view duration (**right**) regarding the fourth subject's videos. The groups from left to right in each case: "at least 4 days before", "3 days before", "2 days before", "1 day before", and "exam day".

Next, the clicks on slides and videos were compared. The results of this investigation are presented in Table 8.

Table 8. The *p*-values when the clicks on slides and videos are compared.

Exam	At Least 4 Days before	3 Days before	2 Days before	1 Day before	Exam Day
1st small	0.7582	0.3452	0.009277	0.00432	0.0001994
2nd small	0.2553	0.1615	1	0.7671	0.05956
Normal	0.001263	0.3961	0.6276	0.9129	0.04389
Supplementary	0.1236	0.1556	0.3519	0.831	0.07645

As can be seen in Table 8, no significant differences exist between the clicks on slides and videos in the case of the 2nd small and supplementary exams. In the case of the 1st small exam, significant differences exist in the groups of "2 days before", "1 day before" and "Exam day" ($p = 0.009277$, $p = 0.00432$, and $p = 0.0001994$, respectively). In the group of "2 days before", 0 people clicked on the videos, while 16 clicks were found on the slides. One day before the 1st small exam, the numbers of clicks were 9 and 22, respectively (144.44% more clicks were found on the slides). Regarding the exam day, 22 and 84 clicks were found on the videos and slides, respectively. This means that 281.81% more clicks were found on the slides.

In the case of the normal exam, significant differences among clicks were only found in the "At least 4 days before" and "Exam day" groups ($p = 0.001263$, and $p = 0.04389$, respectively). In the group "At least 4 days before", while 31 clicks were found on the videos, there were 0 on the slides. Regarding "Exam day", these numbers were 112 and 106, respectively. This means that the students used every information available at their disposal.

According to Figure 4, it can be stated that the videos before the first small exam were the most viewed at least 4 days before it. The case is almost the same before the normal exam. However, in that case, the videos were most watched one day before it. The videos were most watched on the exam days when the second small and the supplementary exam were examined. Clearly, the videos were largely watched on the day of the exams. A similar phenomenon can be observed when the average watch duration is examined. However, the average view duration is the largest on the supplementary exam day.

3.5. Results of the Students

On the first subject (which consisted of only a normal exam), two students received a "2" mark, two received a "3" mark, two received a "4" mark, and five received a "5" mark. This means that no students failed this subject. The average of received marks is 3.90, while their standard deviation is 1.22.

Regarding the normal exam on the second subject, six students did not participate in it, one failed ("1" mark), six received a "2" mark, and one received a "3" mark. Naturally, these statistics changed after the supplementary exam: out of those who took it, three people received a "2" mark, one person a "3" mark, and another one a "4" mark. The latter student is the one who corrected their "1" mark on the normal exam. Nobody failed the supplementary exam. This also means that nobody received worse marks on it. Only the two students who did not participate in the exams failed this subject. The average of received final marks is 2.33, while their standard deviation is 0.65.

On the third subject, students received the following on the first exam: seven "1" marks, three "2" marks, four "3" marks, and one "4" marks. The following were received on the second exam: one "1" mark, one "2" marks, two "3" marks, three "4" marks, and eight "5" marks. Seven students had to attend a supplementary exam because of "1" marks; however, all of them corrected it. Therefore, the final number of various marks were: no "1" marks, two "2" marks, three "3" marks, six "4" marks, and four "5" marks. This means that the average of received final marks is 3.80, while their standard deviation is 1.01.

The following marks were received on the fourth subject after the first normal exam: two students did not attend the exam, three received a "1" mark, three received a "2" mark, five received a "5" mark, four received a "4" mark, and five received a "5" mark. Five students attended the supplementary exam, and two students who received "2" marks on the normal exam received "3" marks on the supplementary exam. The other marks remained the same. This means that the average of received final marks is 3.04, while their standard deviation is 1.43.

Lastly, the received marks of the students were assessed grouped by their semester number, exam type, and subject type. Their results are presented in Figure 5. The abbreviations are the following: 2S (2nd semester), 5S (5th semester), NE (Normal Exam), SE (Supplementary Exam), TS (Theoretical Subject), PS (Practical Subject), and TPS (Theoretical and Practical Subject).

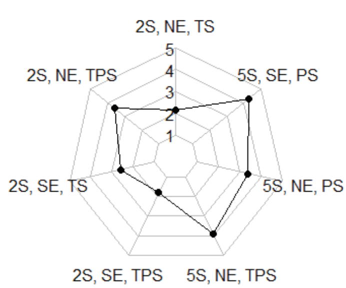

Figure 5. The averages of received marks.

As can be observed in Figure 5, all existing combinations are presented. According to the data, the best average of marks is received by 5S, SE, PS (students in their 5th semester, on the supplementary exam, on a practical subject), while the worst average marks are received by 2S, SE, TPS (students in their 2nd semester, on the supplementary exam, on a theoretical and practical subject).

Moreover, according to Figure 5, students in their 2nd semester received significantly worse marks by 26.06% than those who are in their 5th semester ($p = 0.002838$). Students also received worse marks on the supplementary exam by 9.77% than on the normal exam. This difference is not significant as $p = 0.42$. The differences among subject types are the following: $p = 0.07213$ between theoretical and practical; $p = 0.008938$ between theoretical and both theoretical and practical; and $p = 0.4323$ between practical and both theoretical and practical subjects. As can be seen, there is only one significant difference among subject types: it exists between theoretical and both theoretical and practical subjects. Students, however, reached an average mark of 3.8 on the practical subject, which is the largest average. The smallest average is in the case of theoretical subjects (3.08).

4. Discussion

When answering RQ1, it can be stated that students study before each exam as suggested by the clicks on slides and videos. According to the results, the course materials are accessed more times before each first exam. Before the second exam, however (be it a small or supplementary exam), the slides are not always accessed. The most critical case is the fourth subject, as the slides are basically only accessed before the first small exam.

Regarding RQ2, the watch times and view durations were assessed. According to Figures 1–4, it can be stated that the students study before the exams. Before normal exams, students tend to study throughout the semester, but before supplementary exams, they tend to learn the day before. Naturally, we do not know whether they actually learn something during these periods, but it can be assumed that they at least try.

RQ1 and RQ2 should be looked at before answering RQ3. It is known from their answers that students study before the exams. However, according to the average view durations presented in Figures 1–4, they are sometimes longer than before the exam day. In most cases, however, they are the second-largest per subjects. Moreover, a similar phenomenon can be observed in the cases of slides. In most cases, they are largely accessed on exam days. Clearly, the students cheated on the exams.

When answering RQ4, it can be stated that in the case of the theoretical subjects, mostly the slides were accessed on the exams' day, while mostly the videos were accessed in the case of practical subjects. When the subject is both theoretical and practical, both the videos and slides were used. However, the slides were opened more times (possibly due to time constraints).

In order to answer RQ5, the clicks on videos and slides were compared. Significant differences exist among the clicks on slides on the normal exam and supplementary exam days ($p = 4.686 \times 10^{-10}$ and $p = 0.02636$, respectively): students who are in their 2nd semester of studies clicked more on the slides on the normal exam days while they also clicked more on them on the supplementary exam days. There are no significant differences among the clicks on videos on the normal exam and the supplementary exam days between semesters ($p = 0.1453$ and $p = 0.7891$, respectively). When their videos' average view durations are analyzed, there is a significant difference among them on the normal exam days ($p = 0.0001043$): the average view duration of videos is longer by 341.33% when students watch them who are in their 5th semester. This fact means that 2nd-semester students used more slides, while 5th-semester students used more videos for cheating.

Limitations of the Study

Due to the nature of this research, no new method was conceived to mitigate or minimize online cheating. Moreover, the results of students cannot be compared due to different course structures. Even though their results are detailed and grouped by subjects in this article, the reason they are presented is to show what the students could achieve even with cheating in the case of these various courses. The conclusion is that their results are not good. Ultimately, they are only average even with cheating, and according to the literature, students are likely to cheat one way or another. This happens because of depression, stress, and anxiety, which are caused by the pandemic. Naturally, cheating could be minimized, although privacy issues could arise due to some chosen cheating mitigation methods.

Besides this, the results presented in this article open the possibility to know how and when course materials are accessed. In addition, it can also be ascertained that the motivation of students is dwindling throughout the semester since the course materials are accessed less each passing week. However, the numbers also tell that the students try to learn a few days before the exam, but this varies with exam types. This difference could change if the course materials are taken down before the exam on its day, although this was not investigated in this study.

Even if interaction with course materials is researched in the online space, a possibility exists that student learning periods are similar in the case of face-to-face education. Naturally, that is more difficult to research because their actions cannot be supervised as thoroughly. However, for the time being, it can be assumed that the students have similar learning periods in the case of face-to-face education, and therefore teachers can customize the deadline of assignments based on them.

5. Conclusions

Due to distance education, it was possible to investigate when course materials are accessed relative to exams using Moodle and YouTube analytics. Based on the results presented in this study, students studied throughout the semester for the normal exam in most cases, while they studied a day before the supplementary one. When cheating was assessed, it could be concluded that non-repeater 2nd-semester students used significantly more slides, while the videos' average view duration was significantly longer for non-repeater 5th-semester students. Even with cheating, the students that were in their 2nd semester received significantly worse marks by 26.06% than those who were in their 5th semester. The reason for this is unknown: it is possible that they studied more, or cheated better, or simply just became more used to their university studies.

According to the results, another fact could be concluded: course materials are accessed more times before each first exam. The type of exam is not important in this case. Based on the numbers alone, students may be anxious before each first exam and try to study before it. However, after they see the type of the exam, they could know what to expect in the future. This is the reason why the weekly numbers of course material interactions are dwindling throughout the semester.

Hopefully, education will slowly transition back to face-to-face teaching. While we may have more understanding of online cheating habits, the learning periods of students will (possibly) not change when face-to-face education reappears. Due to the influence of these results, teachers around the world can prepare exams or customize the deadline of assignments based on student learning periods.

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Informed Consent Statement: Patient consent was waived due to the fact that the participants cannot be identified based on the information that is returned by the Moodle and YouTube analytics.

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Article

Identified Challenges from Faculty Teaching at Predominantly Undergraduate Institutions after Abrupt Transition to Emergency Remote Teaching during the COVID-19 Pandemic

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Abstract: COVID-19 has been one of the most significant disruptors of higher education in modern history. Higher education institutions rapidly transitioned to Emergency Remote Teaching (ERT) in mid-to-late March of 2020. The extent of COVID-19's impact on teaching and learning, and the resulting challenges facilitating ERT during this time, likely varied by faculty, institutional, and geographical characteristics. In this study, we identified challenges in teaching and learning during the initial transition to ERT at Predominantly Undergraduate Institutions (PUIs) in the Midwest, United States. We conducted in-depth interviews with 14 faculty teaching at Midwestern PUIs to explore their lived experiences. We describe the most overarching challenges related to faculty teaching through four emergent themes: pedagogical changes, work-life balance, face-to-face interactions, and physical and mental health. Five themes emerged that we used to describe the most overarching challenges related to students and their learning: learning patterns, technology access, additional responsibilities, learning community, and mental health. Based upon the identified challenges, we provide broad recommendations that can be used to foster a more successful transition to ERT in unforeseen regional or global crises in the future.

Keywords: COVID-19; emergency remote teaching; higher education; predominantly undergraduate institutions

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1. Introduction

COVID-19 was first identified in Wuhan, China, in December of 2019. Despite early efforts to control the spread of the virus, on 11 March 2020, the novel infectious disease was found in 114 countries and was classified as a pandemic [1]. Led by guidance from scientists and health officials, governments around the world mandated national lockdowns and placed restrictions on the gathering of people to slow the spread of the virus. Daily life was fueled with uncertainty, stress, and anxiety for many as the disease advanced to urban and rural communities around the globe [2,3]. For all but workers deemed as "essential" or "life-sustaining" (e.g., emergency room medical personnel and supermarket staff), business and industry shutdowns led to a surge of employees working from home or being furloughed or laid-off [4]. Similarly, colleges and universities rapidly transitioned to operate in an emergency remote environment [5,6]. By mid-to-late March, most institutions of higher education in the United States made the abrupt shift to operating in a virtual capacity [5]. Additionally, students who lived in campus dormitories were strongly urged or required to return back to their permanent residences (e.g., family residence) if they were able to do so [7]. There were large uncertainties on how the unprecedented pandemic would impact the operations and outcomes of higher education [8–10].

In most instances, faculty in higher education were given mere days to transition their courses from an existing face-to-face format to remote instruction. Although online education is becoming more common and accepted in higher education [11,12], a clear distinction exists from formally planned online teaching to what became commonly known as emergency remote teaching (ERT) [13]. In most cases, the pedagogical approaches, learning activities, and assessments that are designed for face-to-face courses do not easily translate to a remote format. This is especially true for courses that emphasize hands-on learning through practicums and laboratory work common in the sciences [10]. Faculty had to quickly adapt their courses to ERT by determining if and how to modify course content, how to evaluate student learning through online assessment, and how to effectively deliver instruction in a virtual capacity. The abrupt transition required universities and faculty to rapidly navigate a variety of technology and modality (e.g., synchronous, asynchronous, hybrid) options, and select the most appropriate tools to facilitate online learning [14]. They also had to consider students' acceptance, access, and use of the technologies [15–17].

Faculty had varying levels of experience teaching remotely and knowing pedagogical practices best suited for online learning, and in particular ERT [18–20]. Institutional support and resources available to faculty likely varied by institutional factors such as existing integration of online teaching and technology, degree of information technology support staff, existing resource infrastructure (e.g., internal communities of practice), and financial resources. Sahu (2020) predicted that faculty who were not savvy with technology may not adapt well to online teaching [10], while Christian et al. (2020) added that instructors' increased stress and workload may impact teaching performance [21]. In some instances, faculty may not have known how long the transition to ERT would last. Bao (2020) recommended that faculty should be prepared for unexpected challenges to emerge during ERT and prepare contingency plans for when issues arise [18].

Existing research on the transitionary period from face-to-face to remote instruction showed that many faculty felt ill-prepared to transition to ERT, but none-the-less made significant modifications to their course operations. Johnson et al. (2020) surveyed nearly 900 faculty and administrators across 672 U.S. institutions to assess changes to instructional delivery in the early weeks of the COVID-19 pandemic [6]. The researchers found that a majority of faculty, regardless of previous experience teaching online, implemented new teaching methods and made changes to their assignments or exams. Hollander et al. (2020) indicated that faculty were largely uncomfortable transitioning their courses due to a perceived lack of training in online pedagogy and educational technology [22]. In late March and in May of 2020, Watermeyer et al. (2021) surveyed 1148 university faculty in the United Kingdom and found that only half of faculty felt prepared to deliver online learning, whereas approximately 60% felt confident in their ability to facilitate online learning, teaching, and assessment [23].

One of the most important aspects and expected challenges transitioning to ERT was student accessibility to the learning environment [20]. Many students were displaced from their campus dormitories and were removed from the traditional learning environment they became accustomed to. Students had to quickly find new housing, which for many meant moving back home to live with their families. The variety of students' living situations were expected to be immense, ranging from living in remote areas with limited internet access to shared responsibilities caring for siblings. Sahu (2020) described that student access to the remote learning environment extended beyond having reliable internet and included physical technology devices, which were low in supply due to the migration of working and schooling from home [10]. In addition, Rapanta et al. (2020) suggested that cost, privacy, computer requirements, and necessary bandwidth associated with the technologies pose significant barriers to students' access to ERT [20]. COVID-19 compounded inequalities related to sociodemographics and access to education [19], and threats to racial equity across higher education were exacerbated by the pandemic [24]. Sahu (2020) recommended that faculty needed to be especially flexible and understanding of students' unique situations during ERT [10].

The negative impacts of COVID-19 extended beyond challenges related specifically to teaching and learning. Students experienced a higher prevalence of psychological distress related to uncertainty and anxiety about their own health, safety, education, and concern for the well-being of their family members [25]. Students also had to cope with isolation and loneliness due to social distancing [26]. Wang et al. (2020) conducted an online survey assessing the mental health of U.S. college students during the onset of the pandemic in 2020 [27]. Out of 2031 undergraduate and graduate respondents, 48.14% showed a moderate-to-severe level of depression, 38.48% showed a moderate-to-severe level of anxiety, and 18.04% had suicidal thoughts. Rudenstine et al. (2020) found a high prevalence of depression and anxiety among a sample of adult college students in an urban, low-income public university sample, and linked the presence of mental health issues to COVID-19 related stressors and sociodemographic factors [28]. Increased psychological distress among the college student population, and of particular severity in marginalized populations, were seen in similar studies and on a global scale [29–31].

Emergency Remote Teaching and Predominantly Undergraduate Institutions

It has been estimated that between 750,000 and a million faculty in the United States were required in some fashion to transition their courses to ERT, impacting over 10 million students [6]. Despite the widespread adoption of ERT, higher education in the United States is a complex landscape consisting of institutions with numerous structures, operations, and visions [32], and it can be expected that institutional differences, as well as their locations, would create uneven and unique challenges for them to fulfill their unique missions.

Predominantly Undergraduate Institutions (PUIs) are defined as public or private institutions that primarily emphasize undergraduate education over graduate and research programs. Through an analysis of institutional databases from the National Science Foundation (NSF) and Carnegie Foundation, Slocum and Scholl (2013) classified 2104 U.S. institutions as PUIs [33]. In contrast to doctoral granting institutions that conduct high levels of research (e.g., R1 and R2), PUIs award fewer doctoral degrees and faculty generally have less structured research responsibilities. The National Science Foundation (NSF; 2014) describes PUI grant eligibility as "accredited colleges or universities (including two-year community colleges) that award Associate's degrees, Bachelor's degrees, and/or Master's degrees in NSF-supported fields, but have awarded 20 or fewer Ph.D./D.Sci. degrees in all NSF-supported fields during the combined previous two academic years" [34] (para. 5). However, despite less emphasis in research and doctoral education, many faculty at PUIs, especially in STEM disciplines, consider themselves to be teacher-scholars [35]. PUI faculty commonly integrate research within their teaching and involve undergraduate students in their research agendas [36,37], in addition to conducting scholarship on teaching and learning to guide their teaching through evidence-based pedagogy [38].

Given the teaching-focused nature of PUIs, faculty often have high teaching appointments [39,40], and a less flexible contractual workload compared to faculty at larger research-intensive institutions [41]. Student advising and university service is also a common expectation for PUI faculty [39]. In total, Bowne et al. (2011) reported that faculty in PUIs were expected to have more availability to undergraduate students and were exposed to a higher scrutiny of their teaching and pedagogy practices [42]. However, the close interaction between PUI faculty and undergraduate students has been perceived as a benefit to working at a PUI [40]. The emphasis in providing high quality undergraduate education that is led by pedagogical research and best practices has positioned PUIs to be leaders in shifting higher education from a teacher-centered practice toward a learner-centered practice [43,44].

Across higher education, there has been an increasing trend for undergraduates to be enrolled in distance education. In 2015, approximately 30% of all U.S. college students enrolled in at least one distance education course [11]. However, the growth of online education has been uneven, with smaller institutions having less of a proportion of their students taking courses online. The strong value small institutions hold toward a personalized and intimate learning environment led many of these institutions to become late adopters of distance education [45]. Clinefelter and Magada (2013) reported that the development of online programs was largely limited in institutions with 2500 students or less [46]. Less familiarity, infrastructure, and developed programmatic support with online instruction may have posed additional challenges for PUI faculty to transition to ERT.

2. Conceptual Framework

In this study, we investigated the impacts of COVID-19 on PUIs through the lens of teaching and learning, as teaching and learning are central to the mission of the PUI. Prior to our investigation, a holistic approach to conceptualize the factors influencing teaching and learning in higher education was used. Several theories guided our investigation as no one theory can fully describe the range of factors that influence teaching and learning, and, moreover, that can explicitly be used to examine the rapid and unprecedented change that higher education experienced in 2020 due to COVID-19. Toward this end, a wide array of educational research has attempted to conceptualize the range of influences and their outcomes on teaching and learning in higher education. Theories pertaining to student engagement [47], self-regulated learning [48], patterns of learning [49], and an integrated model of student learning [50] led our investigation. These theories provided an important lens to evaluate COVID-19′s impact on teaching and learning within PUIs and shed light on how COVID-19 may have affected PUIs differently compared to other types of institutions.

2.1. Student Engagement

Due to high levels of student engagement typical of PUIs, they are well positioned to advance student learning and professional development when considering Astin's (1984) Theory of Student Involvement [47]. According to Astin (1984), "the amount of student learning and personal development associated with any educational program is directly proportional to the quality and quantity of student involvement in that program" [47] (p. 519). The theory, which embraces principles ranging from classical learning theory to psychoanalysis, further describes how the effectiveness of educational policy or practice is positively correlated to the capacity to improve student involvement.

Astin (1984) reported that the place of student residence impacts student learning and personal development. For example, Astin (1984) suggested that living on campus promotes student engagement, and has been shown to improve students' artistic interests, liberalism, interpersonal self-esteem, success in extracurricular activities, satisfaction with the undergraduate experience, and even strengthens faculty–student relationships [47]. In fact, Astin (1984) reported that frequent interaction with faculty is the strongest predictor of student satisfaction in college, and an increase in faculty–student interaction improves students' satisfaction with all aspects of their institutional experience. As previously described, PUIs favor strong relationships between undergraduate students and faculty members [40,42]. The displacement of students from their residential dormitories at the onset of COVID-19 [7], and the resulting transition to ERT may have threatened the typical high levels of interaction between PUI faculty and students, thereby impacting student engagement, experience, and performance.

Research on the influence of student engagement in teaching and learning within higher education has evolved since Astin's (1984) Theory of Student Involvement. In a review of student engagement research in higher education, Kahu (2013) described four dominant research perspectives on student engagement: (1) behavioral; (2) psychological; (3) socio-cultural; and (4) holistic [51]. Although each of these perspectives view student engagement through a different lens, there is clear evidence that student engagement is a critical factor in teaching and learning. Of most interest to our study, the behavioral perspective describes how institutional and teaching practice relate to student satisfaction and achievement. For example, institutional practices, such as providing necessary support services [52], and practices that emphasize active and collaborative learning improve student engagement [53].

Kahu (2013) proposed a conceptual framework that combined the four dominant perspectives on student engagement through a wider socio-cultural context [51]. Within this framework, structural influences were categorized through both university and student factors. Of particular interest to our research was the student factor of lifeload. According to Kahu (2013), lifeload is "the sum of all the pressures a student has in their life . . . [and it] is a critical factor influencing student engagement" [51] (p. 766). A student's lifeload can be increased due to employment demands, needs of dependents, financial stress, and health concerns [54]. As noted by Kahu (2013), these factors exert influence during times of crisis [51]. We expected that the COVID-19 crisis increased students' lifeload and thereby had a prominent impact on student engagement during ERT.

2.2. Self-Regulated Learning

Research on Self-Regulated Learning (SRL) suggests that students who are more adept to set goals and plan for learning, and who consistently monitor and regulate their motivation and study habits, are more likely to achieve academic success compared to their peers [48]. Pintrich and Zusho (2007) proposed a model of student motivation and self-regulated learning in the college classroom [48]. In the model, personal characteristics (age, gender, ethnicity) and classroom context (academic tasks, reward structures, instructional methods, and instruction behavior) influence students' motivational processes and self-regulatory processes. Motivational processes are illustrated by students' control beliefs, values, and emotions, whereas self-regulatory processes include the regulating context and are demonstrated by students' ability to regulate their cognition, motivation, and behavior. Outcomes of the model include students' choice, effort, persistence, and achievement in the college classroom.

As higher education moved to a remote learning format, students were undoubtedly placed in a more autonomous learning environment, which requires more self-regulation of their cognition, motivation, and study habits [50]. Rapanta et al. (2020) suggested that faculty will need to be cognizant of the time and effort that students will need to regulate themselves during the abrupt transition from face-to-face to remote learning [20].

2.3. Patterns of Learning

Vermunt and Donche (2017) summarized research on student learning patterns in higher education and described a learning pattern as "a coordinating concept, in which the interrelationships between cognitive, affective, and regulative learning activities, beliefs about learning, and learning motivations are united" [49] (p. 270). Research on patterns of learning were influenced by SRL (e.g., [48]) and Student Approaches to Learning (SAL) (e.g., [55]). Personal factors, contextual factors, and learning patterns affect learning outcomes. Research has suggested four patterns in which students learn: (1) reproduction-directed (e.g., memorizing material for a test); (2) meaning-directed (e.g., understanding the meaning of what is being learned); (3) application-directed (e.g., connecting relationships between what students learn with the outside world); and (4) undirected.

Undirected learning occurs when students do not know how to approach learning [49]. Undirected learning accounts for students' poor self-regulation and leads to doubting their ability to cope with the new learning environment, as well as close reliance on peers and their teachers. Prior research has illustrated students can become undirected learners when there is a transition from one form of schooling to another, such as students coming from another country where pedagogical practices are different, and when students transition from high school to college [56].

Faculty at PUIs generally emphasize learner-centered instructional approaches that require students to take control of their own learning over teacher-centered approaches (e.g., direct instruction). Vermunt and Donch (2017) suggested that, over time, students begin to adopt learning patterns that are best aligned to the teaching approaches used [49]. As a result, it could be assumed that students attending PUIs may have become more accustomed to learning through meaning-directed patterns, as opposed to reproduction-directed learning that could be more appropriate in teacher-directed approaches (e.g., direct instruction). Faculty's change of instructional approaches seen in ERT [6] may have caused students to experience disruption in the learning pattern they have been accustomed to, and, therefore, could catalyze the presence of undirected learning.

2.4. Integrated Model of Student Learning in the College Classroom

The Integrated Model of Student Learning in the College Classroom, proposed by Zusho (2017), effectively employs the strengths of the common student engagement theories previously described (e.g., student involvement theory; [47], SRL, [48]; and patterns of learning [55,57]), and organizes these theories within the context of higher education. The Integrated Model of Student Learning in the College Classroom was particularly useful to guide our research on COVID-19 and college teaching because it not only applied existing student engagement theories to college learning but illustrated the many other variables and their relationships that have influence on student learning outcomes. For example, the model displays the complex and interactive relationships between college students' cognition processes, motivational processes, and contextual and personal factors, including individual characteristics (e.g., age, ethnicity), personality, prior knowledge, and beliefs about learning [50]. Additionally, the model includes the impact of students' lifeload (e.g., Kahn (2013), [51]) on the learning process. The learner variables identified in this model, both independently and collectively, served as a frame of reference and lens to study the complex landscape of college learning, and the added complexity of teaching during a pandemic.

Although the Integrated Model of Student Learning in the College Classroom conceptualizes student learning and learning outcomes, the model also served as a useful reference to view variables from a teaching perspective. For example, included in the model is instructional methods and behaviors, curriculum, institutional support, academic tasks, academic discipline, and instructional planning, monitoring, and evaluation. As illustrated in the model, these teaching-based variables have direct influence on student learning. The investigation of these variables from the teaching perspective (e.g., selection of a teaching methods during ERT) is of obvious importance to understand the implications of COVID-19 on the teaching and learning process in higher education.

3. Purpose

The purpose of this research was to investigate how COVID-19, and the corresponding abrupt transition to ERT during mid-to-late March of 2020, impacted the teaching and learning process. Due to the wide range of institutional contexts in the U.S. higher educational system, we narrowed our approach to focus on PUIs located in the Midwest, United States. Furthermore, we sought to understand the impacts of COVID-19 and ERT through the lived experiences of science faculty teaching at midwestern PUIs. Through documenting and understanding the challenges that faculty and students experienced, we aimed to provide recommendations to best facilitate ERT at PUIs in the event of future crises. Two overarching questions guided our investigation:

1. What challenges did PUI faculty experience during ERT?
2. What challenges did PUI faculty perceive their students to have during the same period?

4. Materials and Methods

This study was part of a larger project that employed an explanatory sequential mixed method research design. Explanatory sequential mixed method research includes two phases [58]. In the first phase, quantitative data is collected and analyzed. Following the quantitative phase, a second phase of data collection uses qualitative methods. The qualitative phase offers additional explanation to the results seen in the quantitative phase.

Although the research participants in this study were involved in both phases of the larger project, the data and results presented in this paper were collected and analyzed in phase two, the qualitative phase, of our larger study.

4.1. Phase One—Quantitative

In the first phase of our research, we identified science faculty who taught predominantly at PUIs located in the Midwest, United States, as our research population for the larger project. A list of PUIs located in the Midwest was generated from an existing report on PUIs in the United States [33]. A sampling frame of faculty teaching biology or biology-related disciplines, and their email contact, was created through an extensive internet search. We used this sampling frame and organizational listservs (e.g., Society for the Advancement of Biology Education Research; Partnership for Undergraduate Life Science Education) to send participation requests for the first phase of the larger project.

Phase one, the quantitative phase, included a digital survey sent via Qualtrics to our sampling frame and to the listservs we identified. The survey was administered in late April and early May of 2020, several weeks after most U.S. institutions transitioned to ERT [5]. Our survey included a modified instrument that measured instructors' use of scientific teaching practices [59], and compared instructors' use of science teaching practices in the same course retrospectively prior to and during ERT. An instrument measuring instructors' comfort with technology was also included on the survey, as well as questions related to instructor demographics and their institutional characteristics. The last question on the survey asked respondents if they would be willing to complete phase two of our study, which included their participation in an incentivized ($50), one-on-one interview following-up on their experience with ERT. This research was approved by Doane University's Institutional Review Board.

4.2. Phase Two—Qualitative

One-hundred and thirty-one respondents completed the quantitative phase of our study. Of those respondents, 59 indicated willingness to participate in phase two, a follow-up, one-on-one interview. Of the 59 individuals willing to participate in the qualitative phase of the study, we purposely selected 14 participants. The 14 participants were selected based upon having diverse characteristics on their implementation of scientific teaching practices prior to and during ERT, organized via a cluster analysis [60]. The 14 participants were also selected to have varying academic positions (e.g., assistant professor, associate professor, professor), years of experience teaching undergraduate STEM, prior experience teaching remotely, and used varying modality types (e.g., synchronous, asynchronous, blended) during ERT. See Table 1 for characteristics of our 14 participants.

Table 1. Characteristics of interview participants.

Participant Number	Position	Gender	Age	Years Teaching STEM	Prior Remote Teaching Experience	ERT Modality	Interview Length (min)
1	Professor	Female	40–49	16–20	No	Asynchronous	104
2	Assoc. Professor	Female	40–49	6–10	No	Asynchronous	108
3	Professor	Female	50–59	20+	Yes	Asynchronous	124
4	Asst. Professor	Male	30–39	3–5	No	Asynchronous	79
5	Professor	Male	NA	20+	No	Blended	79
6	Professor	Male	40–49	16–20	No	Blended	57
7	Asst. Professor	Male	30–49	3–5	No	Asynchronous	79
8	Asst. Professor	Female	40–49	11–15	Yes	Asynchronous	109
9	Asst. Professor	Male	30–39	3–5	No	Asynchronous	36
10	Assoc. Professor	Female	40–49	11–15	No	Asynchronous	93
11	Assoc. Professor	Female	40–49	11–15	No	Blended	70
12	Asst. Professor	Female	40–49	6–10	Yes	Asynchronous	48
13	Assoc. Professor	Male	30–39	6–10	Yes	Asynchronous	78
14	Professor	Male	50–59	20+	No	Synchronous	89

4.3. Data Collection

Due to the potential sensitivity of the topic, anticipated variation of experiences, and exploratory nature of this research, one-on-one interviews were selected for data collection over other means such as focus groups. A semi-structured interview guide was created and deemed most appropriate to elicit thick and rich data [61], while providing the flexibility necessary to probe and validate the meaning of responses [62]. The semi-structured interview guide contained three major sections: (1) changes in faculty scientific teaching practices as a result of ERT; (2) faculty and student challenges related to ERT; and (3) faculty support related to ERT. The interviews were conducted via telephone for ease due to COVID-19 and proximity restrictions. However, as described by Cachia and Millward (2011) [63], telephone interviews are appropriate and effective for administering semi-structured interviews. The completeness, credibility, and accuracy of participant responses were achieved through the moderator's use of member-checking strategies [64]. The interviews were conducted in June of 2020 after the conclusion of the semester. Interviews were conducted by a trained moderator and interview lengths ranged from 36 min to slightly over two hours, with an average length of one-hour and 22 min.

4.4. Coding and Theme Development

An initial codebook was developed and guided by our semi-structured interview guide, by an initial theme analysis from the larger project, from existing literature, and from the researchers' own observations regarding the abrupt transition from in-person to remote teaching. The codebook was discussed and created by the three researchers who coded the transcriptions. After several iterations, the final codebook contained 14 codes and 24 sub codes. The three coders had prior experience in qualitative educational research. One coder held a doctorate in Urban Education, Adult, Continuing, and Higher Education Leadership and was the Director of Institutional Effectiveness at a PUI. The second coder held a doctorate in Agricultural Education with a focus in teaching and learning in agricultural/environmental sciences and inquiry-based instruction and was an Assistant Professor of Environmental Science at a PUI. The third coder conducted the interviews for this study and was employed as a project manager at the Bureau of Sociological Research at the University of Nebraska-Lincoln, and held experience in qualitative methods.

The researchers used the established codebook to code 20% of the interview transcripts. Three coding trials were conducted, and after each coding trial the researchers discussed discrepancies between coding results. After the third trial, intercoder reliability was achieved. Intercoder reliability was accessed by Krippendorff's alpha, a reliability estimate used in subjective judgements [65]. Final intercoder reliability was established at 0.84, and was deemed highly reliable. The 11 remaining interview transcripts were divided among the three researchers to complete coding. Lastly, the coded data were analyzed to determine emergent themes.

5. Results

The PUI faculty in this study experienced a wide-range of challenges during ERT at the onset of COVID-19. Four overarching themes were identified that can be used to describe the most encompassing challenges our faculty experienced during ERT. Additionally, five themes were found that can be used to describe the most encompassing challenges that students faced during ERT.

5.1. Challenges Related to Teaching

5.1.1. Pedagogical Changes

Nearly all faculty described their most significant challenge with ERT as the speed in which the transition to ERT had to occur, and the accompanying pedagogical changes required of ERT. The abrupt change from face-to-face instruction to ERT occurred in a matter of days. Although some PUIs gave faculty additional time to prepare for remote instruction (e.g., a week), the enormous tasks of learning new pedagogical approaches, identifying and incorporating new technologies, and changing academic content to fit a revised calendar, and appropriate for ERT, was difficult for most faculty. Adding to the complexity, was the rapid pace in which these changes had to occur and the many underlying uncertainties the pandemic caused.

The rapid transition to ERT caught most faculty by surprise. Participant 5 described the experience as "sticker shock," as he recalled first learning that his institution was going to remote instruction, "Your set on one mode of teaching and delivery, and then all of a sudden need to go to another one . . . [at my institution] we were told on a Friday that from the following Monday, everything was going online." For Participant 10, the decision to transition to remote instruction was made over her spring break. To make matters more complicated, during her spring break she was leading a field course out of state with students. She explained her conundrum, "Now I get to figure out how to [move courses to a remote format] in one week and try to transition multiple courses that have never been online to an online modality." She continued by saying, "I wasn't even in a position where I could go to a computer and sit down [and] start working on anything." Participant 4 was also on spring break when his institution announced they were going fully remote the week after, "I was on vacation, so I wasn't in a place where I could do any work and they actually ended up extending spring break for another week for students." He explained that although he felt grateful for the extended week to prepare, he still felt under pressure, "I ended up having one week then really to rush and get something put together . . . so [I was] a little bit panicked."

A few of the PUI faculty members we interviewed were already well versed with online instruction or already used online components in their existing courses, and this appeared to have helped them prepare for and teach remotely. However, a majority did not have prior remote teaching experience nor were familiar with pedagogy for online teaching. Participant 2, who had no prior experience teaching remotely, described her struggle, "I just had to [transition to remote instruction] with hardly any research and planning and just not knowing if what I was doing was even the right thing to do." Participant 2 continued by explaining how this experience varied from her typical course redesigns, "Normally, I would only redesign one class a time and instead I was redesigning five classes at a time without having any idea if the things I was doing were going to work or were reasonable." Participant 4, who also had never taught remotely before, shared a similar sentiment, "Remote teaching can be a very effective tool if you know what you're doing and if you're doing it correctly. . . . I'd never done it before and I didn't necessarily know the correct way of doing it." Participant 1, who was also new to remote instruction, summarized her experience, "I found [transitioning to ERT] to be a new challenge to learn new ways to present my material." She continued by saying, "I felt like I was busier and spending a lot more time on my classes when we went online versus when we were face-to-face because I was creating a lot more content for my students."

Most faculty explained that they had to redesign teaching activities and content to make remote instruction work. Participant 6 described his experience transitioning his coursework to remote instruction,

> *So I would look at what I had planned and I would ask myself okay, how can we do this virtually? And I'd say about a third of the time, we could pretty much do it the same way we might've done it in the classroom, and a third of the time it could be modified and a third of the time it was just a no go.*

Some faculty mentioned creating new assignments that were appropriate for an online format. Participant 13 described challenges creating new assessments, "I just [needed] to come up with some form of assessment that would not easily be cheated on [in the remote format] . . . so you know, there were lots of challenges." Like several other faculty, Participant 14 decided to cut down the amount of content taught, but his main concern was the elimination or reduction of lab practices. He explained, "It's really the laboratory, the hands-on application component to it that I think suffered [as a result of remote instruction]." He continued by describing his concern requiring students to complete hands-on learning activities remotely, "It's the inability to standardize what students have available to them . . . so it is that inequity, that extreme variability in what students have available to them is one of the things that makes it very difficult."

Several faculty members mentioned being surprised by the amount of time required to prepare and modify course materials for the remote format. Participant 6 stated, "So I ended up spending a lot more time than I had thought I would trying to modify things," and Participant 14 added "time-wise every step of the way is taking more time than it had previously." However, not all teachers felt the same way. For example, Participant 4, who shared, "It was easier to get stuff prepared than I thought because I had so much less interaction with students, I actually had more time."

Although there was a mixed sentiment on what components of ERT required the most time, nearly all faculty described time management to be a significant challenge. A majority of faculty mentioned that there was a dramatic increase in the time spent emailing students, as Participant 6 expressed, "Trying to respond to the kids remotely versus in real time just took a lot more time and they had bigger needs." Participant 3 who described herself as "an hour ahead of the students most of the time and always behind on grading", added that time management was a challenge for her, specifically "always trying to get back to students in a timely manner." Participant 10 summarized her thoughts on time management by saying, "I spent an inordinate amount of time answering student emails throughout the week."

5.1.2. Work-Life Balance

As universities sent students home and operated remotely, most faculty were strongly urged, if not required, to work from home. Faculty who had families found themselves sharing their new work environment with their spouse and kids. A majority of faculty described difficulties working with kids in the home. Participant 6 described his experience, "The biggest challenges that I expected to see and that I actually saw involved the personal switch of not being in an office for eight hours a day, but instead of being at home with two small children." Participant 2 echoed the sentiment,

> *All of a sudden you know, I was maybe 10 or 15 min before someone, like a child would come in and bug me for something or need something you know, I just didn't have the physical brain power to spend on [work] like I would have liked.*

Participant 10 further expressed challenges teaching from home with small children, "The kid was home and she was running around making noise and it was hard . . . you know, go do something and leave me alone for some chunk of time." Additionally, like what several other faculty mentioned, she described new spousal conflicts from the shared work-home environment, "[My husband] doesn't do work from home. So when he's home, he has nothing else to do. And when I'm home, I have to work and that caused friction and issues." The shared spousal workspace was an issue for Participant 3 as well, "[My husband and I] felt like we were working all the time and it was really difficult to separate." For Participant 10 the biggest challenge was separating work from family time despite being at home. She elaborated on her thoughts,

> *I have a family. I like to work really hard when I'm at work and then when I get home I don't like to be on my laptop a lot or answering a bunch of emails or doing a bunch of grading unless I absolutely [have to]. . . . It took maybe a good few weeks to a month to kind of get into the mode of [doing] work at home . . . that was hard.*

A few teachers described positives from working from home and forming stronger bonds with their family. Participant 9 stated, "I actually like working from home a lot better. I have little kids so it helps me be more involved with my family, I get to eat my meals with them, so I've actually enjoyed it." Several participants also mentioned spousal support, like Participant 3, "My husband also teaches and his school obviously went to remote learning. I've always been very lucky to have somebody else in the house who understands what I'm doing and can support me both emotionally and . . . bounce [off] ideas."

5.1.3. Face-to-Face Interactions

A strong majority of faculty described negative impacts stemming from the loss of a face-to-face learning community. The close-knit learning community and strong interactions between faculty members and their students typical of PUIs appeared to degrade during remote instruction. Several faculty members described a loss in colleague support as a major challenge, as described by Participant 2,

> *Normally … I might go talk to my colleague down the hall who maybe has done this before, or might have some sort of experience with it … and suddenly … I was on my own, without the sort of support that I might normally be able to rely on.*

However, overwhelmingly, faculty members described the loss of face-to-face interaction with students as the largest negative impact. Participant 5 described his experience,

> *[The biggest challenge for me] was I lost my connection with the students. I lost my touch. Absolutely. And so one of the reasons I teach in an institution which has a really low student to teacher ratio like we do is because I like the interaction with the students, getting to know them on a personal basis, a very personal basis. … I'm not sure how I'm going to overcome that [next] semester [if we continue remote].*

Participant 8 shared a similar experience, "I think the hardest part for me wasn't the actual teaching online. It was not seeing my kids, my students." Participants 3 echoed the sentiment, "I like being in the classroom, I like being able to talk to students. You know, the interaction and being able to provide hands-on opportunities." Participant 12 summarized the overarching feeling, "A big part of my personality as a teacher is the face-to-face community, building the peer learning. I foster the positive interdependence I build in the classroom." Although most faculty expressed that the loss of the face-to-face learning community negatively impacted their ability to build student rapport, Participant 1, who described herself as "introverted", expressed that remote instruction allowed her to be "more personalized online [and] helped [her] make connections with students."

Several faculty members mentioned that the loss of face-to-face teaching reduced visual feedback cues that guided their teaching behavior. For example, Participant 3 stated, "when I couldn't see them face-to-face [I didn't] have any visual cues as to whether I was getting through [to students]" and Participant 5 remarked, "I was not able to look at [students] face-to-face and gauge their reaction."

The abrupt change into a remote teaching environment caused some faculty to question their teaching performance. Approximately half of the faculty directly stated that their teaching performance decreased during remote teaching. Participant 4 said, "So my thoughts personally are I think it decreased [my] teaching performance," and Participant 14 remarked, "I doubt that I was effective." Participant 13 described his teaching performance as being "negatively" impacted as he described what the remote learning environment felt like to him, "I can't be there to explain things and make the jokes that I would, and, you know, sort of engage the students. So my teaching performance is more delegated to kind of, to feel like an online tutor."

Some faculty described a benefit to their teaching performance in the long run. Despite the abrupt transition to remote instruction being difficult and a "learning curve" (Participant 14) for most, faculty were able to learn new teaching strategies, incorporate new technologies, and to "reflect on what [teaching] content really matters" (Participant 7). Participants 1 and 14 summarized the attitude of many faculty well by saying, "Yes, I had to learn some new skills, but you know that's a good thing," (Participant 1) and "There were some good things that came of [this experience] that I can use and carry forward" (Participant 14).

The loss of the interactive, face-to-face learning community caused faculty to experience a significant decrease in career satisfaction. Nearly every faculty member overwhelmingly stated they were less satisfied with their work. Participant 12 described what this experience meant to her and to her career satisfaction,

> *The challenges of not interacting with students on a daily basis has greatly decreased my satisfaction with teaching. I got into this and I am at a small private college because the interaction with the students and the community that we build in the classroom is very important to me and so not getting to see students regularly, not having them in my office asking questions, not having the rapport with them, has really made it feel like I'm interacting with a computer and it's very hard [for me] to find that rewarding.*

Participant 2 described her experience and beliefs toward her career satisfaction,

> *I didn't get the pleasurable part of [teaching], which is seeing the students, talking to the students, you know, when they get that little light bulb that goes off over their heads and they like understand something, like I never got any of those rewards. I just felt like it was a lot of the part that I don't like and none of the rewards that I do like.*

5.1.4. Physical and Mental Health

Some faculty experienced health-related challenges caused by the impacts of COVID-19. As faculty began teaching remotely from a computer, moving and walking during the workday decreased, contributing to physical ailments. Participant 1 described her experience,

> *When you teach face-to-face classes you go into a classroom, you're up and on your feet and you walk around the classroom. I didn't have that time every day, I was sitting on my computer working … it's not good for my body so I don't feel the best.*

Participant 3 added "sitting in front of the computer all the time ended up with my neck and shoulders and mouse hand hurting by the time I went to bed every night." Participant 2 described her physical ailments as an "intense pressure on [her] chest all the time" and feeling "overwhelmed constantly" leading to higher blood pressure and lowered ability to sleep.

Despite only a few teachers specifically mentioning physical health issues and none mentioning being physically sick from the virus themselves, nearly every participant discussed mental health challenges related to increased stress and anxiety. According to Participant 13, the experience was "more stressful than [he] thought [it would be]." Participant 10 added "It's extremely stressful. Like the whole thing is stressful." Participant 5 said, although he does not tend to get stressed out much, his well-being "has actually taken a hit" because he was "stressing out a lot more."

When asked about the specific cause of the increased stress and anxiety, several faculty members described uncertainties related to the pandemic. Participant 10 contributed,

> *I mean, and just the plain old, ongoing anxiety of being in the middle of a pandemic and you are shut at home, [sic] cause the, the whole place is essentially under a near quarantine. I mean, that's daily, ongoing anxiety is a real issue and that interferes with your ability to focus and concentrate and think and do work.*

To Participant 11, it was the "stress of just sort of the unknown and the virus." Participant 14 described accepting the uncertainty to deal with the stress, "So yeah I think you know from a mental perspective there were a lot of unknowns and a lot of uncertainties but if you're willing to accept a level of uncertainty then it wasn't so taxing."

A few faculty members related the increase in stress directly to changes in work structure and workload. Participant 6 said, "It was more hours worked per week and it did get stressful at times because I'm also holding down two, we're only supposed to have one, but I'm holding down two service positions." Participant 2 described how the abrupt change in work structure impacted her,

> *It was just all of a sudden everything changed and it was just my work life that changed, but it was also my personal life that changed and it just felt like you know, everything coming so fast. Especially in the month of March everything was changing so fast … like trying to teach classes somehow this way that it, it just, it just felt awful. … You know, like I just felt overwhelmed constantly.*

Other factors leading to increased stress levels were from a "lack of good communication from administration" (Participant 3) and not being "able to interact with students anymore" (Participant 4). Participant 2 described her stress being relieved toward the end of the semester, "It really wasn't until maybe like there was two weeks left in the semester where I was like okay, I feel I can finally breathe."

5.1.5. Summary of Challenges Related to Faculty's Teaching

Key findings related to the themes of pedagogical changes, work–life balance, face-to-face interactions, and physical and mental health are summarized in Figure 1.

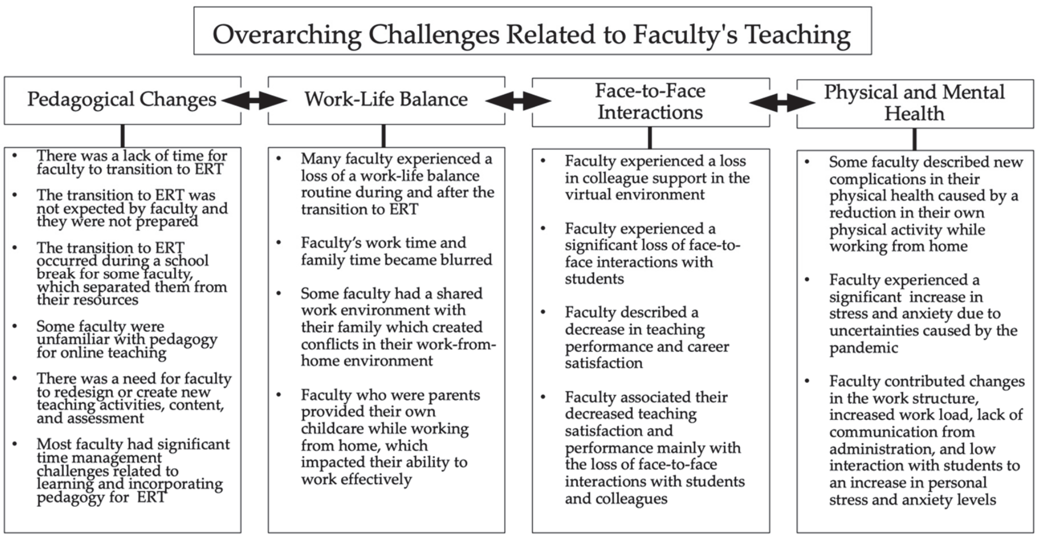

Figure 1. PUI faculty's identified challenges related to themselves and their teaching during the onset of COVID-19 and ERT.

5.2. Challenges Related to Learning

5.2.1. Learning Patterns

According to faculty, students faced a multitude of challenges as a result of the swift change from face-to-face learning to remote learning. However, faculty were split on the severity of these challenges. Some faculty explained that many students just were not in the mindset to take courses remotely, and this had a negative impact on their success in the remote settings. Participant 5 shared, "Students had a tough time. Now, let me rephrase it, some did well, some didn't do well, but on average students had a tough time." Participant 5 continued to describe how his students were not prepared nor did not favor online instruction, and summarized by saying, "[Students] signed up for a face-to-face class for a reason." Participant 6 elaborated, "I didn't realize how much kids were just logging in and zoning out ... until the final exam results came in." He then added, "[Students] just need that supervision [typical in face-to-face formats] to stay on top of things and when they're left to their own devices, it falls apart and they're not self-disciplined to stay on top of it." Some faculty attributed this to typical PUI characteristics, as Participant 4 alluded to,

> *I also was of the opinion going into this that the students really were going to struggle with it because the nature of the school it was, you know, [a] small school and so they're used to getting a lot of contact and a lot of interaction with their faculty and instructors and now all of sudden that was going to change and go away*

In addition to faculty being concerned about their own time management, they also acknowledged that their students struggled with time management and organization stemming from the abrupt course modality change. "Time management was a huge challenge" for Participant 7's students. He continued be saying,

> *[Students] would complain about the bombardment of emails. So like you know a faculty member emailing them and saying do this. And then 10 min later say, no, actually do it this way. And then an hour later say, no, do it this way. They had a really hard time with scheduling and keeping track.*

Participant 3 described her students' experience similarly, "time management was definitely something that students talked about . . . and all of a sudden getting just email after email after email from faculty whereas in the past . . . [they were hearing] announcements in the classroom."

5.2.2. Technology Access

Nearly all faculty described students' lack of access to technology as being one of the largest on-going challenges after transitioning to ERT. Participant 9 "did not expect to encounter [issues with student access]" and described "internet access [as] the problem." In most cases, the transition to remote instruction required students to leave campus dormitories and to move back home, where access to the internet was limited or not available. Participant 2 described her perspective,

> *[Some students didn't] have reliable internet at home and any place they might've gone to get reliable internet like the school or a coffee shop or you know, a library where you used to be able to count on getting reliable internet. Suddenly [students] couldn't go to any of those places . . . it was a problem the entire semester because you know, the entire world was shut down or at least most places were shut down.*

Faculty expressed that students moving home to rural areas had the most significant challenges related to technology access. Participant 10 described a student in her class, "I know I had at least one rural student that basically had no internet and she did have to essentially drive to the McDonald's and sit in the parking lot to do anything." Participant 12 mentioned a similar experience with "a student who had no internet access at home" and the student having "to travel to wherever she could pick up Wi-Fi."

In addition to getting access to the internet, slow internet speed was an ongoing issue, especially for students whose instructor taught through a synchronous modality. Participant 14 described his experience using live video conferencing, "Students would come on, they would be on for a little while, they would get dropped, they would come back on. So, you know, maintaining a continuity with them [was difficult]." Participant 9 shared a similar experience with video conferencing and having students with poor internet connectivity,

> *They're freezing or they're cutting out, or it gives you a really, really big delay . . . and then hearing [and] speaking [issues], that's really frustrating for that person, well, for everybody involved. You can't possibly be getting anything out of a class if that keeps happening to you. I mean, why, why would you ever want to log into a class if that keeps happening to you because of bad connectivity?*

Students' unreliable internet was an issue for teachers using asynchronous formats as well. Poor internet connections led to issues with students submitting assignments and taking quizzes. Participant 10 summarized her experience,

> *I did have most [students] say they had their internet cut out on them when they were doing things. And I would go to look at where they were working on the quiz and I could see that it stopped after two minutes or something.*

Although lack of reliable internet appeared to be the largest challenge related to students' ability to access course material, nearly half of faculty members mentioned students' lack of unrestricted access to a computer. For a few faculty members, their students were on spring break when the transition to remote instruction was announced, and thereby separating students from their resources. Participant 4 described her experience with this,

> *[Students] left their computer in the dorm when they went on spring break and then all of a sudden in the middle of spring break they were told they couldn't come back. So that was a problem . . . it took [students] three weeks to be able to get their computers back from the dorms.*

Participant 14 described some of his students being without computers and taking courses from their phones, which was not ideal. Another contributing factor for students' lack of a computer or internet access was due to the technology being a shared resource in their family's household. According to Participant 1, "[Students] had to figure out the best time of day for them to get online and do online stuff when internet speed was good for them because they were balancing the internet usage with the rest of their family." Participant 2 shared a similar experience, "One student who you know had the one computer and there were essentially three people trying to learn on that one computer."

Participant 14 summarized the issue by saying, "None of [the students] planned for this and so they didn't have appropriate equipment or appropriate internet." Despite these challenges, faculty described working with students to the best of their ability by "being flexible" (Participant 10) and encouraging "understanding and communication" (Participant 8). Some technology challenges were relieved by characteristics of their PUI. Participant 5 discussed his relief in that all of his students had access to computers through his university's one-to-one program, "What really helped me, lucky, was that [students] all had an iPad, so no student couldn't come back to me and say they did not have a device to use to complete the assignment or to work on it." Participant 8 added that his university sent devices to students who did not have computer access. Although, he described challenges of that process,

> *There was a delay for those students getting things set up and there was a delay for our university to realize we have to put a device in these kids' hands and you know so stuff like that was very, very frustrating for our students.*

5.2.3. Additional Responsibilities

Several faculty members expressed that their students shared family-related challenges, especially for students who had kids of their own or who were looking after their younger siblings. Participant 1 explained her students' situation, "Close to 25 percent of [my] students had families and working around and dealing with those two schedules while trying to find time to get their studies done [was difficult]." Participant 10 further explained the ongoing difficulties that her students, who were also parents, had, "If schools are out and your kids are home and you can't afford daycare that is every day . . . and I know that's the case probably for many of our students." Participant 2 summarized the experience of her student who was also a parent,

> *I have one of my students you know, she was a mother of two. She had an eight-year-old and a six-year-old and they had one computer in their house and she was homeschooling you know, her eight-year-old, she was homeschooling her six-year-old. And then you know, she would be using that computer after the kids went to bed to do all of her assignments cause they only had one computer.*

According to faculty, many students were also taking care of their younger siblings during the pandemic. Participant 12 expressed that her students "were helping provide childcare for younger siblings at home," adding complexity to keeping up with class material. Participant 3 also recognized this challenge, "I didn't know if [students] were going to be expected to be homeschooling their little brother or babysitting or what all."

Some faculty also mentioned the frustration that their students experienced moving back into their family's residence. Participant 7 described her students' experiences,

> *I know my students struggled with living back at home. Some of them would struggle with their parents not recognizing that they were still technically in college and so they'd be asked to do stuff around that house all day when they were trying to get work done and it didn't create the same kind of [learning] environment.*

Participant 3 further described students' struggles by saying, "You know [students] had been at least semi-independent adults living on campus and now they go home. I remember what that was like all of sudden you're back under mom and dad's rules . . . that's awful."

Over half of the faculty described challenges their students faced regarding jobs. A few faculty members mentioned that students' job loss or job loss in the family impacted them directly. For example, Participant 7 described, "[My students] reached out directly and said you know, my dad lost his job and I'm picking up an extra shift to try and help out kind of thing and can I have an extension on this or that?" Participant 2 described a similar situation, "Maybe [a student's] family member had lost their job so they needed to pick up you know, an extra job just to make ends meet." Changes in students' job schedules due to the pandemic also posed challenges. Participant 1 explained, "Some of [my students] got new jobs and some of their jobs changed their work schedule." Participant 8 expressed concern with students juggling course work with new job demands, "[Students have] differing schedules or now they have to have a full-time job while they're doing full-time coursework."

5.2.4. Learning Community

Faculty overwhelmingly perceived their students to have experienced significant challenges transitioning from a face-to-face learning community to a remote one. Similar to how faculty expressed their own value toward a face-to-face learning community, they also believed their students valued the close-knit learning community typified by most PUIs. Participant 5 explained, "Many of the students that we have at [my PUI] come because they want personalized attention. They want the small classroom feel. They want to be able to interact with the instructor." Participant 8 believed this to also be true of her PUI, "It's like one big family . . . that's the feel you get when you're on our campus . . . and then what we did [when we went to remote instruction] was isolate [students] away from their college family so that was really hard." Participant 4 shared a similar perception, "[My PUI] is a small school so [students are] really used to getting a lot of contact and a lot of interaction . . . with faculty members and instructors and all of sudden that [went] away."

Students' learning community was impacted beyond a reduction in faculty interaction. Participant 3 described how students left behind the "social lives and athletic events" they were used to. Participant 5 stated a similar opinion, "[Students] had plans for athletics, they had plans to do other things . . . missing their friends. So a lot of other factors come in [that impacted their remote education]." Participant 4 could tell that his students "were struggling with something socially," perhaps due to their "social lives and athletic events being canceled" (Participant 14).

Faculty believed the loss of the face-to-face learning community caused a decrease in motivation, engagement, and performance for most students, but especially for students who were already struggling in face-to-face settings. Several faculty members mentioned that student participation was low during remote teaching and some students were completely absent. Participant 4 described his surprise by saying, "what I didn't anticipate was how many students would really kind of start to drop off . . . in terms of their efforts, and in some cases I had students that really just disappeared," and Participant 9 added that "student participation was probably the second worst problem" for him.

Faculty expressed that lower levels of student engagement, participation, and motivation were difficult to remediate through remote teaching. Participant 4 described his experience, "I don't see [students] face-to-face . . . I can't just say, 'Hey, what's going on? . . . some students would respond to my emails but there were a few that didn't . . . so I even went to the phone and I started to call students." Participant 13 portrayed a similar point of view regarding the online environment,

> *what it really comes down to [for students] is the motivation . . . to get things done. [Students] have to get things done when there isn't anyone there to sort of check-in . . . to look [them] in the eye or to listen. [They] have to be self-motivated.*

The lack of engagement in the remote setting compared to the face-to-face setting may have been challenging for students to stay motivated, as described by Participant 14, "We also had a certain amount of students that I think probably got frustrated with it or bored with it and you know didn't show the discipline to it that's required."

When describing the impact of remote instruction on students' performance, some faculty believed that student performance was negatively impacted, and others believed that performance was consistent from earlier in that semester. Participant 11 believed that student performance decreased, "I mean, overall I felt like the students were a little weaker this semester ... but I don't feel like I did as good a job at helping them learn what they needed to learn." Several faculty members described a clear separation between top performing students, who consistently stayed engaged and had active participation during remote instruction, and students who struggled academically, who tended to lack motivation and self-discipline. Participant 10 described her experience,

> *Those 5 or 6 [students], they're already getting an A, you know, they're going to charge through it. They're going to figure it out. They're going to be fine ... and there were several of them that I kind of pulled along. And then there were a couple of students that I barely heard from.*

Some of the students who underperformed may have also experienced significant disruptions caused by COVID-19, such as home-life challenges, employment troubles, lack of consistent technology access, and mental health struggles, as these events were discussed throughout the faculty interviews. Lastly, faculty described their students to be mostly understanding, but not necessarily happy or extremely satisfied, about the abrupt transition to remote learning.

5.2.5. Stress and Anxiety

Faculty described stress and "generally anxiety as an ongoing experience" (Participant 7) for their students. Several faculty members had students reach out to them "mentioning they were struggling with something (mental health)" (Participant 4). According to Participant 3, "stress was probably one of the biggest things ... for students". She added that the stress was caused by students "trying to figure out what was going on when, when things were due, [and] what's the timing." The stress faculty's students were having had a direct impact on faculty who deeply cared about their students' health and classroom success. Participant 4 described his experience,

> *Some students [were] basically ... like sorry, I haven't done any work ... I haven't been able to do anything since this started. You know emotionally, it is like the emotional toll that they're experiencing. Um, and that became a big problem for students and, and it was challenging for me because, I don't know who was being affected by that and two I mean, I'm not, I'm just not trained on how to help someone in that situation.*

The abrupt change from having a scheduled routine at school and a safe study space to moving and attending class from home contributed to some students' stress, as described by Participant 12, "The upheaval in their lives you know the fear that all of us were experiencing ... and an abrupt move home. [For] some [students] that might not have been a good situation to move home to." In addition to the stress caused by a change in school structure, Participant 10 described student stress being caused by their worries about the potential health implications for themselves or family members contracting COVID-19, "So there's students having all those other things going on [and] worrying about [themselves] getting sick or their, you know, grandparents getting sick."

5.2.6. Summary of Challenges Related to Students' Learning

Key findings related to the themes of learning patterns, technology access, additional responsibilities, learning community, and stress and anxiety are summarized in Figure 2.

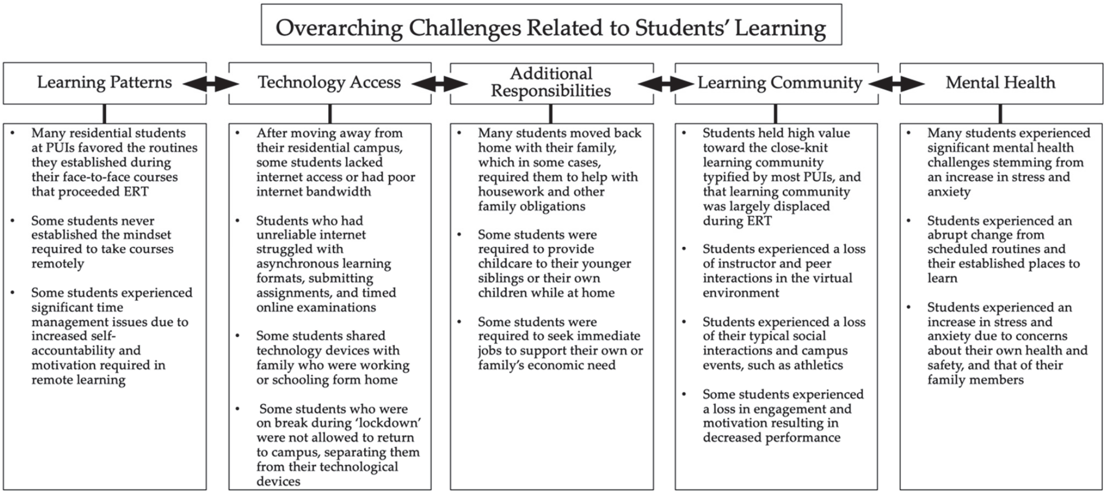

Figure 2. PUI faculty's identified challenges related to students and their learning during the onset of COVID-19 and ERT.

6. Discussion

Although our study was not a comparative study between PUIs and other institution types, the PUI faculty in our study identified challenges that may have been exacerbated by typical characteristics of teaching and learning within PUIs. Faculty at PUIs generally have high teaching loads [39,40]. A majority of our participants described being overwhelmed with the workload required to transition and operate a large number of courses in ERT. Similar to findings by Johnson et al. (2020) [6], a majority of faculty in our study reported changing aspects of their courses to allow for ERT, including employing new teaching strategies, modifying assessments, and reducing course content. Prior research described that smaller institutions may lack the infrastructure and resources to support remote instruction [45,46]. Over half of our participants did not have prior experience teaching remotely, and some felt isolated in their efforts to transition to ERT. Similar to the prediction by Sahu (2020) [10], and findings from similar studies [22,23], a majority of faculty in our study, including faculty who previously taught remotely, reported feeling unprepared to transition to ERT due to a lack of training in online pedagogy and low comfort with the technology required of ERT. However, despite our participants' initial low self-efficacy to employ ERT, most faculty described being able to successfully incorporate new technologies and pedagogy to an extent that got them and their students through the semester.

Rapanta et al. (2020) described that students' accessibility to the learning environment would be a leading factor to contend with during ERT [20]. Faculty in our study confirmed this prediction. They described a proportion of their students not being able to access their course due to having no or limited internet access (e.g., low internet bandwidth), especially in rural areas. Additionally, faculty reported that technology access was hindered for some students due to resources (e.g., computer) being shared by siblings and other family members for remote school and work. Faculty also reported some of their students having to watch over siblings or taking on new job responsibilities. Faculty linked many of these occurrences due to their students' family circumstances (e.g., family job loss, family members being essential workers, etc.). These findings demonstrate the compounded inequality between sociodemographic factors and access to education previously reported [19,24].

Previous research on the implications of COVID-19 illustrated the increased prevalence of college students' psychological distress brought forth by the pandemic [25–31]. The faculty in our study acknowledged the anxiety and stress they believed their students to be experiencing. They described the cause of their students' psychological distress as the general upheaval of their lives, fear of the unknown, changes in school structure and routine, physical isolation from peers and friends, and their ongoing concern for the safety of themselves and their family members. Faculty described students' high level of anxiety and stress having negative impacts on student learning. Furthermore, a majority of faculty described an increase in their own stress and anxiety stemming mainly from technostress and techno-overload [21], but some faculty also contributed stress and anxiety from the inability to separate their work from new family responsibilities that emerged in the work-from-home environment.

Our findings illustrate an increase in what Kahu (2013) refers to as student lifeload, "the sum of all the pressures a student has in their life" [51] (p. 766). It is highly evident, based on our findings and those of similar studies, students' lifeloads were increased due to instances including, but not limited to, new living situations, isolation, needs of dependence, changes in employment, financial difficulty, lack of technology access, changes in the learning environment, and a general increase in stress and anxiety. The factor of lifeload must be first acknowledged and understood when describing the impact of ERT on student involvement, engagement, and performance. Based on our interviews, and as suggested by Sahu (2020) [10], we found that a majority of PUI faculty in our study understood students' unique situations during ERT and provided flexibility and support throughout the semester, although the degree of flexibility and support varied.

Faculty described a decrease in student engagement and performance in ERT compared to the traditional face-to-face setting. We previously described typical characteristics of PUIs, including close relationships and high levels of engagement between faculty and students [36,42], and a strong emphasis on active teaching [42,44]. It was apparent that the interaction between faculty and students was hindered during ERT. Even when teaching through synchronous or blended modalities (e.g., zoom), faculty described a loss in student engagement. This loss may have been catalyzed by faculty's unfamiliarity with delivering and planning online instruction, and student's unfamiliarity learning in this environment, especially given the vast difference between ERT and the highly interactive face-to-face environment that PUI students and faculty were accustomed to [40,42]. Like suggested by our faculty participants, Besser et al. (2020) found that students self-reported higher levels of disengagement and comparatively less learning during ERT [26].

When considering Vermunt and Donche's (2017) Patterns of Learning [49], faculty acknowledged making significant, and necessary, changes to their teaching practices. In some cases, these changes likely disrupted the learning process students were accustomed to. Students who were unable to cope and adapt quickly to the new pedagogical approaches may have been more subjected to become undirected learners, and ultimately performing more poorly compared to their peers who were able to adapt to the new learning environment. Many faculty members described a clear divide among students who performed particularly well during ERT and students who performed poorly. Student factors that were identified as influential to performance aligned closely to those identified in SRL (students' self-regulation of their cognition, motivation, and study habits; [48]). Rapanta et al. (2020) suggested that faculty needed to be aware of the time and efforts that students will require in ERT to regulate themselves [20]. However, few faculty in our study mentioned specific strategies they used to improve their students' ability to self-regulate.

Many of our participants described missing the close interaction with their students. In a similar study, Watermeyer et al. (2021) reported that faculty believed their "pedagogical praxis had been reduced to the fulfilment of rudimentary technical function" [23] (p. 631). A majority of our respondents felt similarly, and most described their overall enjoyment and satisfaction with teaching as a career to be significantly reduced during ERT, and specifically due to a loss of student interaction.

7. Conclusions & Recommendations

The results of this research further demonstrate the significant impact that COVID-19 and the abrupt transition to ERT had on teaching and learning in higher education. Our qualitative investigation explored the lived experiences of 14 PUI faculty members during the onset of COVID-19. Each faculty member shared a unique, powerful, and reflective experience that captured this significant and historic disruption in postsecondary education. Despite the variations in experience, grand similarities were found for the largest and most overarching challenges. The themes identified in our investigation illustrated these widespread challenges, and these themes were described in the context of teaching and learning.

Our results concluded that faculty in our study were not prepared for ERT and had difficulty rapidly transitioning their courses to remote teaching. The transition to ERT required faculty to implement new pedagogical approaches and technologies, and to modify course content, which significantly increased faculty workload. Although faculty believed to have ultimately been successful at incorporating new technologies and delivering instruction in ERT, the success was deemed as minimal for most (e.g., just getting by). Inequalities in student access to the learning environment were compounded by the pandemic, where faculty cited that some students lacked physical access to the virtual learning environment due to technology barriers (e.g., device access; internet access) and demands from their new living environment (e.g., share responsibility to look over siblings; picking up new jobs). Faculty also experienced a change in their work–life balance, especially faculty who were parents to young children, who struggled meeting the demands of childcare with the increased workload. The lifeload of students appeared to be exhaustive, as faculty expressed significant concern about the mental health of their students—a crisis that has been echoed by recent literature. Faculty themselves wore thin and expressed higher levels of anxiety and stress, a general decrease in satisfaction toward their career, and lower teaching performance. There was clear displeasure in the lack of close interactions between faculty and their students during ERT, and many faculty members described the high level of student interactions as the primary reason they teach at a PUI.

The focus of this study was on the challenges that faculty experienced during ERT, yet we would not be diligent if we failed to report faculty's embodiment of resilience and commitment to their students. Despite the high levels of initial stress and anxiety during the early stages of ERT, after several weeks of implementing ERT, faculty described being able to establish new routines, easing some levels of stress, and better navigating the demands of a new normal. There were few positives that were brought forth by the pandemic and ERT, but one of which, according to faculty, was being able to spend more time with immediate family and valuing that opportunity. After the conclusion of the first academic term in 2020, faculty described being better prepared for future instances of ERT. As predicted by Rapanta et al. (2020) [20], faculty in our study described learning new technologies and pedagogical practices that would be helpful in a post-digital era.

Sahu (2020) proclaimed that it is critical for faculty, students, and administrators to learn from this experience [10]. We examined the initial semester in which ERT was implemented due to COVID-19. In the following academic year, COVID-19 continued to negate the traditional face-to-face modality of teaching and learning in higher education. Although most universities were able to welcome students back to their campuses and to resume some aspects of the face-to-face learning environment, many faculty members were told to be prepared to once again implement ERT on short notice contingent upon health and safety directives. As overcoming COVID-19 and the easing of precautionary measures is becoming more imminent, this historic disruption in higher education must be viewed as a history lesson. Higher education must acknowledge the uncertainty that lies ahead and must prepare response plans to future regional and global crises that require abrupt shifts to ERT.

This event clarified the need to meet the basic physical and emotional needs of individuals as a prerequisite for learning. The health and safety of everyone in higher education should remain a top priority in any circumstance. During an abrupt shift to a virtual environment, there should be ready access to support for instructors and students in work–life balance, mental health, and self-care. Inequalities in access to education became more prevalent due to COVID-19 and ERT. Systems should be designed to ensure equal student access to the virtual learning space, including physical technology, internet access, and economic assistance to those in need. A loss of community was identified due to COVID-19 and ERT. Opportunities to extend existing communities of practice into the virtual environment and creating new virtual learning communities can provide faculty a continued sense of belonging, support, and interactive teaching among colleagues (e.g., see [44]). This event tested institutions' infrastructure of teaching and IT support. Each institution can identify discrepancies in necessary support and evaluate what can be done to improve support structures to prepare for future instances of ERT. One area of need identified from this research was the lack of time given for faculty to transition their courses, fostered in part by unfamiliarity with pedagogical approaches and technologies often used in ERT. Resources should be offered that highlight strategies for faculty to successfully transition face-to-face courses to ERT. The strategies offered should be student-centered and be designed to support a strong and personalized virtual learning community. This is especially important as faculty identified a loss of faculty–student interaction and engagement during ERT, and this is something that is extremely valued within PUIs. Lastly, expectations and strategies to ensure students actively participate in emergency remote learning should be explored, including strategies for students to develop self-regulated learning skills.

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Article

Assessment of Cognitive Student Engagement Using Heart Rate Data in Distance Learning during COVID-19

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Abstract: Student engagement allows educational institutions to make better decisions regarding teaching methodologies, methods for evaluating the quality of education, and ways to provide timely feedback. Due to the COVID-19 pandemic, identifying cognitive student engagement in distance learning has been a challenge in higher education institutions. In this study, we implemented a non-self-report method assessing students' heart rate data to identify the cognitive engagement during active learning activities. Additionally, as a supplementary tool, we applied a previously validated self-report method. This study was performed in distance learning lessons on a group of university students in Bogota, Colombia. After data analysis, we validated five hypotheses and compared the results from both methods. The results confirmed that the heart rate assessment had a statistically significant difference with respect to the baseline during active learning activities, and this variance could be positive or negative. In addition, the results show that if students are previously advised that they will have to develop an a new task after a passive learning activity (such as a video projection), their heart rate will tend to increase and consequently, their cognitive engagement will also increase. We expect this study to provide input for future research assessing student cognitive engagement using physiological parameters as a tool.

Keywords: student engagement; heart rate; active learning; non-self-report; self-report; distance learning; higher education; COVID-19

1. Introduction

Education allows society and its territories to be transformed. As society changes, the education style must adapt to its demands [1]. Educational institutions focus their resources on achieving quality teaching and professional development for their students, who expect education to be suitable, reasonable, interactive, agreeable, and practical [2]. Achieving these expectations directly impacts student engagement and become a matter of concern for teachers and institutions; therefore, measuring student engagement becomes a valuable and necessary tool for institutions [2]. Student engagement has been defined as the physical or mental energy and effort students apply and invest in their academic environment [3]. Also, student engagement envelops the disposition and energy that students maintain in a learning process, persistence in the face of obstacles, and the value given to learning [4]. A higher level of student engagement generates deep learning, active participation, and a positive response to challenges [4].

The interest in raising student engagement has led to the importance of its measurement [5,6]. So far, in Colombia, student engagement has been measured using self-report methods, such as questionnaires, in which students directly report their perceptions; sometimes, these methods can be subjective and divert attention [7]. Furthermore, according to the literature review, a different approach has not yet been implemented in this country.

Higher education has been affected by the pandemic of COVID-19, generating impacts on education systems. Institutions have had to adapt their methodologies to a virtual environment and implement new teaching and online assessment strategies [8]; this transition has received different terms like remote teaching, online learning, or distance education [9]. Some obstacles students face with this situation are an unstable internet connection, restricted access to technological tools, and inadequate space to take classes [9]. Lassoued et al. have classified these difficulties into four categories: personal (self-imposed), pedagogical, technical, and financial obstacles [10].

This paper presents an investigation conducted in Colombia to measure cognitive student engagement by measuring students' heart rate during the COVID-19. In the United States, Darnell D. K. and Krieg P. A. [7] implemented a similar method in a group of medical students; the researchers measured cognitive student engagement using wristwatch-style monitors, which detected and recorded the heart rate of the study subjects during lecture classes that applied active learning activities [7]. In India, Senthil and Lin performed a study using a wireless wearable sensor to collect the heart rate of university students for measuring engagement, comparing the heart rate in a state of rest against the heart rate during active learning activities in lecture classes [11].

The structure of this paper is as follows: first, we introduce a background of previous works focused on the diverse methods for measuring cognitive student engagement. Next, we present the methodology, divided into three phases: (1) research preparation, which describes the instruments and tools necessaries for began the data collection, (2) execution of the research. This phase includes the collection of three types of data, quantitative data of heart rate, qualitative data of annotations taken by the researchers during the development of each virtual lesson, and the qualitative data of the questionnaire, (3) and data treatment, in this phase we proceed to the cleaning and processing of data for validating five hypotheses, as well as the comparative analysis of the non-self-report method vs. the self-report method using a quadrant model. Then, we proceeded to the analysis and results of the three phases of the methodology. Finally, we reported our conclusions and future directions of research.

2. Background

Student engagement can be perceptible in the behavioral, cognitive, or affective dimensions [3]. Behavioral engagement occurs when students get involved in their learning, for example, selecting times or places to study [12]. Cognitive engagement happens when students make a mental effort on the topic they are learning; when students use deep or superficial study methods, they can identify the type of mental effort [12]. Finally, affective engagement refers to the students' emotions, such as interest, enjoyment, or frustration [12].

Cognitive engagement is defined as the level of psychological investment that students make in the learning environment [13]. It considers mental efforts focused on reflecting, implementing strategies, and willingness to carry out the requirements for understanding complex ideas and train themselves in skills with a high degree of difficulty to master the material and achieve new knowledge [14]. Literature also describes cognitive engagement as the preference from the student of performing challenging tasks and being self-regulated, a condition that leads to planning and monitoring their own learning [15]. Cognitive engagement contributes the flexibility in problem-solving and a positive attitude toward facing failures [14].

Cognitive engagement has two levels depending on the student's effort: superficial and active engagement [16]. Superficial engagement is a minimal effort in the learning like simple memorization, help-seeking, and effort-avoidant strategies; on the other hand, active engagement implied deep understanding and expertise in activities such as attention, planning, connecting, and monitoring the learning [14].

In the literature, the studies found have implemented different methods to measure student engagement evaluated from the perspective of the study subject, the student. These methods can be classified into two categories: self-report methods and non-self-report methods [17]. One of the characteristics of the self-report methods is that the study subjects report the data directly. The most used tools are questionnaires and interviews. On the other hand, the non-self-report methods use tools that allow collecting the data without consulting directly with the study subject, such as capturing a video during class, which can later be used to analyze the emotions that the person experiences [17]. It is important to highlight that various studies have been developed for measuring student engagement from a third-party agent perspective, like a professor, a psychologist, or a researcher; these studies include teacher ratings, observation, and many others. Our study implemented a method that determines the cognitive student engagement using the data measured directly from students. Consequently, the background is focused on giving examples of good practices implemented to determine student engagement examining the student point of view and behavior directly. In this sense, it isolates studies that assessed engagement from a third-party perspective only.

Different countries have used self-report methods; in most cases, the researchers used questionnaires or surveys created or adapted from previous investigations. Table 1 shows some studies that have used self-report methods.

Table 1. Self-report measurement methods.

Author	Study Title	Year of Publication			Measurement Method	Research Location	Level of Education	
		2010–2015	2015–2018	2018–2020	Method Detail	Country	School	College
Lei et al.	Engagement data of robotic students in a synchronous-hybrid course			x	Conducting a national survey of student engagement in a telepresence environment.	USA		x
Dekhane et al.	Mobile App Development to Increase Student Engagement and Problem Solving Skills			x	The students had to develop mobile games; with a questionnaire and a pre and post quiz, the researchers evaluated the variables.	USA		x
Awang-Hashim R. et al.	Malaysian University Student Learning Involvement Scale (MUSLIS): Validation of a Student Engagement Model			x	Measurement of student engagement through the MUSLIS questionnaire.	Malaysia		x
Alioon and Delialioğlu	The effect of authentic m- learning activities on student engagement and motivation		x		Measurement of student engagement and motivation through the NSSE- National Survey of Student Engagement and MSLQ- Motivated Strategies for Learning Questionnaire.	Turkey		x
Zhoc et al.	Higher Education Student Engagement Scale (HESES): Development and Psychometric Evidence			x	Development of a case study using the HESES-Higher Education Student Engagement Scale survey.	Hong Kong		x
Ma et al.	Initial Development Process of a Student Engagement Scale in Blended Learning Environment			x	Design of a survey based on the NSSE.	China		x
Balaam et al.	Exploring Affective Technologies for the Classroom with the Subtle Stone	x			By means of the "Subtle stone", a handheld orb, students inform what they feel when they press it.	United Kingdom	x	

In the USA, the researchers have used surveys and questionnaires to measure student engagement; they carried out activities different from the traditional class. In one case, Lei et al. applied the National Survey of Student Engagement in a lesson composed of six people; three of them were physically present, and the other three in telepresence [18]. In another study, the students developed a mobile game using a tool (GameSalad) created by the researchers, and then they measured student engagement using a questionnaire [19].

In Malaysia, Awang-Hashim R. et al. used a survey to evaluate the scale of participation in student learning at the University of Malaysia (MUSLIS) consisting of 24 items; later, they performed the data analysis using specific software [20]. In Turkey, Alion and Delialioğlu implemented m-learning material in a computer networks course to measure student engagement and motivation using the NSSE- National Survey of Student Engagement and the MSLQ- Motivated Strategies for Learning Questionnaire, m-learning is the method that allows students to acquire certain types of knowledge anywhere and anytime utilizing wireless technologies, here is important to state that e-learning materials are designed to be watched on computers, while the visualization of m-learning materials is better on tablets or smartphones [21].

In China, Zhoc et al. applied the HESES-Higher Education Student Engagement Scale survey, which allowed to evaluated five facets of student engagement: academic engagement, cognitive engagement, social engagement with classmates, social engagement with teachers, and affective engagement [22]. Another study applied a survey to measure student engagement, Ma J. et al. used a guide for the formulation of projects of innovation and technological development in a mixed environment, that is, the combination of face-to-face and virtual class; the survey evaluated three modules: behavioral, cognitive and emotional behavior [23].

Although questionnaires and surveys are the most common tools, some researchers have used other tools; for instance, in the United Kingdom, Balaam et al. developed a handheld orb named Subtle Stone for implementing an interactive method with the students, the study subjects, had to press the Subtle Stone to indicate the emotion that they were experimenting in a class [24].

Table 2 presents some studies that have used non-self-report methods in different countries. These methods usually collect and analyze data on the physiological characteristics of the study subjects, such as facial expressions, eye movement, heart rate, among others.

Some studies conducted in China, the USA, Canada, and Ireland analyze facial expressions to determine factors such as emotions or student engagement. In Hong Kong, Zeng H. et al. developed an analytical system that recognizes emotions through facial expressions, named EmotionCues; they use a camera and software that detects which emotion a student is expressing [17]. In another study conducted in China, Zhang H. et al. identified affective states such as boredom, confusion and engagement through a facial recognition system [6]. In the USA, Alkabbany et al. recorded a video during a reading of 10 to 15 min; this video focused on the angle of the posture of the face and the gaze, after, the researchers analyzed these characteristics to identify student engagement [25]; in another study also carried out in the USA, Whitehill J. et al. analyzed facial expressions using Machine Learning to determine the level of engagement [5]. In Canada, Sakulchit et al. identified the emotions that children experienced before, during and after taking a blood sample through facial expressions [26] and in the case of Ireland, using an application, Farrell et al. analyzed the subject's head posture to determine if the student was looking at the screen. Thus, they detected the person's emotional state, which finally allowed them to determine the student engagement [27].

Table 2. Non-self-report measurement methods.

Author	Article Title	Year of Publication			Method of Measurement	Research Location	Student Level of the Study Subject		
		2010–2015	2015–2018	2018–2020	Method Detail	Country	School	College	Other
Zeng H. et al.	EmotionCues: Emotion-Oriented Visual Summarization of Classroom Videos			x	Recognize emotions by analyzing facial videos.	China-Hong Kong	x	x	
Zhang H. et al.	An Novel End-to-end Network for Automatic Student Engagement Recognition			x	Face recognition with I3D- processing of 3D images or videos	China		x	
Alkabbany et al.	Measuring Student Engagement Level Using Facial Information			x	Detect facial actions (head posture, gaze).	USA		x	
Farrell et al.	Real Time Detection and Analysis of Facial Features to Measure Student Engagement with Learning Objects			x	An application identified the emotional state and the position of the head.	Ireland-Dublin			x
Whitehill J. et al.	The Faces of Engagement: Automatic Recognition of Student Engagement from Facial Expressions	x			They collect facial expressions and analyze them with machine learning (ML), a program that detects high or low interaction.	USA		x	
Sakulchit et al.	Evaluation of Digital Face Recognition Technology for Pain Assessment in Young Children			x	A program, API (Application Programing interface), analyzed images taken of the face and identified emotions of the study subjects.	Canada			x
Herpich F. et al.	Mobile Augmented Reality impact in Student Engagement: an Analysis of the Focused Attention dimension			x	They measured student brain signals to see the impact of augmented reality on student engagement.	Brazil		x	
Hayashi et al.	A Quantitative Study on Learner Engagement Evaluation: Integrated Analysis of Biosignals Including Pulse Wave and Eye Movements			x	Measuring eye movement with three electrodes built into glasses.	Japan	x	x	
Darnell and Krieg	Student engagement, assessed using heart rate, shows no reset following active learning sessions in lectures			x	They measured students' heart rate for identifying cognitive students engagement.	USA		x	

Other physiological characteristics analyzed in the studies presented include the study of brain signals and eye movement. In Brazil, Herpich F. et al. measured the signals emitted by the brains of students when interacting with educational technology [28]. In Japan, Hayashi et al. used lenses with integrated electrodes to analyze the user's eye movement and thus determine student engagement [29].

Finally, the heart rate is another physiological characteristic that researchers have used to measure student engagement [7,11]. In a study performed in the United States, Darnell D.K. and Krieg P.A. measured student engagement, specifically cognitive engagement, analyzing the students' heart rate. Researchers analyzed the heart rate behavior using wristwatch-style monitors during active learning activities [7].

Heart rate has been a tool widely used for identifying and monitoring emotions, attention, autonomic process and mental conditions [30–34]; heart rate is associated with the autonomic nervous system, which responds to a stimulus or resting states [33,35]. Emotions have three components: cognitive, physiological and behavior [34]. These components allow researchers to use the heart rate to measure more advanced factors like cognitive engagement [7,35]. Cognitive engagement can be determined through the heart rate since the exposure to stimulus or tasks activates neural mechanisms and, consequently, triggers an acceleration or deceleration in the heart rate, which has been an indicator of alertness and drowsiness [36–38].The advantages of using heart rate include it is non-invasive, easy, and cheap to get [33,34], experiments with heart rate are simple to set up and can be used in conjunction with other biometric measures like facial expressions and respiration [38,39]. The disadvantages associated with the heart rate are the conditions of the environment under which happen the data collection since they are challenging to eliminate, and also the response time to a stimulus is long; these two points generate more uncertainty [30,40,41].

Active learning activities allow student engagement to be improved and induced [42,43]. The concept of active learning refers to activities that induce students in a thinking process about the new information and connect it with experience or knowledge [42,44]. There is a great variety of activities that can be considered as active learning, such as discussion in small groups, peer activities, individual activities that required a mental effort, interactions, study cases, problem resolution, laboratories, quizzes, and games, all of them have to guarantee that students think effectively [42–46]. The advantages include that students feel more secure sharing their ideas in small groups, developing critical thinking, retaining new knowledge, developing communication and leadership skills, and feeling more motivated and interested [42,44–47].

In Colombia and Latin America, as some researchers stated, the investigations regarding education and student engagement have focused on the following topics: study habits and motivation for distance learning [48], academic dropout and its relationship with the student's conditions and the organizational context of the academic institution [49] the relationship between student engagement and academic performance determined through the academic average [50], and the relationship that emotional intelligence and happiness orientation have with student engagement [51].

Other research examines the opinion of students in schools regarding how they experience student engagement after conducting, recording, and analyzing surveys [52]. Bertel-Narváez M. P. et al. performed a literary review of education in Latin America, highlighting that the motivation of learning is a fundamental aspect of developing research in Latin America [1]. Studies and research developed in Colombia have used traditional methods such as interviews, surveys, questionnaires, and the corresponding analysis. However, in this country, the studies developed have not yet used more advanced methods, which measure student engagement with physiological characteristics.

In Colombia, the studies performed have not implemented a method that uses physiological characteristics to measure cognitive engagement. This work developed exploratory research, similarly to the analysis proposed in the United States by Darnell D.K. and Krieg P.A. [7] and adapted for this study during the pandemic. We used the heart rate for measuring cognitive student engagement. In some studies, the heart rate is also used for determining the emotional aspect [38], which means that emotional and cognitive engagement generate a variation in the heart rate. For that reason, a good way to differentiate these dimensions is through the activity or stimuli to which the student is exposed. In this study we selected active learning activities, which are focused on activating the cognitive engagement. For collecting data, the students used a heart rate band linked to a mobile application while participating in virtual lessons that contained active learning activities; every student collected her or his heart rate during four lessons; the total data collection took three months. This research took place at Escuela Colombiana de Ingeniería Julio Garavito in Bogotá, Colombia, in a sample of 20 students, from which we discarded four students after data cleaning.

3. Materials and Methods

This study adopted the methodology developed by Carrasco and cited by Viñan J.A. et al. [53]. It consists of three phases (Table 3); the first phase entails the research preparation, the second phase the execution of the research, and the third phase regards the data treatment. The objective of this study was to determine the cognitive student engagement using the heart rate as the primary measurement tool and using a questionnaire as a complementary tool.

Table 3. Research methodology.

METHODOLOGY		
Phase 1	**Phase 2**	**Phase 3**
Research Preparation	**Execution of the Research**	**Data Treatment**
• Active learning activities. • Participants. • Heart rate band preparation.	• Quantitative data (non-self-report method). • Qualitative data of annotations. • Qualitative data of the questionnaire (non-self-report method).	• Data Cleaning. • Data processing. • Non-self-report method vs. self-report method

The development and detail of each phase are described below.

3.1. Phase 1. Research Preparation

This phase consists of four activities to prepare instruments and tools necessary for began the data collection. Figure 1 details each activity.

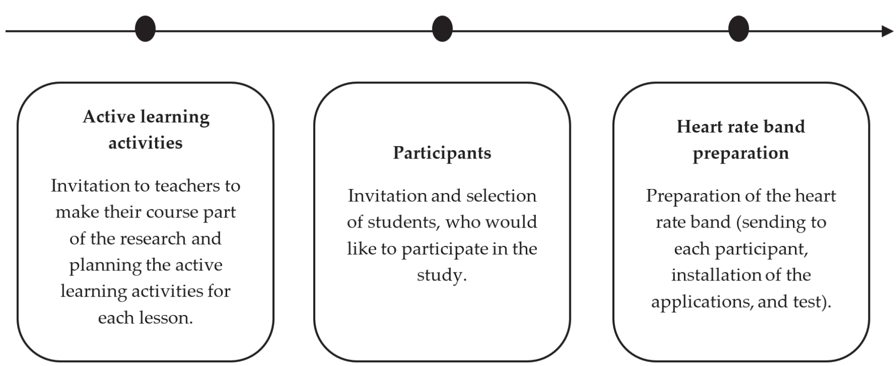


Figure 1. Research preparation.

Below, we explain the considerations made for developing each activity.

3.1.1. Active Learning Activities

All the activities planned with the professor include active learning activities performed in virtual lessons during the situation of COVID-19. In each lesson they developed the method Think Pair Share proposed by Kaddoura [54] and adapted it to this study, which we detail below:

1. Think: the professor asked a question, observation, case study, or video that induced the student to think. The student had to think and write down the answers.
2. Pair, partner or individual: students had to share the answer with one or two partners to analyze each one and reach a consensus on the best answer to the question asked. When performed individually, the student must perform an activity, as instructed by the professor.

3. Share: then, the professor asked each pair of classmates to share their answers with the whole lesson. However, in some cases, the students did not share their answers but gave the solution to the professor directly.

3.1.2. Participants

The following characteristics were important for selecting the participants:

1. They must be legal age.
2. They must have a compatible cell phone.
3. They must live in Bogotá or neighboring cities.
4. Students must participate voluntarily.

In this study, we measured the heart rate of 20 students, from which we discarded four students after cleaning the data. We defined the number of participants after reviewing the sample used in similar studies carrying out non-self-report methods. (Table 4).

Ethical considerations were taken into account following the guideline given by Escuela Colombiana de Ingeniería Julio Garavito, the area of *Política de Tratamiento de Datos* (Data Processing Policy Department) reviewed and approved the document of data treatment used in this study, that posteriorly was signed by each student. The following ethical guidelines were implemented in the research:

1. We preserved participants' anonymity.
2. Each participant's personal data was used only for the objectives of the research and we obtained the students' permission for using these data, keeping the real name confidential.
3. The activities developed in each lesson avoided exposing participants to mental stress.
4. We informed participants about the correct use of heart rate bands, a tool that is not dangerous or risky.
5. We gave each participant an informed consent with the corresponding information about how the research will be developed.

Table 4. Number of participants in studies of non-self-report methods.

Study	Number of Participants
EmotionCues: Emotion-Oriented Visual Summarization of Classroom Videos	Case 1: 15 children Case 2: 13 students
Multimodal affect recognition in learning environments	8 children
Measuring Student Engagement Level Using Facial Information	14 students
Mobile Augmented Reality Impact in Student Engagement: an Analysis of the Focused Attention Dimension	5 students
A Quantitative Study on Learner Engagement Evaluation: Integrated Analysis of Biosignals Including Pulse Wave and Eye Movements	Case 1: 6 students Case 2: 10 students
Artificial neural networks-based classification of emotions using wristband heart rate monitor data	12 individuals

3.1.3. Heart Rate Band Preparation

This investigation used heart rate bands, which can measure the heart rate with a frequency of one minute; these have a Photoplethysmography (PPG) heart rate sensor, which applies low-intensity infrared (IR) light on the skin. An optical sensor measures light reflection, which changes depending on the blood flow through the illuminated spot. Since blood flow changes during a heartbeat, it is possible to measure the heart rate.

The considerations for preparing the heart rate band were the following:

1. Each course was composed of 5 or 4 students who participated in the research.
2. The heart rate band must be delivered to each participant.
3. Each participant must install the heart rate recording app on their cell phone.
4. To verify the correct functioning of the heart rate band, the students made a preliminary test.

3.2. Phase 2. Execution of the Research

We divided the execution of the investigation into three categories, which composed the data collected: quantitative data, qualitative data of annotations, and qualitative data of the questionnaire. The quantitative data (obtained through a non-self-report method) refers to data of heart rate collected through the heart rate app during the development of each virtual lesson. The annotations of qualitative data refer to the data collected by the researchers while attending each lesson and taking note of the activities carried out and their respective time. Finally, the qualitative data refers to the questionnaire (self-report method) that each student filled out at the end of each lesson, which evaluated the cognitive student engagement. Figure 2 presents each data category collected in this phase. Below, we explain the conditions required in each data category.

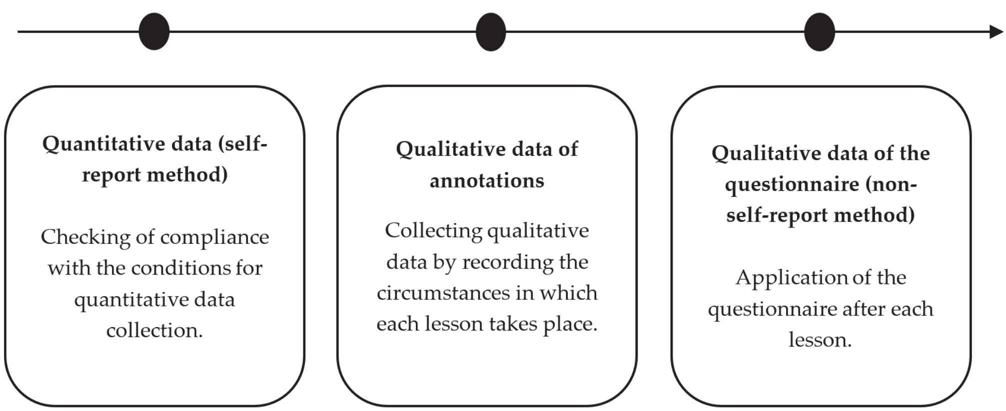


Figure 2. Execution of the investigation.

3.2.1. Quantitative Data (Non-Self-Report Method)

The conditions verified in the quantitative data collection were the following:

1. The students must wear the heart rate band five minutes before starting the virtual lesson.
2. The students must activate and connect the Bluetooth between the cell phone and the heart rate band.
3. Participants must follow the instruction for measuring the baseline heart rate; it refers to each participant's heart rate during a rest state.
4. Participants must connect to the lesson on time.
5. The participants agreed to send the data after finishing each lesson.

3.2.2. Qualitative Data of Annotations

To collect annotations qualitative data, the researchers considered the following aspects:

1. Identify when the virtual lesson started, splitting the greeting from the main topic.
2. Recognize when active learning activities started and finished.
3. Take note of the moment when participants intervened.

4. Identify activities that can generate some emotions in the participant not planned by the research.
5. Record the exact time when the virtual lesson ends.

3.2.3. Qualitative Data of the Questionnaire (Self-Report Method)

A questionnaire is a self-report tool to measure student cognitive engagement. However, using this method will allow us to compare the report made by the students and the results obtained with the measurement of heart rate and helping to identify factors that may affect the student's heart rate behavior during lessons.

As described above, the participants filled out a questionnaire after completing each virtual lesson; the main objective is to identify the students' cognitive engagement reported, allowing us to compare the participants' answers and the heart rate behavior.

To identify student cognitive engagement in different contexts, the queries in the questionnaire were selected following three studies, which applied questions focused on measuring student engagement. For the design of the questionnaire for this study, we selected questions focused on measuring student cognitive engagement.

- Study one: Exploring Factors and Indicators for Measuring Students' Sustainable Engagement in e-Learning [55]

In this research through a questionnaire, they analyzed six factors in student engagement in the e-learning environment: factor 1. psychological motivation, factor 2. peer collaboration, factor 3. cognitive problem solving, factor 4. interactions with instructors, factor 5. community support, and factor 6. learning management. For our study, we selected and adapted factor 3 (Cognitive problem solving).

- Study two:Examining engagement in context using experience-sampling method with mobile technology [12]

The following measures were applied in the above survey: study time, study location, reasons for study, behavioral engagement, cognitive engagement, self-efficacy, academic motivation, and prior academic achievement. For our questionnaire, we adapted the measures used in cognitive engagement.

- Study three:Initial Development Process of a Student Engagement Scale in Blended Learning Environment [23]

In this study, Ma J. et al. designed and constructed a student engagement scale framework in higher education during blended learning environment. They evaluated the three dimensions of student engagement (cognitive, behavioral, and emotional). For our questionnaire, we selected the items used in cognitive student engagement.

Table 5 presents the format used in the questionnaire, the self-report method used in this study, which the students filled after finishing each virtual lesson. We used a Likert scale from 1 to 5 (1: totally disagree and 5: totally agree) to rate each item. The interpretation given to this scale related to cognitive student engagement was the following: An answer of 1 indicated a low cognitive engagement, an answer of 5 indicated a high cognitive engagement, and an answer of 3 was taken as a neutral position regarding the question.

Table 5. Self-report method the questionnaire format.

	Self-Report Method: The Questionnaire
1	I can deduce new interpretations and ideas from the knowledge I have learned in today's lesson.
2	I can deeply analyze thoughts, experiences, and theories about the knowledge I have learned in today's lesson.
3	I can judge the value of information related to the knowledge learned in today's lesson.
4	I tried to approach the topic of today's lesson with a new perspective.
5	In today's lesson, I tried to learn new material by mentally associating new ideas with similar ideas that I already knew.
6	While learning new concepts in today's lesson, I tried to think of practical applications.
7	I made sure I understood the material I studied in today's lesson. (I am aware of what material I understood or did not understand).
8	In today's lesson, I tried to memorize the answers to the questions in the study guides for the tests.
9	To understand what the technical terms meant, I memorized the definitions provided in the texts or today's lesson notes. (I'm trying to memorize the vocabulary for this lesson).
10	I tried to write down exactly what my instructor said during the lectures in today's lesson.
11	I used what I have learned to solve practical problems in today's lesson.
12	I make connections between the things that I have learned in today's lesson.
13	I tend to apply the knowledge I have learned in lesson to real problems or new situations.
14	When I learned new material, I summarized it in my own words.
15	I mentally combined different pieces of information from the course materials in an order that made sense to me.
16	In doing the readings for the lesson, I tried to figure out what part of the reading would be on the test. (I'm studying the course materials to get the information needed for the test).
17	I study ideas exactly as they are expressed in lesson or in my readings.
18	Establish a learning plan to be able to direct my activities in the lessons.
19	I have clear learning objectives at each stage of the course.
20	I make good use of my study time for this course.
21	I connect what I have learned in this course with another subject.
22	I ask myself questions and think about a topic when I read learning materials from the course.
23	I use what I have learned from homework and tests to promote my next learning step.
24	I think about what I have already learned to understand a new course topic.

3.3. Phase 3. Data Treatment

This phase included three activities that allowed us to perform the data treatment (Figure 3). The first consisted of cleaning data, the second entailed data processing, and the last compared the non-self-report method with the self-report method.

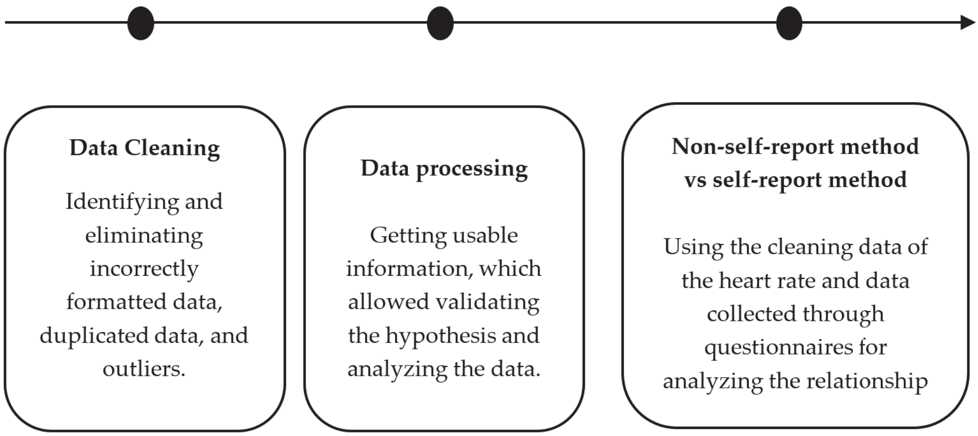


Figure 3. Data treatment.

Below, we present the requirements considered in each activity.

3.3.1. Data Cleaning

First, we organized the data, classifying it into three categories: participants, lessons, and activities. The criteria used for cleaning the data were the following:

1. Transform the date and time data to a single format.
2. All participants must have data from at least three virtual lessons; otherwise, it is discarded.
3. We normalized the data and filtered those that were greater than three standard deviations (3SD). Then, we compared the total data with the resulting data after applying the criterion of 3SD and decided to delete data that removed less than 15% of the total data. We considered this criterion and percentage under the following categories: each participant in each lesson.
4. We cleaned the data that did not have modifications in numeral 3 (the normalization with 3SD). We analyzed each participant's activity in each lesson and eliminated the atypical data.

3.3.2. Data Processing

Intending to have a general view of data, we applied a clustering of all data. After, we processed and organized the data to verify the following hypothesis:

Hypothesis 1. *The heart rate may increase during an active learning activity or rest and then return to the mean level.*

Hypothesis 2. *The heart rate decreases from the beginning to the end of the lesson.*

Hypothesis 3. *The drop in heart rate is biphasic, further decreasing during the early stages of the lesson.*

Hypothesis 4. *The heart rate decreases at the beginning and increases at the end of the lesson.*

Hypothesis 5. *The heart rate decreases in passive learning activities, such as watching a video.*

For each hypothesis, we developed the following data processing:

For Hypothesis 1 we selected and labeled active learning activities in each lesson for each participant; we also labeled activities before and after each one, considering only those corresponding to theoretical explanation, beginning of a lesson, or end of a lesson. Subsequently, we plotted the mean heart rate before, after, and during each active learning activity using a data science platform.

For Hypothesis 2 for each participant in each lesson, we plotted the heart rate against time. We applied linear regression with the aim of identifying if the heart rate trend decreased or increased.

For Hypothesis 3 to analyze the biphasic behavior, we divided the data into two sections. We showed the first 20 min of each lesson against the next 70 min. We plotted the heart rate against time in each section; finally, we applied linear regression.

For Hypothesis 4 we selected the first and last minutes of each lesson, ranging between 2 to 10 min, to analyze the behavior at the beginning and end of each lesson. The time range is variable since each lesson started or finished the topic and activities at a different time. Then, we graphed each time range and applied linear regression to identify the behavior at the beginning and end of each lesson.

For Hypothesis 5 we performed the same processing of the first hypothesis, with the difference that at this phase, we selected and labeled the passive learning activities.

3.3.3. Non-Self-Report Method vs. Self-Report Method

In the research developed by Nonis et al. the results suggested to combine two types of methods for measuring engagement, they proposed to combine the User Engagement Scale questionnaire with an additional physiological measurement (a facial expression recognition system) [56]. In this section, for analyzing the behavior of quantitative data of the heart rate (non-self-report method) against qualitative data of the questionnaire (self-report method), we performed a quadrant model to show the variation of these two data types (Figure 4).

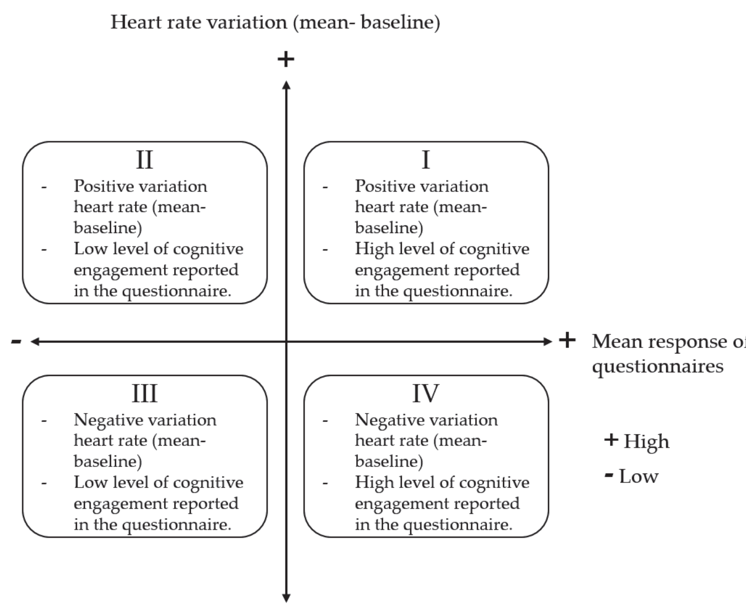


Figure 4. Quadrant model of heart rate variation vs. mean response of questionnaires.

For quantitative data, we calculated the mean heart rate for each participant and subtracted the heart rate baseline to identify whether there was a positive or negative variation. For the qualitative data of the questionnaire, we calculated the mean response to the questions of questionnaires filled out in each lesson; each question indicates a high or low level of student cognitive engagement, thus if the student's mean response was below 3, it indicated a low engagement, and if it was above 3 it indicated a high cognitive engagement. Quadrant I represented a positive variation of the heart rate and a high level of cognitive engagement reported in the questionnaire by students, quadrant II indicated a positive variation of the heart rate and a low level of cognitive engagement reported in the questionnaire by students, quadrant III represented a negative variation of the heart rate and a low level of cognitive engagement reported in the questionnaire by students. Finally, quadrant IV indicated a negative variation of the heart rate and a high level of cognitive engagement reported in the questionnaire by students.

4. Analysis and Results

4.1. Phase 1. Research Preparation

Four groups of five students of the subject Human Talent Management participated in the research, led by two professors. The activities planned and developed in each lesson followed the method: *Think Pair Share* [54]. Also, other activities considered were online quizzes, group activities, activities in pairs and individual activities. The lessons were in remote teaching using a virtual platform for communication and online programs for the development of the activities.

The 20 participants belong to the industrial engineering program; Figure 5 presents the characteristics associated with them:

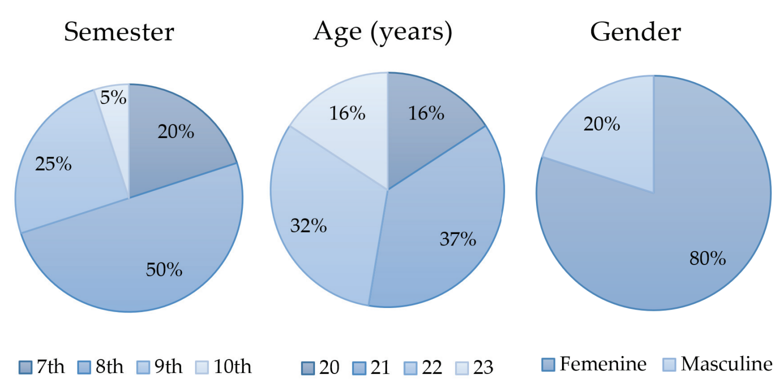


Figure 5. Information participants.

The participants followed the instruction and conditions for the preparation of the heart rate band. Due to compatibility issues and connection issues, we discarded the data from participant 0 and 19.

4.2. Phase 2. Execution of the Research

Using the heart rate band, we measured the heart rate of each participant during the virtual lessons. We took note of different conditions that could alter the student's heart rate and the moment in which the professor developed active learning activities. Also, we collected the baseline heart rate of each participant (Table 6). In this study, we used the baseline for identifying the heart rate response to activities developed in each lesson; the difference between the baseline and the heart rate could be negative or positive depending on the engagement of each participant. The behavior of the heart rate compared with the baseline is the response to a stimulus, according to the study of Siennicka et al. [33]. We do not show the baseline heart rate of four participants (participant 0, participant 9, participant

18, and participant 19) in Table 6, due to the reasons explained above. In the cleaning data section, we will explain the reason why participants 9 and 18 were also discarded.

On the other hand, we applied the questionnaire described in the methodology, we used a Likert scale to rate each item, as follows: (1) totally disagree, (2) in disagreement, (3) partially agree, (4) I agree, and (5) totally agree. In Table 6, also we show the mean according to the response given by participants in the questionnaire.

Table 6. Mean response in the questionnaire and baseline heart rate for each participant.

Participant	1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	17
Baseline Heart Rate (bpm)	77.2	74.8	70.3	73.3	72.9	77.8	76.9	74.8	78.9	86.0	77.3	71.2	70.7	80.4	75.0	75.0
Mean Response in the Questionnaire	3.95	2.72	2.50	4.68	3.83	3.17	3.58	3.42	4.26	3.13	4.42	3.51	3.10	3.94	3.83	3.99

4.3. Phase 3. Data Treatment

4.3.1. Data Cleaning

Applying the criteria described in the methodology, we transformed the data into the same time format requested by the data science platform; we used this tool to perform some steps of data cleaning and data processing. We discarded two participants because they had data from fewer than three lessons (participant 9 and participant 18). Then, we applied the normalization criterion to the participants and lessons shown in Table 7. Finally, we analyzed the behavior of each participant in each activity and eliminated the outliers.

Table 7. Data normalized and discarded under the criteria of 3SD.

	Part 1	**Part 2**	**Part 3**	**Part 4**	**Part 5**	**Part 6**	**Part 7**	**Part 8**	**Part 10**	**Part 11**	**Part 12**	**Part 13**	**Part 14**	**Part 15**	**Part 16**	**Part 17**
Lesson 1	X	X		X	X		X									
Lesson 2		X					X			X		X	X	X		
Lesson 3						X							X			
Lesson 4			X	X	X						X	X	X			X

4.3.2. Data Processing

Before analyzing each hypothesis, we clustered all the data dividing each group to identify the general and predominant behavior of the heart rate. First, we applied the elbow method. We obtained that, in all groups, the best value of K was seven, and then we proceed to the data clustering.

Table 8 shows the cluster for each group, the number of items classified in each cluster, and the centroid based on the heart rate. We presented the table organized in descending order according to the centroid, and we highlight the two clusters with the most items.

The clusters highlighted indicate the predominant behavior of the heart rate in each group, varying from between 66 and 77, except for Group 1, which is between 70 and 82. This behavior shows that the predominant data was not in the extremes, which contained the minority of items.

Figure 6 presents the distribution of items in each cluster in the four groups graphically. In each graph, the behavior of each cluster is similar in each lesson. Although each participant had a different baseline, it did not alter the classification in the clustering. For this reason, we were able to perform a general analysis of data. We conducted an ANOVA test afterwards; for better data treatment, we conducted additional analysis by categorizing the heart rate according to participants, lessons, and activities.

Table 8. Number of items and centroid of each cluster.

GROUP 1			GROUP 2			GROUP 3			GROUP 4		
Cluster	Number of Items	Centroid HR (bpm)	Cluster	Number of Items	Centroid HR (bpm)	Cluster	Number of Items	Centroid HR (bpm)	Cluster	Number of Items	Centroid HR (bpm)
4	99	60.2	1	218	63.1	6	149	58.1	1	86	60.7
3	247	66.3	**5**	**416**	**69.9**	**0**	**402**	**66.8**	**3**	**243**	**69**
6	**428**	**70.9**	**0**	**341**	**76.4**	**4**	**429**	**74.9**	**0**	**262**	**75.8**
1	340	75.9	3	241	82.2	2	306	82.9	2	197	81.3
0	**360**	**81.6**	6	158	88.5	1	310	91.7	6	135	87.5
5	337	87.8	4	69	96	3	217	99.2	4	81	94.9
2	200	95.5	2	18	107.9	5	59	109.4	5	27	105.6

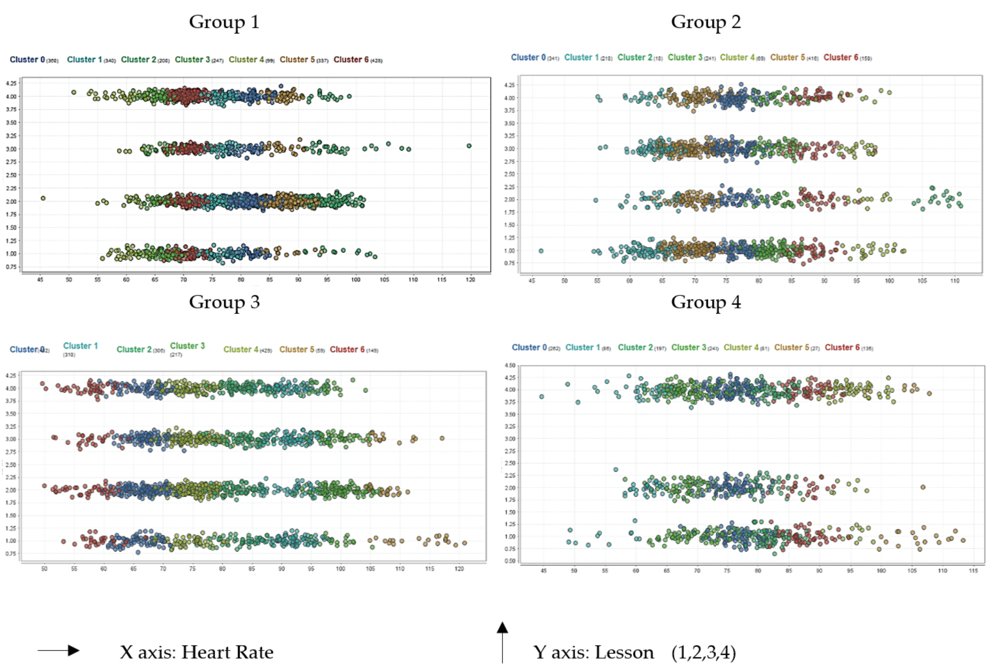


Figure 6. Distribution of items in each cluster for the four groups.

For each hypothesis, after applying the data processing we obtained the following results:

- Hypothesis 1.

After selecting and labeling the mean heart rate (MHR) of each active learning activity with its activities before and after, we obtained four behaviors, which described the mean heart rate before, during, and after an active learning activity. We show an example of each behavior in Figure 7.

- Behavior one (low MHR-high MHR-low MHR): The behavior of the mean heart rate before and after the active learning activity is lower than the behavior during this activity. This behavior coincides with H1.
- Behavior two (high MHR-low MHR-high MHR): The behavior of the mean heart rate before and after the active learning activity is higher than the behavior during this activity. This behavior is contrary to H1.

- Behavior three (low MHR-high MHR-high MHR): The behavior of the mean heart rate before the active learning activity is lower than the behavior during this activity, while the behavior of the mean heart rate after this activity is higher than the active learning activity. This behavior presents an increase during an active learning activity as described by H1, but then, after the MHR, it continues to increase.
- Behavior four (high MHR-low MHR-low MHR): The behavior of the mean heart rate before the active learning activity is higher in comparison with the behavior during this activity, while the behavior of the mean heart rate after this activity is lower than the active learning activity. This behavior does not correspond with H1.

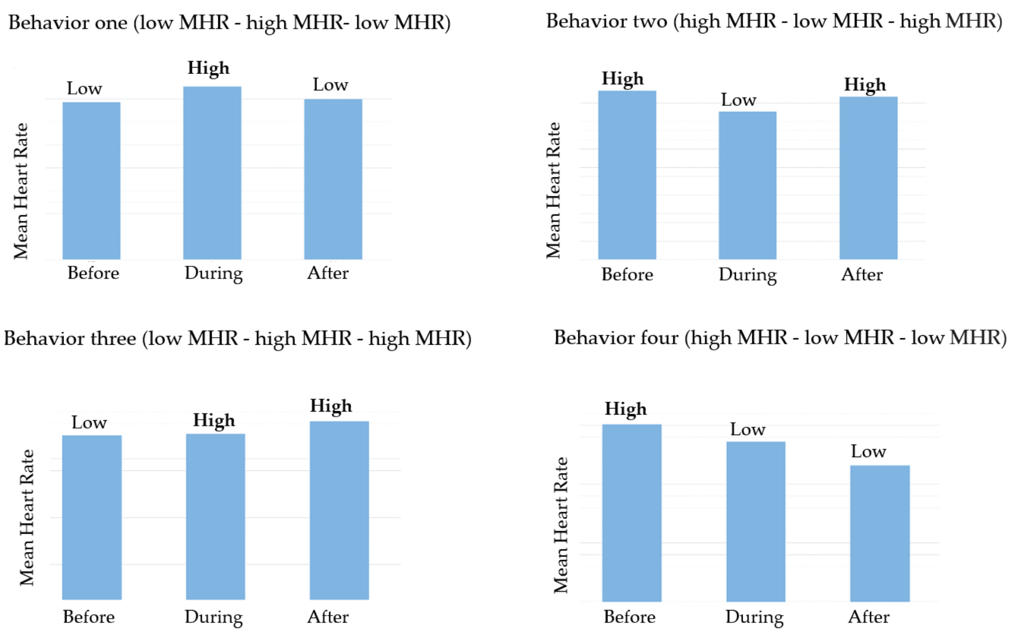


Figure 7. The behavior of the mean heart rate before, after, and during an active learning activity.

For this analysis, we examined 58 active learning activities; Table 9 presents the results obtained in each behavior. It is important to note that the activities that we considered before an active learning activity were theoretical explanation, the beginning of a lesson, or instruction given by the professor. If the activity is theoretical explanation, the student could be in a rest state; thus, the heart rate may be lower than an active learning activity. On the other hand, if the activity is the beginning of a lesson, the heart rate may vary due to external factors depending on the activity that each student was doing before starting the lesson. Finally, if the previous activity is the instruction given by a professor, the student can be attentive without doing any activity that involves deep learning. These three activities have in common that they are not active or passive learning activities; for this reason, they can be grouped for the analysis of H1.

It is important to note that the activities that we considered before an active learning activity was either theoretical explanation, the beginning of a lesson, or an instruction given by the professor. If the activity is *theoretical explanation*, the student could be in a rest state; thus, the heart rate may be lower than an active learning activity. On the other hand, if the activity is *the beginning of a lesson*, the heart rate may vary due to external factors depending on the activity that each student was doing before starting the lesson. Finally, if the previous activity is *an instruction given by a professor*, the student can be attentive without doing any activity that involves deep learning. These three activities have in common that they are not active or passive learning activities; for this reason, they can be grouped for the analysis of H1.

Table 9. Number of active learning activities according to each behavior.

Behavior	Number of Active Learning Activities	Percentage
Behavior one (low MHR-high MHR-low MHR)	24	41.40%
Behavior two (high MHR-low MHR-high MHR)	13	22.40%
Behavior three (low MHR-high MHR-high MHR)	7	12.10%
Behavior four (high MHR-low MHR-low MHR)	14	24.10%
	58	100%

Behavior one (low MHR - high MHR- low MHR) coincides with H1. As shown in Table 9, 41.4% of the activities presented this behavior, which has the highest percentage compared to the other behaviors. On the other hand, behavior two (High MHR-low MHR-high MHR) represents the contrary situation to H1. The main reason why this situation could happen was the activity: interaction between students and professor, which could generate an immersive state in the students, causing a decrease in the heart rate.

Behavior three (low MHR - high MHR - high MHR) is not common and it is consistent with the results of the study of Darnell D.K. and Krieg P.A., who stated that after an active learning activity the heart rate did not continue to increase but returned to the behavior it had before this activity [7]. Finally, behavior four (high MHR - low MHR - low MHR) represents a resting, due to the heart rate decreased during an active learning activity. This result indicates that the participant did not need to make a significant cognitive effort because of previous knowledge and clarity regarding the discussed topic.

Since MHR behavior during an active learning activity is the most relevant factor in this study, we applied an ANOVA (Table 10) with $p < 0.05$ between two variables: the baseline heart rate and the mean heart rate during active learning activities. If the value F is greater than the critical value for F, it implies that the means of the two variables are significantly different.

Table 10. ANOVA-Active learning activities.

Active Learning Activity	F	Critical Value for F	Had Heart Rates Statistically Significant Differences?
Quiz	0.181	3.890	No
Discussion of a topic in group or pair	37.492	3.865	Yes
Share responses to an activity	11.834	3.910	Yes
Individual activity	24.341	3.857	Yes
Interaction between students and professor	6.801	3.860	Yes

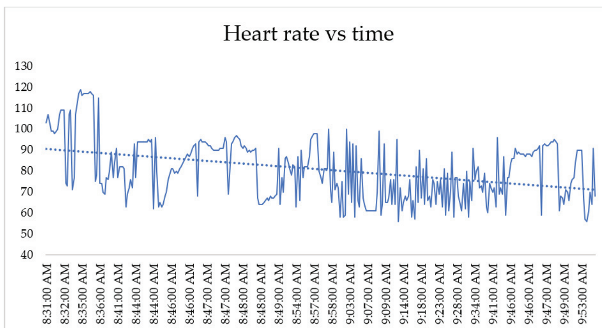
Except for the quiz, all active learning activities had statistically significant differences in heart rate when participants developed these activities compared to each participant's baseline. The case of the quiz had a particularity, a set time was given to finish it, but some participants could finish earlier, so they could carry out other activities in the remaining time, such as taking a break; this condition could be the main reason why in the ANOVA this activity was not statistically significant.

Overall, we partially accept H1 adapting the initial approach to the following: the mean heart rate has a significant variation with an active learning activity, indicating cognitive engagement in the student experiment. This approach is also supported by the statement made by Mayson and Oleksy, "heart rate is useful in the detection of cognitive attention because it changes when cognitive attention is directed to a particular situation" [57].

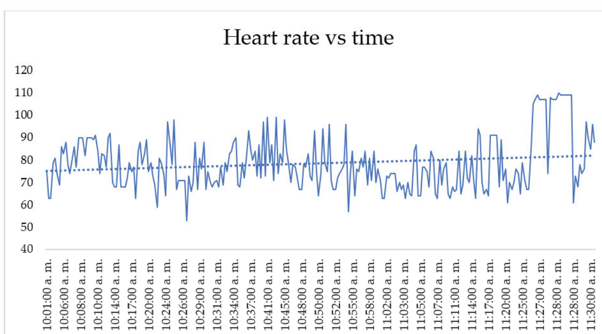
- Hypothesis 2.

For this hypothesis, we graphically represented the heart rate values of each virtual lesson and applied a linear regression. In each graph it was possible to identify if the heart rate trend (HRT) increased or decreased during each lesson (Figure 8). We were able to identify two behaviors:

- Behaviour one (HRT decreased): The heart rate decreased from the beginning to the end of the lesson. It corresponds with H2.
- Behaviour two (HRT increased): The heart rate increased from the beginning to the end of the lesson. It is contrary to H2.



Behavior 1: The heart rate decreased



Behavior 2: The heart rate increased

Figure 8. Heart rate trend decreased or increased from the beginning to the end of the lesson.

In total, we evaluated 15 lessons; Table 11 shows the summary of each behavior.

The expected trend of the heart rate was not evident in all lessons; although in the study of Darnell D. K. and Krieg P. A., the authors found a decreasing trend among all the lecture lessons analyzed [7], the results we obtained in virtual lessons suggest that the trend in heart rate from the beginning to the end of the lesson may depend on external or internal factors. The external factors are related to connectivity problems or the environment in which the participant takes the lesson; the internal factors are related to the moment in which the students develop active learning activities and their duration, either at the beginning, in the middle or the end of the class. For these results, we partially accept H2 with the following adaptation: the trend of the heart rate from the beginning to the end of the lesson depends on external and internal factors, the internal factors are linked with the active learning activities, mainly the duration and the moment in the lesson that the professor develops them.

Table 11. Summary of heart rate trend.

Heart Rate Trend	Number of Lessons	Percentage
Behavior one (HRT decreased)	9	60%
Behavior two (HRT increased)	6	40%
	15	100%

- Hypothesis 3.

For this hypothesis, we selected the virtual lessons that presented a decrease in the heart rate trend according to H2; after that, we divided the data into two sections—the first 20 min of each lesson against the next 70 min. Figure 9 shows an example of a lesson divided into two sections with its linear regression.

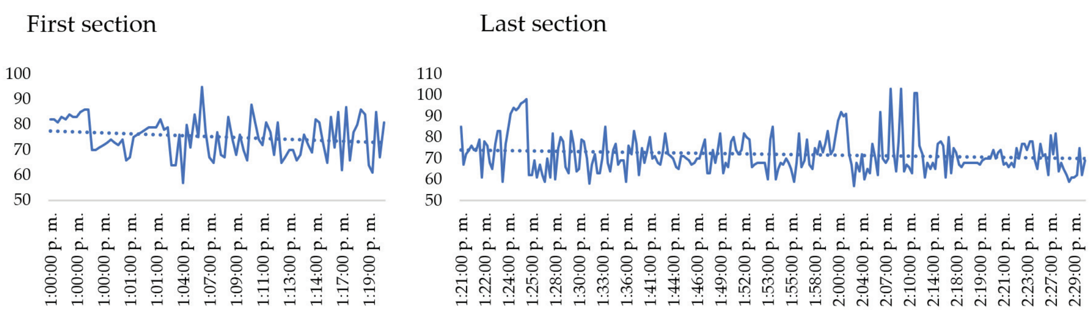


Figure 9. Behavior biphasic during a lesson.

A negative slope means a decrease in the heart rate trend, in the Table 12 we show the slope of each section of the lessons analyzed and its correspondence with H3; for the correspondence, we evaluated if the first and last section had a negative heart rate trend and if the slope in the first section was minor to the slope in the last section, which indicated a further decrease during the early stages of the lesson.

Table 12. The trend of first and last section in each lesson.

Lesson	Slope			Correspondence with H3
	General	First Section	Last Section	
1	−0.019	−0.053	−0.017	Yes
2	−0.0055	0.028	−0.0098	No
3	−0.0027	−0.0579	0.0132	No
4	−0.0047	−0.0483	−0.0086	Yes
5	−0.0046	0.0181	0.0112	No
6	−0.058	−0.1459	0.0143	No
7	−0.0157	−0.0563	−0.0085	Yes
8	−0.0051	−0.0666	−0.0228	Yes
9	−0.011	0.3008	−0.0115	No

We show the summary of correspondence with H3 of the 15 lessons in Table 13, which displays the nine lessons analyzed in Table 12 and the six lessons that had an increase in H2 and which do not correspond with H3 (Table 11). H3 has a strong dependency on H2 since it requires a drop in heart rate throughout the lesson, a condition that was not met in all lessons; for this reason, we included the six lessons for the analysis in the correspondence with H3 (Table 11). Since 73% of the lesson did not show the behavior expected, we reject H3.

Table 13. Correspondence with hypothesis 3.

Correspondence with Hypothesis 3	Number of Lessons	Percentage
Yes	4	27%
No	11	73%
	15	100%

- Hypothesis 4.

We present the behavior that occurred at the beginning and end of each virtual lesson in Table 14. We also show the correspondence with H4.

Table 14. Behavior of the heart rate at the beginning and end of each lesson.

Behavior of the Heart Rate in Each Lesson	Slope Beginning	Slope End	Correspondence with Hypothesis 4
Decreases at the beginning and decreases faster at the end	−0.2088	−0.5779	No
Decreases at the beginning and increases at the end	−0.2096	0.5495	Yes
Decreases at the beginning and decreases faster at the end	−0.1698	−0.2714	No
Increases at the beginning and increases slower at the end	0.2757	0.1136	No
Increases at the beginning and decreases at the end	0.2085	−0.6794	No
Increases at the beginning and decreases at the end	0.8469	−0.8181	No
Decreases at the beginning and increases at the end	−0.1623	0.3963	Yes
Increases at the beginning and decreases at the end	0.1784	−0.2863	No
Decreases at the beginning and decreases faster at the end	−0.1795	−0.4427	No
Decreases at the beginning and decreases faster at the end	−0.1799	−0.9221	No
Increases at the beginning and decreases at the end	0.0139	−0.0167	No
Increases at the beginning and decreases at the end	0.0699	−1.5297	No
Decreases at the beginning and increases at the end	−0.0914	0.9825	Yes
Increases at the beginning and increases slower at the end	1.4176	0.6167	No
Increases at the beginning and increases slower at the end	0.8603	0.1399	No

The heart rate decreased at the beginning and increased at the end in 20% of lessons; for that reason, we reject H4.

We analyzed each heart rate behavior presented at the beginning and the end of the lessons (Table 15). The percentage for each behavior is similar between them, so it is possible to conclude that there is no standard pattern. In another study, the researchers verified a standard heart rate behavior during various lessons. However, they evaluated it during lecture classes and the students were physically present [7]. In our study, the lessons were virtual, with different factors that could influence the heart rate of the participants, like connection problems, and the influence of external factors according to the place where they take the lessons that could affect their level of attention, etc.

Table 15. Summary of each behavior at the beginning and the end of lessons.

Behavior of the Heart Rate	Number of Lessons	Percentage
Decreases at the beginning and increases at the end	3	20%
Decreases at the beginning and decreases faster at the end	4	27%
Increases at the beginning and decreases at the end	5	33%
Increases at the beginning and increases slower at the end	3	20%
	15	100%

- Hypothesis 5.

In this hypothesis, we applied a process similar to H1, considering the activities before, during, and after passive learning activities, in this case, a video projection. We obtained four behaviors, which described the mean heart rate (MHR) before, during, and after a passive learning activity.

- Behavior one (high MHR-low MHR-high MHR): the behavior of the mean heart rate before and after the passive learning activity is higher than the behavior during this activity. It corresponds with H5.
- Behavior two (high MHR-low MHR-low MHR): the behavior of the mean heart rate before the passive learning activity is higher in comparison with the behavior during this activity, while the behavior of the mean heart rate after this activity is lower than the passive learning activity. It corresponds with H5.
- Behavior three (low MHR-high MHR-high MHR): the behavior of the mean heart rate before the passive learning activity is lower compared to the behavior during this activity, while the behavior of the mean heart rate after this activity is higher than that of this the passive learning activity. It is contrary to H5.
- Behavior four (low MHR-high MHR-low MHR): the behavior of the mean heart rate before and after the passive learning activity is lower compared to the behavior during this activity. It is contrary to H5.

However, this hypothesis focuses on the behavior before and during a passive learning activity since that the first two behaviors represent a decrease and the last two an increase in heart rate during a passive learning activity. Table 16 presents a summary of the combination of these behaviors and their percentage.

Table 16. Correspondence with hypothesis 5.

Behavior	Number of Activities	Low/High	Percentage	Correspondence with Hypothesis 5
Behavior one (high MHR-low MHR-high MHR)	2	5	45%	Yes
Behavior two (high MHR-low MHR-low MHR)	3			
Behavior three (low MHR-high MHR-high MHR)	1	6	55%	No
Behavior four (low MHR-high MHR-low MHR)	5			
	11	11	100%	

The increased in the heart rate could occur because, before each video, professors instructed their students to pay attention and to make an activity after the video projection, which could prevent students from entering a resting state during the video projection. These results allow us to rebuild H5 with this approach: if students are previously advised that they will have to develop an activity after a passive learning activity (such as a video projection), their heart rate could increase and, consequently, so could their cognitive engagement. Overall, we partially accept H5 with the exposed approach.

We present a summary of the results of each hypothesis in Table 17.

Table 17. Hypotheses results.

Hypotheses Results	
Hypothesis	**Results**
Hypothesis 1 (H1)	We partially accepted H1 adapting the initial approach to the following: the mean heart rate has a significant variation with an active learning activity, indicating students experiment with cognitive engagement.
Hypothesis 2 (H2)	We partially accepted H2 with the following adaptation: The trend of the heart rate from the beginning to the end of the lesson depends on external and internal factors. The internal factors are linked with the active learning activities, mainly the duration and the moment in the lesson that the professor develops them.
Hypothesis 3 (H3)	The drop in heart rate was biphasic, with a further decrease during the early stages of the lesson in only 27% of cases. For that reason, we rejected H3.
Hypothesis 4 (H4)	The heart rate decreased at the beginning and increased at the end in 20% of lessons; for that reason, we rejected H4.
Hypothesis 5 (H5)	We partially accepted H5 with the following adaptaion: if students are previously advised that they will have to develop an activity after a passive learning activity (such as a video projection), their heart rate could increase and consequently, so could their cognitive engagement.

4.3.3. Non-Self-Report Method vs. Self-Report Method

In this section, we constructed a quadrant model for relating the non-self-report method with the self-reported method. We analyzed two scenarios, the first related the mean responses of the questionnaire with the general heart rate variation (HRV). In this last variable, we took the data for the heart rate during whole lessons, that is, all activities. In the second scenario, we analyzed the same relationship of variables but in the second variable, we only considered the HRV of active learning activities (ALA).

- First scenario: General heart rate variation vs. mean response of the questionnaire

In this analysis we evaluated the 16 participants classifying them in the four quadrants (Figure 10). Ten were in the quadrant I, one in the quadrant II, one in the quadrant III, and four in the quadrant IV.

The classification of the 10 participants in the quadrant I indicates that they had a positive HRV, that is, an increase in the general mean heart rate (MHR) concerning the baseline. These students also reported a high cognitive engagement in questionnaires. This quadrant is the best scenery in this study because it proved that a positive HRV is related to a high engagement.

One participant was in the quadrant II; she/he had a positive HRV but reported a low level of engagement in the questionnaire. This result indicates that the student did not feel a high cognitive engagement during the whole lesson, but he could have moments or activities that caught their attention, increasing their heart rate. If a participant was in quadrant III, she/he had a negative HRV, and in the same way, the student reported a low level of engagement in the questionnaire.

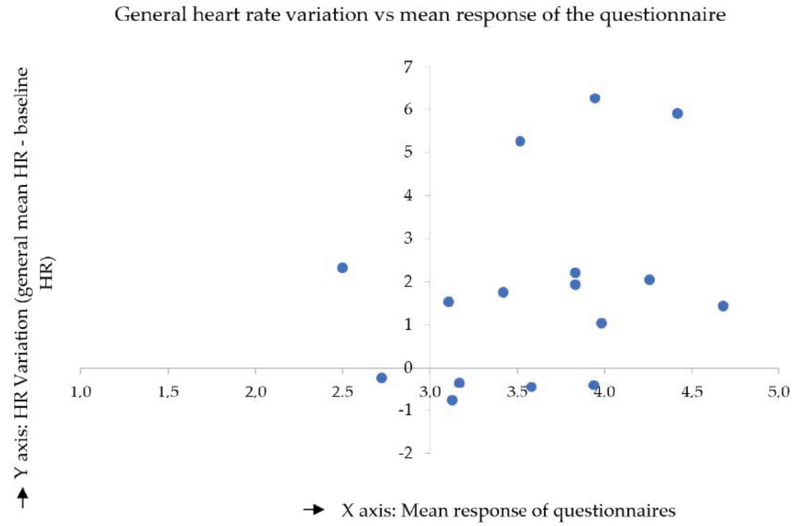


Figure 10. First scenario—Quadrant of general heart rate variation vs. mean response of questionnaire.

Finally, four participants were in the quadrant IV; they reported a high engagement in the questionnaire. However, the general MHR decreased with respect to the baseline, a circumstance that may indicate that students were in an immersive state and not necessarily a low level of attention or a low level of cognitive engagement; this affirmation coincides with the results of the study made by Ronney et al., who analyzed the behavior of the participant's heart rate while watching a film; the results demonstrated that a drop in the heart rate might suggest an immersive environment followed by an increase in the attention paid to the film [58].

- Second scenario: Heart rate variation of active learning activities vs. mean response of the questionnaire

In the same way as in the first scenario, we evaluated the 16 participants with the difference that here we related the HRV during active learning activities (ALA) and the mean responses in the questionnaire (Figure 11).

Nine participants were in quadrant I, seven of them presented a positive HRV below three points when an ALA was developed. This behavior is similar to the first scenario, which indicates that ALA had a great influence on the behavior of a whole lesson. The quadrant I represents that participants were making a mental effort for acquiring a high level of attention, a circumstance that resulted in a positive variation of the heart rate. The other two participants had a positive HRV greater than three points. This quadrant represents the best scenario; with these results, we can affirm that a positive HRV is linked to a high cognitive engagement.

Two participants were in the quadrant II, unlike the first scenario where we found one participant in quadrant II and the other participant in quadrant III. This behavior indicates that, although the participant in quadrant III reported a low cognitive engagement in the questionnaire, the ALA developed by the professor caught her/his attention, which meant an increase in the HRV and caused her/him to be in the quadrant II in the second scenario.

Five participants were in the quadrant IV. As we explained, this quadrant represents an immersive state of the participants. The participant who was in the quadrant I in the first scenario is now in the quadrant IV in the second scenario. This change means that she/he was in an immersive state when the professor carried out ALA. On the other hand, one of the participants had a significant negative HRV, below eight points, which indicates that her/his concentration was higher during ALA.

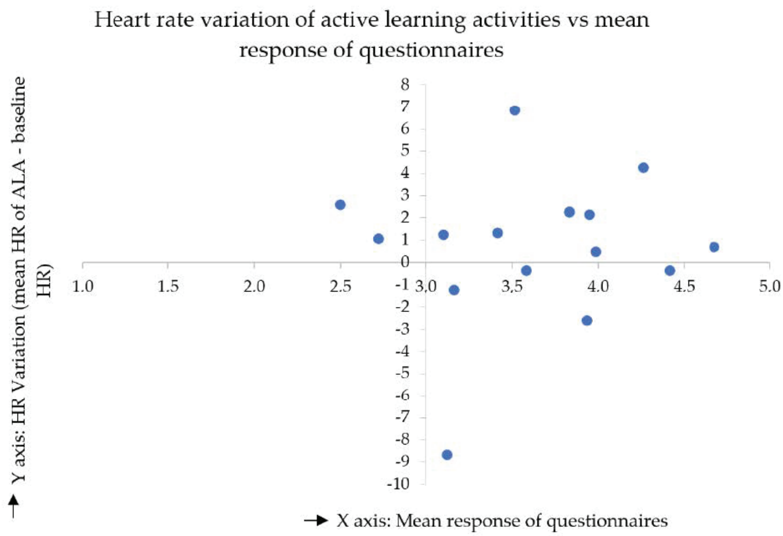


Figure 11. Second scenario—Quadrant of heart rate variation of active learning activities vs. mean response of questionnaires.

Overall, with the analysis performed and illustrated in the first and second scenario, the study shows that although there were heart rate variations (causing location changes for some participants inside the quadrant), the number of subjects for each quadrant is similar. This condition allows us to suggest that ALA developed by professors determinea the behavior of the MHR throughout the whole lessons.

Using the quadrant analysis it was possible to ascertain that combining a non-self-report method (heart rate) with a self-report method (questionnaire) is advantageous for measuring cognitive student engagement, since the comparison of the heart rate against the report given by each participant provides more information about the influence of ALA on the heart rate.

5. Discussion

In this study, we conducted exploratory research implementing a non-self-report method to measure the cognitive student engagement, with a physiological characteristic, the heart rate. We have measured and analyzed this variable, using a heart rate band, in 16 participants from the Industrial Engineering program, in a Colombian University located in Bogota. With the collected data, we evaluated five hypotheses. Below, we will present and discuss the results of each hypothesis.

- Hypothesis 1.

To analyze H1, we evaluated the behavior of the heart rate before, during, and after an active learning activity (ALA); we found that 41.4% of data correspond with H1. Since ALA was an important matter in this study, we applied an ANOVA test to evaluate the heart rate during an ALA against each participant's baseline, an analysis that demonstrated a statistically significant difference between these variables. We partially accepted H1 adapting the approach to the following: the mean heart rate has a significant variation with an active learning activity, indicating students experiment with cognitive engagement.

In comparison with similar activities developed in a face-to-face environment, the heart rate had a variation if the student was exposed to active learning activities; however, in the study performed by Darnell et al. [7], the heart rate had a significant uptick, while in our study, in virtual lessons, the heart rate had a significant variation that could be positive or negative. With this perspective, we could deduce that one of the main factors that affect the student engagement is the environment and not the activity that is developed. For that reason, we conclude that it is valuable to design activities that consider the learning environment to capture the student's attention and improve her/his knowledge.

- Hypothesis 2.

We evaluated H2 with the heart rate trend; if it was negative indicated a decrease and if it was positive indicated an increase in the heart rate from the beginning to the end of the lesson. From a total of 15 lessons, 60% presented the behavior expected by H2. For these results we partially accept H2 with the following adaptation: the trend of the heart rate from the beginning to the end of the lesson depends on external and internal factors, the internal factors are linked with the active learning activities, especially the duration and the moment in the lesson that the professor develops them.

In the study of Darnell et al. [7], the heart rate had a decreasing trend in the morning lessons; they found that this behavior was caused mainly by external factors as mental fatigue, and the accumulation of multiple classes, among other reasons. We found that these aspects happened in virtual lessons, but internal factors also affected the trend. These factors are linked with the active learning activities that professors can plan and monitor during each lesson.

- Hypothesis 3.

H3 had a strong dependence on H2, because H3 requires the trend during a lesson to decrease. After evaluating the 15 lessons, we found that only 27% of them had the behavior expected in H3, and for this result we rejected H3.

The biphasic shift with a faster decline in the first minutes and a slower decline in the remainder of the class was not confirmed in the study developed in the United States [7]; we did not find the biphasic behavior described in the development of virtual lessons.

- Hypothesis 4.

After analyzing the behavior of the heart rate at the beginning and the end of each lesson, we found that only 20% of the lessons achieved H4. After the analysis we concluded that here is not a standard pattern related to this hypothesis, and for this reason we rejected H4.

The behavior at the beginning and the end of the lesson in the study of Darnell et al. [7] showed a drop at the first three minutes and an uptick in the last three minutes of the lesson; for this reason, they excluded these three minutes for the analysis of the others hypothesis. They determined that this behavior could happen for external factors related to a face-to-face environment, such as arriving in a classroom and speaking with other students or thinking about the next class or next activities after finishing each lesson. In our study, we did not find a notable change at the beginning and the end of each virtual lesson; we take into account the data of these moments for other analysis.

- Hypothesis 5.

We analyzed 11 passive learning activities and found that 45% of them presented the behavior described in H5. All activities were a video projection; however, before students watched the video, the professor indicated to them that there would be an activity after the video, a factor that could influence the results. We partially accepted H5 with the following adaptation: if students are previously advised that they will have to develop an activity after a passive learning activity (such as a video projection), their heart rate could increase and, consequently, so could their cognitive engagement.

The study performed in student of medicine in the United States [7] found that during a short video projection, the heart rate appears to decrease greatly since it is categorized as a passive activity, the difference with our study consisted in the instruction that the professor gave to students, which was developed a task after a video projection, a condition that modified the behavior of the heart rate.

In addition to the analysis of the hypotheses, we made the relationship between the quantitative data vs. qualitative data from the questionnaire.

5.1. Non-Self-Report Method vs. Self-Report Method

We related the heart rate variation (HRV) of whole lessons and the HRV during the active learning activities (ALA) against the response that participants gave in the questionnaire; the VHR refers to the difference between mean heart rate and the baseline, we explored the behavior of the 16 participants.

We used a quadrant model (Figures 10 and 11); two quadrants stood out over the others; Quadrant I reflected that the HRV was positive and the responses in the questionnaire indicated a high level of cognitive engagement, the majority of data was located in this quadrant; the first stage, HRV of whole lessons, had 10 participants, and the second stage, HRV during ALA, had nine participants. Quadrant IV was the second predominant one. It represented an HRV negative, but the questionnaire's response indicated a high level of cognitive engagement; this situation reflected that participants could be in an immersive state during the ALA, and not necessarily a low level of engagement. Finally, the results suggest the behavior of the heart rate during a whole lesson might be determined for the ALA that professors developed in each lesson.

5.2. Limitations, Recommendations, and Future Research

We used the heart rate as a tool for measuring student engagement in virtual lessons during the COVID 19 pandemic, and we had limitations regarding the difficulty of eliminating environmental and external influences generated by the inconveniences of having access to resources and tools necessary for the development of the lessons, such as internet connection problems, unstable electricity, lack of an appropriate space without interruptions, a computer without the required capacity to run several programs and software at the same time (lesson connection software and programs to develop activities during class), and inconvenience with the phone that collected heart rate data (the reason for removing some data from the study). These limitations affected the level of attention of the participants and sometimes caused them to carry out other activities in parallel to the lessons. The difficulty of eliminating environmental and external influences is a known limitation in the use of heart rate as a tool for identifying engagement; for this reason, for future research, we recommend using the heart rate as a non-self-report method in combination with a self-report method such as a questionnaire that allows the identification of external factors that could affect the participant's attention in addition to the perception that she/he had of the lesson and the activities developed.

Another alternative we recommend in order to reduce the influence of external factors is to use supplementary biometric measures that allow us to identify additional characteristics which affect the heart rate, like emotions, motivation or level of concentration, factors that have a strong influence on student engagement. The supplementary biometric measures we suggest are: detection of facial expression, breath rate, skin temperature, and conductance or brain signals.

In this study, we made an exploratory investigation limited to the number of participants, the quantity of heart rate bands, and to a specific subject (human talent management). The sample number of participants was between the ranges of other studies in the sector; however, we recommend that for future studies the researchers increase the sample and evaluate the student engagement in other engineering subjects. We hope that our study can serve as the basis and input for future research related to the analysis of cognitive student engagement using heart rate as a non-self-report method.

Using the heart rate for analyzing the student engagement has the advantage that data is collected in real-time. However, the data processing and the analysis require additional time. This limitation means that teachers do not receive feedback in real time to make the necessary decisions to modify or adapt the methodology of the course. For this reason, a future challenge could be the development of a model that processes and evaluates the data of the heart rate in a shorter time or even in real-time, which can be used by all students in a lesson and provide feedback to the professor.

The heart rate is a physiological parameter used mainly by enterprises to evaluate customer behavior. Carrying out this study, we aim to demonstrate that the heart rate is a prominent tool that can determine cognitive student engagement. We expect that this study could be a base for future research looking to deepen the evaluation of the variables that influence heart rate in an academic environment.

6. Conclusions

Student engagement allows educational institutions to improve their decisions regarding methodologies, evaluation of quality, and feedback. The methods to determine student engagement are divided into self-report methods, such as questionnaires, surveys and analysis of these, and non-self-report methods, which use physiological characteristics such as heart rate, brain signals, analysis of facial expressions, etc. In Colombia, the investigations only used self-report methods.

In this study, we develop an exploratory investigation to determine the level of student cognitive engagement through heart rate, during the development of active learning activities. We used heart rate bands and a mobile application to collect the data, in a sample of 16 students who were taking the Human Talent Management subject of the industrial engineering program of a higher education institution in Bogotá, Colombia.

The results confirm that heart rate can be used as a tool for measuring cognitive student engagement in distance learning, especially if the professor develops an active learning activity, since statistically, the heart rate has a significant variation with respect to the baseline heart rate during the development of these activities. At this point, it is important to clarify that this difference could be positive or negative. A positive variation implies an increase in the heart rate because the study subject is making a mental effort, and a negative variation means an immersive state, i.e., the active learning activity captured the student's attention and immersed her/him in this environment, causing her/him to isolate herself/himself from any other activity. In the development of virtual lessons, one of the main concerns of the professors is to identify activities that encourage the participation of students, capture their attention, and allow the transmission of knowledge. In this study, we found that active learning activities achieve these objectives, because spaces are generated within the lessons that allow students to concentrate on the activities developed, resolve doubts and connect their past experiences with new knowledge.

Using a quadrant model, we confirmed that combining a non-self-report method and a self-report method allows us to analyze the engagement in a broader perspective. This association allows us to relate the engagement reported by the students with the results obtained from the physiological characteristic. In our study, one of the results suggested that, during an active learning activity, most participants reported a high level of cognitive engagement, and the heart rate variation had a significant difference with respect to the baseline, a result that was evident in the ANOVA. However, in this analysis it was possible to identify that this difference could be positive or negative.

In the development of this research we found that students feel more comfortable, feel less pressure, and are more willing to participate in a study if factors such as student engagement are measured using a non-self-report method, because they sent us the heart rate data immediately after the end of the lesson without having to remind them to send the data. However, the opposite happened with the self-report method, because we had to ask them to fill out each questionnaire at least twice and sometimes up to four times. The above shows that students are interested in participating in non-self-report methods and shows the importance of rethinking the way self-report methods are implemented.

We confirm that the heart trend from the beginning to the end of the lesson depends on external and internal factors. The external factors include instability in the internet connection and activities that students may be developing in parallel to lessons, and the internal factors, which professors can control, are linked with the active learning activities. The internal and external factors that are presented in a face-to-face lesson are very different from those that are presented in a virtual lesson. In a face-to-face lesson, the external factors that affect the concentration of students are reduced due to the learning environment that a classroom provides. However, in a remote environment, the external factors are greater and variable. For this reason, the active learning activities that professors develop become more relevant, especially in terms of the duration and time of the lesson in which they are performed. These activities provide a balance at the beginning, in the middle and at the end of the lesson.

Concerning passive learning activities, if students are previously advised that they will have to develop a task after a passive learning activity (such as a video projection), their heart rate could increase and, consequently, so could their cognitive engagement. The instructions of the activities to be carried out after the video projection were focused on the topic that the students were learning and generated a discussion between the work groups or between the students and the professor. This particularity should be considered if professors want to implement a passive learning activity to promote cognitive engagement.

We find that heart rate did not present a pattern in the biphasic analysis or a pattern behavior at the beginning and the end of the lesson. The four heart rate behaviors found at the beginning and at the end of the lesson allow us to deduce that the variation depends on external factors that may occur before and after the class, and that the professor cannot control; for example, other academic activities of other subjects or personal activities that can cause a variation in heart rate.

We expect that this study can provide input for future research assessing student cognitive engagement in higher education and motivate researchers to use physiological characteristics as a measurement tool.

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Abbreviations

The following abbreviations are used in this manuscript:

MUSLIS	Malaysian University Student Learning Involvement Scale
NSSE	National Survey of Student Engagement
MSLQ	Motivated Strategies for Learning Questionnaire
HESES	Higher Education Student Engagement Scale
ALA	Active learning activities

PPG	Photoplethysmography
3SD	Three standard deviations
MHR	Mean heart rate
H1	Hypothesis 1
H2	Hypothesis 2
H3	Hypothesis 3
H4	Hypothesis 4
H5	Hypothesis 5
HRT	Heart rate trend
HRV	Heart rate variation
bpm	Beats per minute

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education sciences

Article

Resilience and COVID-19. An Analysis in University Students during Confinement

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Abstract: The COVID-19 pandemic has changed life for millions of people. The social-emotional consequences of the confinement need to be analysed urgently. This study examines self-perceived resilience and its most important determining factors in a sample of university students facing COVID confinement. The measuring instrument used is the Connor-Davidson Resilience Scale, divided into four factors and applied to a sample of 253 graduate and postgraduate students. Different methods of descriptive statistics and statistical hypothesis testing were used to calculate the results with the statistical program SPSS–22. The results showed generally high levels of resilience among the university students analysed, irrespective of socio-demographic variables. Factor analysis shows resilience to be highest among male students and those over 25. Self-perceived resilience was also higher among students who lived alone or with people other than their parents. Finally, students of the health sciences were more likely to adapt to change, deal with today's challenges, and think of themselves as people capable of bouncing back after hardship.

Keywords: resilience; university students; COVID-19; confinement

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1. Introduction

The COVID-pandemic has changed the lives of millions of people all over the world [1]. The health crisis and situations of confinement are leading to socio-economic, humanitarian, psycho-emotional and educational effects. Regarding education and the socio-emotional effects of the confinement, the United Nations Educational, Scientific and Cultural Organization (UNESCO) [2] (p. 1) warns of a possible "global learning crisis at all levels of the education system", which includes universities.

This learning crisis comprises both a reduction in the amount of content students are exposed to and the competencies they develop, and also affects emotional and mental-health depending on their ability to deal with the challenges posed by the pandemic [3,4]. Resilience in teachers [5,6], students [7] and the education system [8] is going to be an important factor in the measures dealing with the effects of the pandemic. It is, therefore, necessary to reassess the relationship between students and teachers, on the one hand, and students and learning, on the other, with due consideration for the social and family circumstances under which students faced the confinement. Considering all of the above, we ask the following questions: what have been the effects on university students, what strengths do they highlight in themselves, and how much resilience can they draw on to deal with this challenge?

COVID-19 has forced 1.57 billion students of all educational levels out of school. According to UNESCO [8] (p. 1), this crisis "will have long-lasting consequences for education systems in terms of access, quality, equity and management, which are likely to persist beyond the pandemic." These consequences will also be stronger for students from low-income families [9] and/or those with special educational needs. The impact will be especially strong, however, on those students who cannot cope with the confinement emotionally. Save the Children [10] divides the pedagogical effects of the confinement into four main groups: (1) loss of competencies and knowledge; (2) difficulty individualising learning; (3) loss of interest in learning; and (4) lack of direct assistance from teachers. Other education-related effects are an increase in the amount of hours dedicated to studying and to chores, which leads students to feel "overwhelmed and saturated", and increased worrying about evaluation methods, which in turn causes increased feelings of uncertainty [11]. Also described are the psycho-emotional effects on student learning. On the one hand, we see emotional detachment from school or university, teachers, subjects, and classmates, while on the other, post-traumatic stress, confusion, anger, anxiety, boredom, frustration, and loneliness [12], which may create health problems [13].

In response to this situation, an online education system known as "emergency remote teaching" was set up [14] (p. 2). It was designed to meet the challenge of the worldwide school and university closures. These socio-political and educational efforts were aimed at providing distance teaching that would guarantee access to all content for all students, with a distinct concern for equity and inclusion [15]. This attempt, however, created three big gaps among students, depending on different variables [16]. First, an access gap affecting students' access to computers, adequate study spaces, and reliable internet connections, thus, a gap caused by socio-economic factors. Second, a usage gap, for example, in the amount of hours students spend using these technologies and the quality and suitability of the pages they visit. This gap, too, is related to the socio-cultural level of students' families, with the data showing students from low-income families spend more hours online, but of lower quality. Thirdly, there is also a pedagogical competence gap related to the pedagogical skills of teaching staff, and the quantity and quality of educational resources and e-learning platforms available.

2. Literature Review

2.1. Definition of Resilience

The concept of resilience comes from physics, where it is defined as the ability of a body to recover its shape and size after being deformed. In the social sciences, resilience is a recurring construct in studies on academic achievement in the face of difficult situations or contexts [17]. This concept has been approached from different angles [18], as shown by Bonanno's studies [19], which define resilience as the result of the interaction of protective factors on traumatic situations, as as contrasted with other studies that define it as a process that grows in the face of adversity [20]. According to the latter, resilience as a process that is constructed based on the skills that the individual puts into practice to overcome a trauma [21]. Therefore, they consider resilience as the ability to overcome traumatic situations that is based on the interaction between the subject and their coping strategies.

In the same vein, Vanistendael's proposal [22], supported by Cyrulnick [23], further refines the concept of resilience as a person's ability to resist possible psychological trauma caused by a problematic and harmful environment. It is, therefore, the result of an internal drive to heal, of the human resistance to a condition, resistance which leads one to reject resigning oneself to suffering or to reality itself. This is, thus, an acquired ability [24] resulting from a person's adaptability to traumatic situations.

2.2. Resilience in Young People in Situations of Captivity

Adaptability and coping are two terms linked to the study of the concept of resilience [25]. Although any person can develop resilience, recent studies on positive adaptation in response to extreme adversity propose that resilience is relatively more common among children and adolescents who have been exposed to adversity, trauma, and misfortune [26].

Richardson's research [27] shows the relevance of coping with traumatic situations and the importance of having been through difficult situations for the development of resilience.

His studies establish that having previously adapted to other difficult life situations allows individuals to adjust more quickly to new difficult situations. This conclusion is supported by other studies [28–32]. COVID-19 has been a traumatic experience for many people. The pandemic is a threat not only to people's physical health but also their mental well-being [4]. Many people feel fear, sadness, and anxiety [12]. In fact, fear of the virus is spreading faster than the virus itself because of people's fear of becoming ill, dying, losing one's livelihood or loved ones, or being socially excluded and separated from one's family [33].

This article focuses on the impact of COVID-19 on university students, who are at a vital stage in their social and affective development. According to Erickson [34], people between 18 and 30 years of age are at a point in their lives where they either end up achieving intimacy or isolating themselves from the world. Young people need to relate with others similar to themselves in order to establish deeper relationships and look for mutual commitment, for intimacy that fosters a sense of security, company, and trust, because they need this to feel motivated to take decisions based in independence and self-determination. Viewed from this perspective, the current situation with confinement, its forced isolation, and the changes it causes in learned social habits can have significant effects. Thus, some studies have pointed out how people's losing or having to change certain habits and routines has affected their physical and psychological well-being, in addition to creating psychosocial stress [1,3,11]. These studies show how the confinement modified the eating, sleeping, and physical-exercising habits of a large part of the population, which led to significant changes in many people's daily behaviours. The messages emanating from governments and the mass media have also had a profound impact on people's behaviours and feelings. The excess information (some of which is unconfirmed and contradictory), exaggerations, doomsday scenarios, and overly specialised content have given rise to feelings of fear, frustration, and discouragement [35], as well as dysphoric mood states. Politicians' statements have not reassured people, raised awareness, nor provided adequate information, as Yasir et al. [36] would have liked. Rather, they have generated negative and contradictory emotions among the population. Some platforms are being used by users to disseminate rumors and fake news [37]. For this reason, this study aims to gauge how much resilience university students perceived in themselves in a situation of confinement.

According to many studies on resilience among young people [25,38,39], active coping (doing something to get out of the predicament) and positive reframing (looking for the positive and favourable in the predicament) correlate positively with the building of resilience. However, very few studies have been conducted on the relationship between resilience and forced confinement. The few studies that have been conducted on this subject analyse the relation between resilient processes and situations of kidnapping or illegal detention, showing how people who go through such situations have many different ways of building resilience; most of them related with the length of the isolation, the conditions, and the relationships they established with the people they had contact with.

There have been some studies on COVID-19 and university students, and they have highlighted the strong psychological [4] and academic impact of the pandemic [17]. According to the authors of these studies, the quantity and quality of a person's physical bonds and social networks (life capital) are a protective factor, since successful coping is more positively related with offline social capital (physical relationships) than with online social capital (virtual relationships). The variables that these studies have found to be important in building resilience are family cohesion [40], breaking isolation through sustained virtual communication, and finding motivational tasks that create funny situations through one's sense of humour [41].

However, other studies related with extreme stress caused by illnesses similar to COVID-19 maintain that building resilience in such situations is more complex than under less stressful circumstances that are not chronic [20]. Other risk factors associated with building resilience would thus need to be identified. In any case, these conclusions require prospective studies to better clarify this matter.

2.3. Previous Studies on University Students, COVID-19 and Resilience

Since the start of the COVID pandemic, much research has been conducted in the field of education. Some focuses on the impact of COVID-19 on learning in university students in different countries.

2.3.1. Resilience and Education

The relationship between resilience and education has received a lot of attention in the social sciences in recent years. Numerous studies in student populations have analysed the impact of problematic situations on academic development and how the appearance of resilience tutors [6] or specific events can lead to the development of resilience. Thus, personal satisfaction, classroom climate, personal relations between teachers and students, and other factors can develop resilience in students, becoming real protective factors and improving academic and educational performance [42].

Nambiar [43], Sujarwo et al. [44] and Fatoni et al. [45] all found a high level of satisfaction, both among faculty and students, with the experience of online learning. They also highlighted the quality of the teaching, the two-way interaction, and the methods adapted to the situation of confinement. Having more time available for other activities was also viewed positively. Conversely, Quintiliani et al. [46] found difficulties related with adapting to the new situation, maintaining attention during class, performing evaluations, coping with increased stress, and worrying about academic performance. Zhou and Zhang [47] mentioned the importance of students' mental health in the learning process and found the main obstacle to this during the lockdown to have been the lack of interaction with teachers and fellow students. Apolloni et al. [48] highlighted good communication in online education as a protective factor generating resilience in situations of confinement. In the same vein, Eva et al. [49] and Dewantoro and Rachmawati [50], having analysed the correlation between academic resilience and students' subjective well-being, pointed to negative emotions as an important risk factor that needs to be dealt with in similar situations.

2.3.2. Resilience and COVID

Other studies have brought to light the relation between COVID-19 and the emotional problems university students experience when coping with it [51–53]. For example, Olmos-Gómez [54] found frustration, malaise, and decreased resilience to be the main problems in students who either did not engage in physical activity or frequently watched pandemic-related news [55]. Liu et al. [56] reached similar conclusions regarding the importance of physical health, emotional support, and resilience as factors promoting psychological well-being among students. Similarly, Eva et al. [49] found that students who were able to regulate their emotions during the confinement obtained greater personal satisfaction and better academic results. As for Zhou and Zhang [47], they found the greatest problem facing students during the lockdown was the lack of personal relations with teachers and fellow students, while Ferreira et al. [57] highlighted the importance of family and neighbours as resilience-promoting factors during the confinement. These studies are in line with Yu and Yu [58], who report significant differences in how students deal with emotional problems depending on their sex and academic degree. Furthermore, Oducado et al. [59] found an increase in fear, anxiety, and stress among postgraduate students during the lockdown, which matches Kaparounaki et al.'s findings [60].

The studies conducted on resilience, coping, and COVID-19 reveal sex-related differences. Labrague [61] reported higher levels of fatigue and malaise among females than among males during the lockdown. In the same vein, Karasar and Canli [62] found females, university students, and people with mental-health problems to be more vulnerable and also more prone to suffer depression in situations of confinement. Conversely, Liu et al. [56] did not find any differences related with students' age, sex, or educational level. Other studies, such as Ye et al. [63], highlight the differences in adapting to the lockdown according to social context, support received, or situations of disability.

San Román-Mata et al. [64], in a study similar to the present one that also applied the Connor-Davidson Resilience Scale but in a non-university population, concluded that employed people, those with higher education, people working in emergency services and those with dependents presented higher rates of resilience.

In the same way that these studies describe the effects they found and emphasise that the inequalities and challenges facing students should be tackled by focusing on the social, contextual, and cultural differences deriving from the lockdown, Peimani and Kamalipour [65] maintain that the challenges they detected have nothing to do with the type of teaching offered—online or offline—but are directly related with the way in which the differences and inequalities in the education process are dealt with pedagogically.

3. Materials and Methods

The aim of this research was to measure the perception of resilience of university students, both undergraduate and graduate, studying different degrees in different universities in the city of Valencia (Spain), to the COVID-19 lockdown using the Connor-Davidson Resilience Scale (CD-RISC 23) [21]. The research hypothesis is that the higher the score on any of the factors describing the construct of resilience, the higher the score on general resilience, and vice versa. Therefore, the aim is to identify whether self-perceived resilience during confinement is more influenced by one factor than others.

This study uses the Connor-Davidson Resilience Scale (CD-RISC 23) to measure resilience among university students during the COVID-19 confinement. The participants were 253 university students, both graduate and postgraduate, with ages ranging from 17 to 42 years. Recruitment and testing were conducted online during April and May 2020. The participating students accessed the scale through the Google Forms platform, where they were also asked to provide informed consent, thereby confirming they knew their participation was voluntary and anonymous.

3.1. Instrument

The Connor-Davidson Resilience Scale (CD-RISC 23) is a 23-item, five-point Likert scale originally divided into five factors measuring resilience. This study used the Spanish version by Crespo, Fernández-Lansac and Soberón [66], which is divided into four factors. The data were analysed using the parameters set out by Connor-Davidson using a scale on which higher scores indicate higher resilience. This scale was chosen for its reliability, which has been proven in various studies in the social sciences. The Spanish version groups the items into the following four factors.

To establish the criteria for each factor, its standard deviation from the mean was calculated in order to determine its variance. Variability was observed in the responses of students with high resilience, so the decision was made to differentiate top-ranking scores from high ones. Accordingly, to make the study's results easier to understand, a distinction is made between subjects showing high resilience and those presenting the highest resilience scores, which are referred to as solid resilience (Table 1). The cut-off values for resilience are: low < 7.45; high between 7.45–11.67; and solid > 11.67.

3.2. Procedure

The scale's reliability was assessed with Cronbach's alpha, which measures internal consistency through the average correlation between items. The result was 0.84, which shows the scale to be well adjusted to the construct. The adequacy of the factors of the scale has been contrasted using the KMO sample adequacy measure and Bartlett's test. The KMO coefficient is 0.828, showing a high level of factor consistency. The significance level of Bartlett's Sphericity is 0.000. Data processing was performed using descriptive analyses in order to determine the sample's profile: principal component factor analysis to establish the factors, checking the adequacy of the scale's factorization, KMO sample adequacy and Bartlett's test, and dispersion measures such as standard deviation and analysis of variance. To test the hypothesis, a chi-squared test and the Pearson correlation coefficient were used, with $p < 0.05$ as the indicator of significance. The factors were ranked based on their standard deviation from the mean. As the answers from students with high resilience were found to be variable, the decision was made to differentiate top-ranking scores from high ones. Consequently, the results distinguish between students with "high" resilience scores and those at the top, who have "solid" resilience.

Table 1. Cuts separating the Factors.

	VALUES		
FACTORS	**Low**	**High**	**Solid**
F1. Persistence/tenacity/self-efficacy Items 10–12, 16, 17, 23–25	<15.03	15.03–19.90	>19.90
F2. Control under pressure Ítems 6, 7, 14, 15, 18, 19, 20	<15.20	15.20–20.29	>20.29
F3. Adaptability and support networks Items 1, 2, 4, 5 y 8	<14,48	14.48–18.16	>18.16
F4. Control and purpose Items 13, 21 y 22	<21.29	21.29–27.09	>27.09

3.3. Participants

The sample consisted of 253 university students, both graduate and postgraduate, studying for different degrees at different universities in the city of Valencia (Spain), such as the Catholic University of Valencia, the Universitat de València, Florida Universitaria, and CEU San Pablo. Participants were selected using intentional non-probabilistic sampling. Female students made up 88.1% of the sample and male students the remaining 11.9%. Female students made up the vast majority because the participants were overwhelmingly from the learning sciences. As to age, 39.9% were in the 17–20 range, 45.1% were 21–24 years old, and 15% were over 25. The average age was approximately 22 years. Regarding students' level of study, 34.8% were in the first year of their Bachelor's degree, 25.3% in the second, 11.1% in the third, and 20.2% in the fourth, with 8.7% pursuing a postgraduate degree. The breakdown by field of knowledge was as follows: 10.3% were students in the social sciences, 5.6% in the health sciences, 63.9% in the learning sciences, 11.5% in engineering or the exact sciences, and 8.7% were doing postgraduate studies. Since this is a very heterogeneous sample in terms of the number of participants, caution should be exercised in interpreting the results (for example, in the case of health sciences students). Finally, during the confinement the students were either living alone (2%), with their parents (86.2%) or with other people (11.9%) (Table 2).

Table 2. Description of socio-demographic variables.

	Age	
	Frequency	Percentage
Age 17–20	100	39.9
Age 21–24	116	45.1
+25	37	15
Total	253	100.0
	Sex	
	Frequency	Percentage
Men	30	11.9
Women	223	88.1
Total	253	100.0

Table 2. *Cont.*

Degrees		
	Frequency	Percentage
Social Sciences	26	10.3
Health Sciences	14	5.6
Education/Learning Sciences	162	63.9
Engineering or Exact Sciences	29	11.5
Postgraduate	22	8.7
Total	253	100.0
Course		
	Frequency	Percentage
First Year	88	34.8
Second Year	64	25.3
Third Year	28	11.1
Fourth Year	51	20.2
Postgraduate	22	8.7
Total	253	100.0
Living arrangements		
	Frequency	Percentage
Alone	5	2.0
With my parents	218	86.2
With another person	30	11.9
Total	253	100.0

4. Results

4.1. Resilience and Socio-Demographic Variables

Generally speaking, the university students analysed presented high or solid levels of resilience under confinement conditions. To be exact, 57.7% presented high resilience, 14% solid resilience, and only the remaining 30% presented low levels of resilience. An analysis by socio-demographic variable showed the following variations.

Regarding sex, there is no significant relation between this variable (0.345) and high resilience scores: 73% of male and 72% of female students had high or solid resilience (Figure 1).

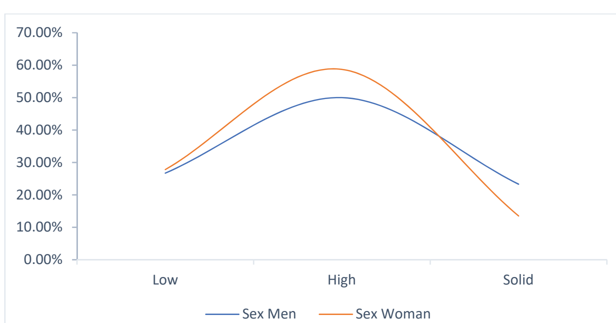

Figure 1. Relationship between Sex and Resilience.

Regarding living arrangements, there was again no significant relationship (0.204) with resilience. Still, the university students that lived together with people other than their parents presented a higher percentage of high and solid resilience (83%) than those living alone (80%) or with their parents (70%) (Figure 2).

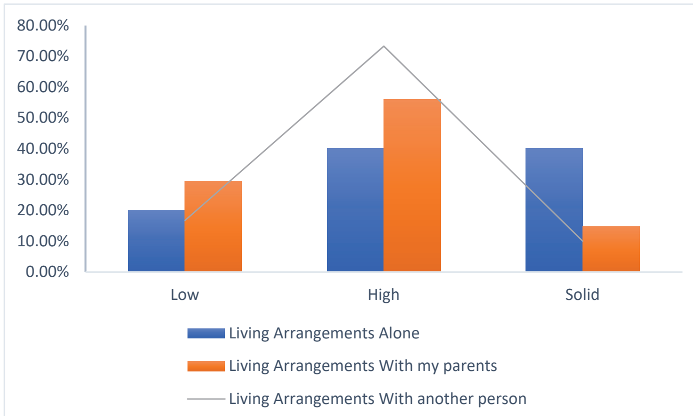

Figure 2. Relationship between Living arrangements and Resilience.

In relation to age, the highest rate of high and solid resilience was found in students between 17 and 20 years (79%) of age, followed by those aged 21–24 (66%). Students over 25 years presented a rate of high and solid resilience of 73%. Here, again, there is no significant relation between age and level of resilience (0.349) (Figure 3).

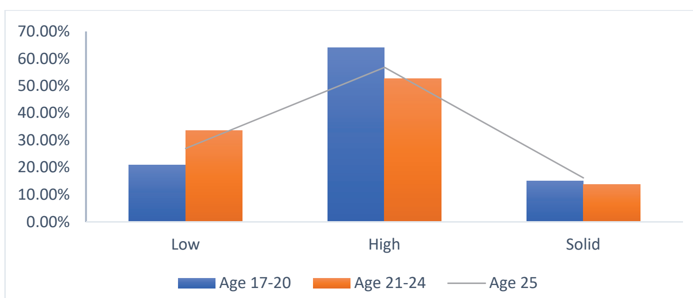

Figure 3. Relationship between Age and Resilience.

As for the type of degree being pursued, the highest rates of both high and solid resilience (85%) were found among students of the health sciences (nursing, optics and optometry, psychology, biology, and biotechnology), followed by those in the learning sciences (primary education, early-childhood education, combined early-childhood and primary education, physical activity and sports sciences, social work and pedagogy), at 73%. The same percentage (73%) was found among postgraduate students, followed by those in the social sciences (69%) and, finally, those studying engineering and exact sciences (architecture, industrial engineering, chemical engineering, telecommunications, and business administration), with 58%. Conspicuous for their low resilience were the students from the sciences (41%). Again, there is no significant relationship between the variables (0.514) (Figure 4).

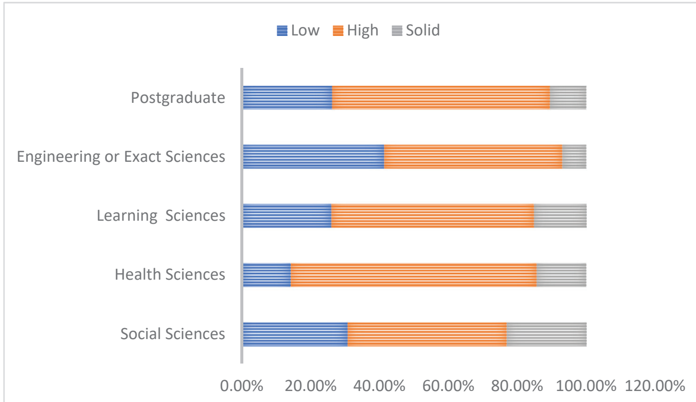

Figure 4. Relationship between Degree and Resilience.

With respect to the academic year students are in, the analyses indicate that the highest percentage of low resilience was to be found among second-year (32.8%) and fourth-year students (31.3%). The highest percentage of high resilience was to be found among first-year (66%) and postgraduate students (68%), and third-year students showed the highest rate of solid resilience (25%). As with the other socio-demographic variables, no significant relation with resilience was found (0.430) (Figure 5).

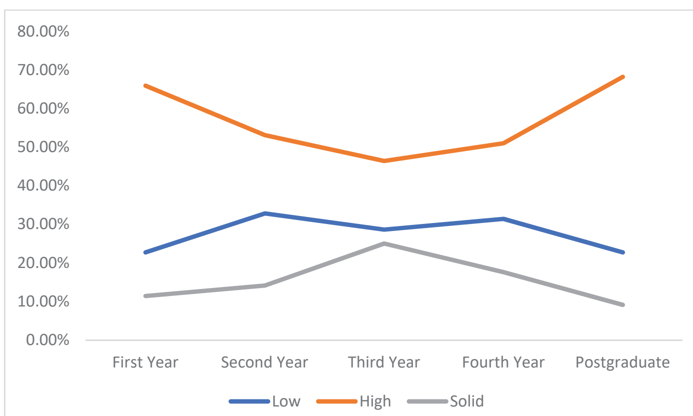

Figure 5. Relationship between Course and Resilience.

4.2. Analysis of the Factors Associated with Resilience

This section examines each factor's influence on and relation with the general resilience result in order to confirm or disprove the hypothesis stated at the start of this study.

4.2.1. Persistence/Tenacity/Self-Efficacy (Factor 1)

An analysis of persistence/tenacity/self-efficacy and resilience reveals a relation of dependence between these two variables (0.000). Interestingly, there were 55 cases of low persistence that also have low resilience. The same type of relation exists with high resilience, i.e., students with high or solid persistence also have high or solid resilience. However, a striking reverse relation was found among the 74 students with low persistence, 19 of whom had high resilience (Table 3).

Table 3. Persistence/tenacity/self-efficacy and Resilience level.

		Resilience		
		Low	**High**	**Solid**
Persistence/tenacity/self-efficacy	Low	21.8%	7.5%	0%
	High	5.1%	34.4%	3.1%
	Solid	0.8%	15.8%	11.5%
Total		27.7%	57.7%	14.6%

With reference to the age and persistence, the data show that the highest rate of low persistence was found among students aged 17 to 20 years (33%), while those over 25 stood out because of their high level of persistence (78%). The variable "age", therefore, showed no significant relation with persistence (0.939).

Regarding sex and persistence, male students showed a slightly higher rate of high and solid persistence (73.3%) than female students (70.5%), although both sexes had high rates of high and solid persistence. There does not appear to be any relation between these two variables (0.39).

Regarding the degree students were pursuing, the highest percentages of high and solid persistence occurred among students in the health sciences (85%) and those doing a postgraduate degree (84%), who were also the ones with the lowest rates of low persistence. Conversely, students in engineering and the exact sciences had the highest rate of low persistence (44%). There appeared to be no significant relation between the two variables (0.417).

As for academic year, the highest rate of high and solid persistence was found among postgraduate students (81.8%), while second-year students presented the highest rate of low persistence (37.5%). There was a significant relation between the two variables (0.003).

Regarding living arrangements, students living with people other than their parents (83%) and living alone (80%) showed the highest rates of high and solid persistence, while low persistence was highest among those living with their parents (31%) followed by those living with people other than their parents (23%) and those living alone (20%). There was a significant relationship between these two variables (0.257).

4.2.2. Control under Pressure (Factor 2)

With respect to control under pressure and its relation with resilience, students with low control under pressure also presented low resilience (76.5%) and those with high and solid resilience had high and solid control under pressure (100%). The majority of students in this study presented high control under pressure (52.2%). This correlation was reflected by the chi-squared test, which indicates the existence of a significant association (0.000) between these two variables, i.e., the higher the variable "control under pressure", the stronger the variable "resilience" is (Table 4).

Table 4. Control under pressure and Resilience level.

		Resilience		
		Low	**High**	**Solid**
Control under pressure	Low	76.5%	23.5%	0.0%
	High	13.6%	81.8%	4.5%
	Solid	0.0%	41.5%	58.5%
Total		27.7%	57.7%	14.6%

Regarding age, students over 25 years showed the highest rate of high and solid control under pressure (75.7%), followed by the 17–20 age group (74%) and, finally, the students aged 21 to 24, who had the lowest rate of high and solid control under pressure (71.5%). The group aged 17 to 20 scored highest (24%) on solid control under pressure. No significant relation was observed between these two variables (0.865).

Regarding sex, both female and male students showed similar rates of control under pressure in all three categories, i.e., low, high, and solid. Men had slightly higher rates of high (53.3%) and solid (26.7%) control under pressure than women (52% high and 20% solid). No statistically significant relation was found between these two variables (0.566).

Concerning degree, students from the learning sciences presented the highest rate of low control under pressure (29.1%), followed by postgraduate students (26.3%). Students from the health sciences had the highest rate of high control under pressure (64.3%), and students from the social sciences the highest rate of solid control under pressure (38.5%). There does not appear to be any significant relation between these variables (0.451).

With regard to academic year, second-course students presented the highest rate of low control under pressure (35.9%), first-year students the highest rate of high control under pressure (56%), and postgraduate students the highest rate of solid control under pressure (27.3%). No significant relationship was observed between these two variables (0.711).

As for living arrangements, students living alone or with people other than their parents presented higher rates of high control under pressure (60% in both groups) than those living with their parents (50%). Also, students living alone had a higher rate of solid control under pressure (40%) than the other groups. No significant relation was observed between these variables (0.364).

4.2.3. Adaptability and Support Networks (Factor 3)

The factor "adaptability and support networks" and resilience are highly dependent (0.000). The data indicate that the lower the rate of adaptability, the lower the rate of high resilience. In the same way, low adaptability correlates with low resilience. Furthermore, students with high and solid scores on this factor also show high and solid levels of resilience (Table 5).

Table 5. Adaptability and support networks and Resilience level.

		Resilience		
		Low	**High**	**Solid**
Adaptability and support networks	Low	77.2%	22.8%	0.0%
	High	17.4%	72.9%	9.7%
	Solid	1.9%	53.8%	44.2%
Total		27.7%	57.7%	14.6%

Regarding the relation between age and adaptability, older students had a higher percentage of low adaptability and support networks than the youngest age group (17–20 years). On the other hand, the 17–20 age group and those over 25 had markedly higher rates of high adaptability (61% and 59% respectively) than those aged 21 to 24 (52.6%). There is a significant relation between these two variables (0.617).

As to the relation between sex and adaptability, the data show male students lead in high (60%) and low (26.7%) adaptability, while female students scored higher on solid (21.5%) adaptability. There was no apparent relation between these two variables (0.555).

The data on the relation between the degree students are studying for and the factor "adaptability" showed that students from the social sciences presented the highest rate of low adaptability (38.8%), while those from the learning sciences (26%) had the highest score for solid adaptability. Finally, students from engineering and exact sciences were ahead of the others on high adaptability (72%). There is no apparent relation between these two variables (0.200).

Regarding the relation between the academic year students were in and adaptability, postgraduate students were the highest scorers on low adaptability (27.3%), while first-year students had the highest rate of high adaptability (62%) and fourth-year students the highest rate of solid adaptability (25.5%). There appears to be no relation between these variables (0.821).

Finally, regarding the relation between living arrangements and adaptability, the students living alone had the highest rate of high/solid adaptability (100%) compared with those living with people other than their parents (80%) and those living with their parents (76.6%). Students living with their parents were also those with the highest rate of low resilience (23.4%). No significant relation is apparent between the two variables (0.516).

4.2.4. Control and Purpose (Factor 4)

With respect to the relation between the factor "control and purpose" and resilience, students with low control and purpose also had low resilience (91.5%). Conversely, students with high and solid control and purpose had higher levels of high and solid resilience. Furthermore, the chi-squared test revealed a better fit with the construct. No relation is observed between these variables (0.000) (Table 6).

Table 6. Control and purpose and level of Resilience.

		Resilience		
		Low	**High**	**Solid**
Control and purpose	Low	91.5%	8.5%	0.0%
	High	10.9%	85.7%	3.4%
	Solid	0.0%	31.9%	68.1%
Total		27.7%	57.7%	14.6%

The relation between age and control and purpose stands out because of its variability. On the one hand, students aged 21–24 showed a higher rate of low control and purpose (25.9%) than those aged 17–20 (20%) and those over 25 (24.3%). On the other hand, the youngest age group (17–20 years) showed better rates of high and solid control and purpose (80%). There is no significant relation between the two variables (0.72).

Regarding sex and its relation with control and purpose, female students showed a higher rate (58%) of high control and purpose than male students (53.3%). However, male students had a higher rate of solid control and purpose (23.35%) than female students (17.9%). There is no detectable relation between these variables (0.76).

As to degree and how it relates with control and purpose, engineering and postgraduate students presented the highest rates of low control and purpose (27.6% and 26.3% respectively), as opposed to students from the health sciences, who had the highest rate of high control and purpose (64.3%). The leaders in solid control and purpose were the students from the social sciences (26.9%). No relation between these two variables is observed (0.896).

Concerning the academic year students are in and the factor "control and purpose", the data indicated that first-year and postgraduate students had the lowest rates (18.2% in both groups) of low control and purpose and, at the same time, the highest of high control and purpose (65.9% and 63.6% respectively). On the other hand, fourth-year students showed a higher rate of solid control and purpose (18.2%). There is no observable relation between these variables (0.697).

Finally, regarding students' living arrangements and control and purpose, students living alone or with people other than their parents had the lowest rates of low control and purpose (0.0 and 16.7% respectively) as well as the highest rates of high control and purpose (60% and 66.7%). Students living alone were also those scoring highest on solid control and purpose (40%). Strikingly, students living alone showed no low control and purpose at all. There appears to be no significant relation between the two variables (0.452).

As for the four factors analysed—“persistence/tenacity/self-efficacy”, “control under pressure”, “adaptability and support networks”, and “control and purpose”—they showed that students over 25 and male students had higher resilience than the rest of the students. Students who lived alone or with people other than their parents also showed higher self-perceived resilience, as did students from the health sciences.

5. Discussion

The university students in COVID-19 confinement who were analysed in this study showed generally high rates of high and solid resilience. The measuring instrument used was a self-report scale, so the data collected showed that students viewed themselves as highly capable of surmounting obstacles and overcoming the hardships imposed by their circumstances. The majority of students participating in this study adapted to confinement without showing any evidence of psychological harm, regardless of their sex, age, living arrangements, the degree they were pursuing, or the academic year they were in. This is consistent with Fínez and Morán-Astorga [26], who state that children and adolescents have a more positive and more resilient response to adversity.

These results might be attributed to the short duration of the confinement, which lasted barely two months. However, this explanation is difficult to check because what few studies have been conducted on the relationship between the building of resilience and length of isolation have found very diverging data on the subject. The study by Hawryluck et al. [67] demonstrates that the post-traumatic effect of a confinement situation does depend on the length of said confinement. Consequently, one would be justified in deducing that there would have been negative emotional effects among the students analysed if the confinement had lasted longer, or that there might eventually be in case of a new confinement. Hence the importance of implementing educational policies geared towards maintaining in-class teaching.

The students who showed the highest rates of resilience as a function of the socio-demographic variables analysed presented the following profile: students, both male and female, aged between 17 and 21 years, who were living with people other than their parents, who were studying for degrees in the health sciences (although these data are not generalizable due to the small sample of health sciences students participating in this study). The data obtained do not show any consistent indication that the socio-demographic variables analysed can be used to define the construct of resilience. These results match those of Crespo, Fernández and Soberón [66], which show that socio-demographic variables have no significant relation with the construct of resilience.

The data obtained on the factors shaping the definition of resilience showed these factors to be significantly and directly related with the concept of resilience. In other words, the higher a factor, the higher the level of resilience among the students analysed, and vice versa. This fact proves how well adjusted the factors are to the construct.

Factor 1, “persistence/tenacity/self-efficacy”, can be defined as the ability to handle the challenges of a situation, to look on the bright side, and to perceive oneself as a strong person. Thus, higher rates of persistence/tenacity/self-efficacy are found among older students, most of them male, who were pursuing health-related or postgraduate degrees, and who spent the confinement either living along or with people other than their parents. Students with high and solid levels of persistence also possessed high and solid resilience, but there is also an important percentage of students with low persistence who still had high resilience. This suggests—as do Seligman [28]; White, Driver and Warren [29]; and Liu, Li, Ling and Cai [31]—that when people have traumatic experiences, they adapt to these new situations and view themselves as capable individuals, and this, in turn, allows them to subsequently adapt more quickly to new adverse situations. Therefore, the fact that some students with low persistence still presented high resilience [68] might be explained by their having been through similar situations previously.

Factor 2, "control under pressure", can be defined as the ability to be in control of adverse or stressful situations by taking decisions, turning problems into opportunities, and regulating one's emotions. In the present context, those showing higher control under pressure were the oldest (over 25) and the youngest students (17–20 years), males, who are pursuing health-related degrees, and were living alone. As with the previous factor, higher control under pressure equals higher resilience. Indeed, no student with low control under pressure had high resilience. Likewise, no student with solid control under pressure showed low resilience. This factor, therefore, appears to correlate with the ability to self-regulate and to control situations in order to take decisions. It is all the more surprising, then, that some students have low control under pressure and, at the same time, high resilience. A possible explanation could be that health-care students were more accustomed to stressful situations. This made them better adapted to the confinement in spite of not perceiving themselves as possessing strong control under pressure. This would be in line with Jackson and Usher [69], who maintain that nursing and health-care professionals are continuously working in stressful environments, which makes them more likely to be able to respond to the pandemic in a more resilient way. The fact that students who are living alone showed high rates of control under pressure and resilience in this study contradicts the results presented by Ballverka et al. [11], which show that students who lived with family during the confinement adapted better to face the stressful situations it generated.

Factor 3, "adaptability and support networks", is the ability to cope with and adapt to change that stems from possessing a will to succeed and having supportive relationships. In the context of this study, the highest rates of adaptability and support networks were found in the youngest age group, first-year female students pursuing health-care or postgraduate degrees, and living alone. The majority of students who participated in this study showed a significant relation between the factor "adaptability" and the construct of resilience, which is in line with the research conducted by González-Méndez, Ramírez-Santana and Hamby [70] and Feeney and Collins [71]. Other studies also found support networks and resilience to be directly related [72,73]. It is possible that the students with high adaptability and support networks maintained certain habits from their daily lives, albeit with light adaptations to the new reality. This high adaptation to the new reality of the confinement exerts a positive effect on physical and psychological well-being [1,3]. Also, being able to take classes online and to preserve certain studying habits as well as maintain social relations with classmates (perceived social support) may explain the high adaptability shown by the participants in this study [11]. Curiously, there was once more a percentage of students who simultaneously had low adaptability and high resilience. Conversely, some students had high adaptability and low resilience. These two contradictory situations could be explained by these students not meeting the criteria for adaptability (prior positive experiences, supportive relationships, and the ability to adapt and cope) but, as some studies show, obtaining high resilience scores on other variables contained in the other factors.

Factor 4, "control and purpose", can be defined as a person's ability to act with balance, decision, and a clear sense of purpose in spite of unfavourable circumstances. Here the highest rates of control and purpose appeared in students from the youngest age group, both male and female students, who were studying for degrees related to health care, and who were living alone. It is worthy of note that the students who were living alone showed no low control and purpose at all, which would indicate that they perceived themselves as balanced, purposeful people in the face of confinement. This contradicts Cao, Fang, Hou, Han, Xu, Dong and Zheng [7], who found students who were living alone to have higher rates of anxiety and post-traumatic stress caused by COVID-19. It would be interesting to examine the contextual variables to find an explanation for this difference. A possible explanation could be that people living alone have no one else to continuously discuss their situation with and fuel each other's feelings of frustration and fear [35]. Not having other people around also prevents conflicts and/or arguments with them. In short, living alone helps to ease certain tensions that cause negative feelings [11]. Another interesting finding to emerge from this study is that the students with the highest rates of control and purpose and resilience were the youngest ones. This could be directly related with how fear is perceived. According to some studies on evolutionary psychology, young people have fewer cognitive tools for assessing threating situations, which allows them to view the confinement with less fear. Since fear is a prime contributor to emotional problems [12], young people's lower fear leads them to score higher on resilience.

6. Conclusions

Foremost among the conclusions of this study is the generally high level of resilience among its sample of university students in a situation of confinement. This high level is independent of sex, age, living arrangements, academic year and/or degree.

The results obtained from the answers provided by the university students during the COVID-19 confinement showed a significant relationship between the four factors analysed and the construct of resilience. According to the date, students over 25 years, for almost all factors, and males, with a not very significant difference with female students, had higher scores on the construct of resilience. Students living alone or with people other than their parents also perceived themselves as more resilient. The students from the health sciences evinced a higher ability to adapt to change, to deal with the challenges posed by the confinement, to see the bright side of things, and to perceive themselves as capable of rebounding from difficult situations. This last conclusion should be confirmed by further studies with larger sample sizes.

The answers to the questions asked by this study show that the majority of the participating students considered themselves to possess high or solid resilience. Their most salient strengths were the ones associated with factors 1 and 4. In other words, they viewed themselves as strong individuals capable of dealing with the challenges posed by the confinement and of seeing the bright side of things. Most of them also felt capable of acting with balance, decision, and a clear sense of purpose in spite of any unfavourable situations they might have been going through.

Finally, socio-demographic variables have proven not to contribute in any significant way to the building of resilience during confinement. However, there were two variables that throughout the study obtained higher scores on all factors—degree and living arrangements—but these results cannot be generalised because of the limited size of the sample.

This study demonstrated the importance of social contact as a protective factor against the increases in stress, anxiety, fear, loneliness and other negative feelings experienced by university students during the forced confinement (COVID-19), as also described by other studies. Therefore, all parties involved need to re-examine educational policies and restrictive measures pertaining to school and university closures. Situations similar to the past confinement may occur in the future, so policies should be put in place to meet the needs that have been detected and thus limit the learning difficulties and the social and emotional effects that such situations can cause. More particularly, educational policies should tackle the learning gap, lack of resources, and absence of emotional support revealed by the different studies conducted on the subject at hand.

Future research should correct the confinement-related limitations which affected this study. First, larger samples should be used that can be extrapolated to the rest of the university population. Second, this study was not able to make a comparison with students who were not in a situation of confinement. This limitation should be addressed in the future. Third, samples should test for certain psychological and psychiatric criteria. Future research should look into the role of these criteria, determine the impact of isolation duration on self-perceived resilience, and broaden its scope to examine other stakeholders as well, such as basic education students.

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education sciences

Case Report

The Psychological Impact of the COVID-19 Pandemic in Remote Learning in Higher Education

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Abstract: Stressful events can cause a significant impact on education; however, it is not yet clear how the interplay between anxiety, work, and social dysfunction relates to learning impairments. In this study, we investigated the impact of the COVID-19 pandemic on students' learning and mental health. This study was conducted during four modules of a remote Psychopharmacology course between 5 October and 20 December 2020. We collected data from 28 Psychology undergraduate students at the University of São Paulo, Brazil. We used pre- and post-test multiple-choice questions to obtain a quantitative measure of learning. Students completed an online survey to report demographic information, functional impairment (Work and Social Adjustment scale; WSAS), generalized anxiety (Generalized Anxiety Disorder scale; GAD-7), coronavirus anxiety (Brazilian adapted version of the Coronavirus Anxiety Scale; CAS-BR), and self-perception with the remote lectures' methodology. In our sample, 42.9% of respondents experienced symptoms of generalized anxiety disorders (GAD-7 $\geq$ 15), and 53.6% had moderate to severe functional impairment (WSAS > 20). We also observed an overlapping profile of highly anxious and dysfunctional students. A chi-square test of independence revealed a relation between pairs of multiple-choice questions answers and GAD-7 scores, indicating that less anxious students were more likely to perform better in pairs of pre- and post-tests. Intriguingly, the correlational analysis suggested that students with moderate to severe functional impairment (WSAS scores > 20) were less likely to change from an incorrect to a correct answer to pairs of pre- and post-tests. This data suggests that psychological distress and anxiety states might influence students' ability to coordinate social and work activities and performance during remote learning. Although this study evaluated a small sample of students, our data highlights the importance of investigating anxiety and functional impairment measures as part of the remote-learning curriculum.

Keywords: Coronavirus Anxiety Scale; psychology; working and social adjustment scale; GAD-7; anxiety; functional impairment

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1. Introduction

Since May 2020, the world has been facing the COVID-19 pandemic, and students have faced severe alterations in routine worldwide. Brazil is one of the leading countries in the number of infections and deaths and, as of 20 December 2020, Brazil held the third most significant number of confirmed cases of COVID-19 in the world at 7,162,978 and the second most considerable rate of confirmed deaths from this disease at 185,650 deaths [1]. One of the few collective prophylactic measures nationally adopted in Brazil was the suspension of in-person learning activities. Specifically, most college courses were transferred to a remote environment to keep the undergraduate students actively enrolled in classes during social distancing [2].

In the face of the many constraints, uncertainties, and adversities related to the COVID-19 pandemic, mental health issues have gained public and research attention, with recent alarming rates of indicators of depression and anxiety [3–5]. Recent studies pointed out that the most affected groups were young adults, women, individuals with a previous mental disorder diagnosis, and individuals at higher risk from coronavirus [6–8]. Adaptability to remote learning during the COVID-19 pandemic can be challenging in many South American countries. Poor delivery of educational content to undergraduate students can make students anxious and trigger mental health disorders.

The main objective of this study was to determine whether high levels of anxiety and functional impairment impact students' learning performance in remote education during the COVID-19 pandemic. Our first aim was to assess the impact of psychological distress and anxiety on students' performance in pairs of pre- and post-classes multiple-choice questions. To test the working hypothesis that students with high levels of psychological distress and anxiety would have a negative performance during remote learning, we correlated changes from an incorrect to a correct answer to pairs of pre- and post-tests with psychometric instruments that measure functional impairment (Work and Social Adjustment scale; WSAS), generalized anxiety (Generalized Anxiety Disorder scale; GAD-7), and coronavirus anxiety (Brazilian adapted version of the Coronavirus Anxiety Scale; CAS-BR). Our second aim was to perform a qualitative analysis on protective factors that were likely to contribute to effective learning in the context of remote education during the COVID-19 pandemic. We analyzed students' perceptions of learning strategies to test the hypothesis that active methodologies (such as Information and Communication Technologies; ICT) can overcome dysfunctional and anxiogenic states to favor the learning process.

2. Materials and Methods

2.1. Ethics

The ethics committee of the Faculty of Philosophy, Sciences, and Letters of Ribeirão Preto at the University of São Paulo (FFCLRP/USP; CAAE 32077620.1.0000.5407) approved this study.

2.2. Experimental Design

Measures of learning were obtained quantitatively using pre- and post-test multiple-choice questions within a virtual learning environment. We developed 4–6 multiple choice questions for each of the 4 study modules allocated in a one-semester psychopharmacology course. All questions encouraged critical thinking about psychopharmacology and clinical knowledge relevant to clinical psychology practice. Sets of study material were selected for each module and made available to students at the University of São Paulo online platform one week before the online lectures. Students answered the same multiple-choice questions at an online platform (Socrative) before (pre-test) and after (post-test) a two-hour talk. At the end of the course, students were asked to complete an online survey at Google Forms platform to report demographic information, functional impairment, generalized anxiety, and self-perception with the methodology of the online lectures.

2.3. Participants

A total of 28 Psychology undergraduate students of the Faculty of Philosophy, Sciences, and Letters of Ribeirão Preto, University of São Paulo, participated in this study. The remote psychopharmacology course occurred between 5 October and 20 December 2020. Before providing informed consent, participants were informed about the nature, objectives, risks/benefits, and anonymity of responses for this study. Inclusion criteria were age 18 and voluntary participation in the survey without compensation.

2.4. Measures

2.4.1. Basic Information

Participants reported their age and history of anxiety disorder. Students were also asked to rate, using a 5-point anchored Likert scale (1 = Strongly disagree to 5 = Strongly agree), if they had studied before synchronous classes as instructed (e.g., “I always studied the topics suggested by the professor before the synchronous online lecture”).

2.4.2. Psychological Effects of the Coronavirus Outbreak

Students were asked to rate, using a 4-point time anchored scale, how often they experienced the psychological effects of preoccupation (1 = 1 to 3 h, to 4 = 7 h or more) and fear (1 = less than 1 or 2 days, to 4 = almost every day) of the coronavirus outbreak (Lee, 2020). Coronavirus preoccupation was measured by the item, “Over the last two weeks, how much time did you spend thinking about or watching media about coronavirus?” Coronavirus fear was measured by the item, “Over the last two weeks, how often have you experienced significant anxiety, fear, or worry about coronavirus?”

2.4.3. Coronavirus Anxiety

The Brazilian adapted version of the Coronavirus Anxiety Scale is a psychometric instrument used to measure coronavirus-related fear and anxiety [3,18]. The CAS-BR items measure physiologically-based symptoms experienced when triggered by coronavirus-related information and thoughts. Using a 5-point time anchored scale (1 = not at all to 5 = nearly every day over the last two weeks), students rated how frequently they experienced each anxiety symptom. The original CAS study reported that CAS exhibited good diagnostic properties with an optimized cut score of $\geq$9 (90% sensitivity and 85% specificity) to classify anxious adults with dysfunctional anxiety [9]. Lee’s replication study proposed to lower the CAS cut-off score to $\geq$5 when assessing the general population [10]. In the Brazilian study, Youden indices were all very low (<0.50) and authors were unable to identify the optimal cut-score for psychiatric screening purposes [3]. Therefore, we did not use a cut-score for measuring coronavirus anxiety in our study sample. The CAS-BR exhibited good internal consistency reliability (α = 0.83) in this study.

2.4.4. Generalized Anxiety

The adapted version of the Generalized Anxiety Disorder scale is often used to indicate clinical symptoms of generalized anxiety [11]. Students were asked to rate seven items of the GAD-7, using a 4-point time anchored scale (0 = not at all to 3 = nearly every day), regarding how frequently they experienced symptoms of generalized anxiety over the past two weeks. GAD-7 cut points of 10 and 15 can be interpreted as representing moderate and severe anxiety levels, respectively. The Brazilian adaptation of the GAD-7 presented an excellent indicator regarding validity and reliability in previous studies [12]. GAD-7 exhibited good internal consistency reliability in this study (α = 0.88), according to previous studies [3,9,13].

2.4.5. Functional Impairment

The adapted version Work and Social Adjustment Scale (WSAS) is a psychometric instrument used to measure functional impairment [14]. Students were asked to rate five items of the WSAS, using a 9-point severity scale (0 = not at all to 8 = very severely), regarding how much impairment they experienced due to fear and anxiety over the coronavirus (e.g., “Because of my fear and anxiety over the coronavirus, my ability to work or study is impaired.”). The WSAS is a five-item scale that measures (1) the ability to work or study; (2) home management; (3) social leisure activities; (4) private leisure activities; and (5) the ability to form and maintain close relationships with others. Students were stratified by severity based on WSAS ratings [14]: a WSAS score above 20 suggests moderate to severe psychopathology; scores between 10 and 20 are related to significant functional impairment, and scores below 10 appear to be related to subclinical symptomatology.

According to previous studies, this adapted scale exhibited good internal consistency reliability ($\alpha = 0.85$) [3,4,8].

2.4.6. Students' Perception of Learning Strategies

Students rated, using a 5-point anchored Likert scale (1 = Strongly disagree to 5 = Strongly agree), 9 questions relating to their perceptions of answering pairs of multiple-choice questions in online lectures in structuring or advancing their learning (e.g., "I felt that I learned more during classes when I answered the questionnaires").

2.5. Statistical Analysis

The demographic and psychometric characteristics of the sample were summarized as means (M) and standard deviations (SD). Continuous data normality was checked out with the Shapiro–Wilk test and analyzed using independent samples t-test and Pearson's correlation as indicated. Pairs of answers to multiple-choice questions were treated as categorical data (expressed as proportions) and analyzed using Pearson's chi-square test of independence. Pairs of multiple-choice questions were normalized to the maximum number of questions that each student answered in all four study modules for correlations with CAS-BR, GAD-7, and WSAS scores. Spearman's rank correlation coefficient assessed the correlation between continuous variables, normalized (proportions), or ordinal data (coronavirus fear and preoccupation). Venn diagrams were constructed online [15]. Data were analyzed using JASP (Version 0.14.1, USA), and significant results were considered when $p < 0.05$.

3. Results

3.1. Participants

The study's sample consisted of 20 women (71.4%) and 8 men (28.6%). Students had a combined mean age of 21.2 (19–26). There was no age difference between women and men ($t(26) = 1.11$, $p > 0.05$). The independent samples t-tests revealed that the total CAS-BR, GAD-7, and WSAS scores were not different between gender ($t(26) = 1.48$, $p = 0.15$; $t(26) = 0.95$, $p = 0.36$; $t(26) = 0.59$, $p = 0.55$, respectively). Therefore, data from men and women were pooled for the subsequent analysis. Most of the participants reported never being diagnosed with an anxiety disorder (85.7%).

3.2. Psychological Effects of the Coronavirus Outbreak, Generalized Anxiety, and Functional Impairment

Our data demonstrated good convergent validity between all psychometric instruments used in this study (Table 1). In our sample, 42.9% ($n = 12$) of the students had severe anxiety indicators according to GAD-7 scores ≥ 15. Furthermore, 53.6% ($n = 15$) of the students had moderate to severe functional impairment according to WSAS scores > 20. Although we did not use a cut-score for measuring coronavirus anxiety in this study, the averaged CAS-BR scores in our sample (M = 2.75, SD = 3.17) were very similar to our previous study [3].

Most of the students spent 1 to 3 h ($n = 15$; 53.6%), followed by 3 to 5 h ($n = 7$; 25.0%), 5 to 7 h ($n = 4$; 14.3%), and 7 h or more ($n = 2$; 7.1%), thinking about and/or watching media about the coronavirus. Coronavirus preoccupation correlated positively with GAD-7 but not with CAS-BR and WSAS scores (Table 1). When asked about anxiety, fear, or worry about the coronavirus during the past two weeks, most of the participants spent less than a day or two ($n = 10$; 35.7%) or 3 to 7 days ($n = 10$; 35.7%), followed by nearly every day feeling elevated anxiety about the coronavirus ($n = 8$; 28.6%). Coronavirus fear correlated positively with CAS-BR, WSAS, and GAD-7 scores (Table 1). There was a strong correlation between coronavirus preoccupation and fear (Table 1).

Table 1. Matrix correlation between psychological scales (items 1 to 3), psychological effects of coronavirus pandemic (items 4 and 5), multiple-choice questions (items 6 and 8), and respective means and standard deviations. Pearson's chi-square values are shown across the table (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, # $p = 0.057$).

	1	2	3	4	5	6	7
Psychological constructs							
1. CAS-BR	—						
2. GAD-7	0.66 ***	—					
3. WSAS	0.64 ***	0.72 ***	—				
Psychological effects							
4. Coronavirus preocupation	0.28	0.42 *	0.37	—			
5. Coronavirus fear	0.54 **	0.59 ***	0.56 **	0.77 ***	—		
Multiple-choice questions							
6. Correct to correct	−0.13	0.14	0.22	−0.16	−0.08	—	
7. Incorrect to correct	−0.11	−0.29	−0.38 *	0.06	−0.08	−0.66 ***	—
8. Other	0.30	0.18	0.20	0.15	0.20	−0.36 #	−0.40 *
Mean	2.75	13.86	20.57				
SD	3.17	5.02	9.29				

Psychological constructs are represented by the Brazilian Coronavirus Anxiety Scale (CAS-BR), Generalized Anxiety (GAD-7), and Working and Social Adjustment Scale (WSAS). Psychological effects are represented by coronavirus preoccupation and fear. Multiple-choice questions are represented by correct to correct, incorrect to correct, and other (incorrect to incorrect or correct to incorrect) answers in the pre-test and the post-test.

3.3. Analysis of Student's Performance on Multiple-Choice Questions

Since not all students who completed the survey answered all the pre- and post-module multiple-choice questions of all four evaluated study modules, only students who provided answers to all the pre- and post-tests in a particular study module were included in our analysis. Therefore, we used 422 pairs of pre- and post-tests, and 138 pairs of questions were excluded from our analysis. First, we checked if frequencies of correct and incorrect answers collected in the pre-test and the post-test were independent of the number of multiple-choice questions collected in one module ($n = 16$), two modules ($n = 52$), three modules ($n = 134$), and four modules ($n = 220$) (Figure 1). The Chi-square test revealed that frequencies of correct or incorrect answers were independent of the number of questions collected in both the pre-test (χ^2 (3) = 3.72, $p = 0.29$; Figure 1A) and the post-test (χ^2 (3) = 3.46, $p = 0.32$; Figure 1B). Therefore, although not all students answered the same number of pairs of questions during this study (i.e., some students did not participate in all study modules), the proportion of correct and incorrect answers were consistent in all four study modules. We then pooled the frequencies of correct and incorrect answers and found a strong association between educator's synchronous intervention and correct/incorrect answers (χ^2 (1) = 29.74, $p < 0.001$; Figure 1C). The percent of correct answers increased from 62.3% ($n = 263$) in the pre-test to 79.4% ($n = 335$) in the post-test. Likewise, the percent of incorrect answers decreased from 37.7% ($n = 159$) in the pre-test to 20.6% ($n = 87$) in the post-test, confirming the potential utility of pre- and post-test multiple-choice questions as a measure of learning.

A more detailed analysis (Figure 1D) demonstrated that 56.4% ($n = 238$) of responses to pairs of multiple-choice questions were correct, suggesting that students consulted the available online material one week before the online lectures. In addition, a total of 23.5% ($n = 99$) of responses to pairs of pre- and post-tests were changed from incorrect to correct, suggesting that students could learn new content. Other combinations (20.1%) of multiple-choice questions (i.e., correct to incorrect or incorrect to incorrect; $n = 25$ and 60, respectively) also occurred, suggesting that students were either uncertain about the correct answer or were not engaged in the learning tasks. In addition, we cannot exclude potential issues of failure in delivering learning content.

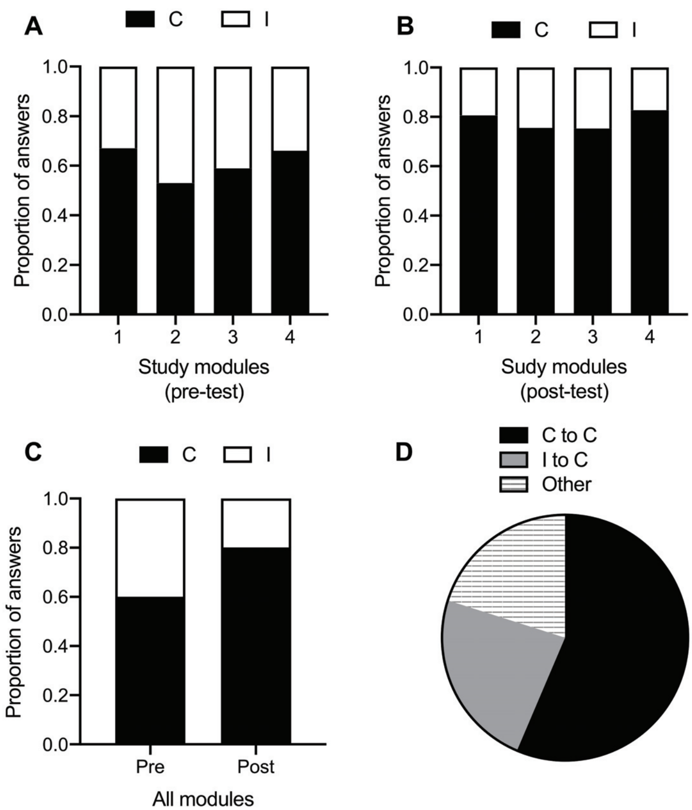

Figure 1. Correct and incorrect answers in study modules. As evidenced by the module-to-module comparison (**A**,**B**) and overall frequency of correct answers (**C**), there is an increase of correct answers from the pre-test to the post-test. Frequencies of correct (black) and incorrect (white) answers shown in the pre-test (**A**) and the post-test (**B**) also demonstrate data were independent of the number of multiple-choice questions collected in modules. The percent of changed answers (**D**) from correct to correct (black) were 56.4% (n = 238), incorrect to correct (gray) were 23.5% (n = 99), and other combinations of multiple-choice questions (stripes) were 20.1% (encompassing both correct to incorrect and incorrect to incorrect; n = 25 and 60, respectively).

3.4. Impact of Generalized Anxiety and Functional Impairment on Student's Performance on Multiple-Choice Questions

We used the GAD-7 and WSAS scales to check how students who experienced clinically significant impairment because of generalized anxiety (GAD-7 scores $\geq$ 15) and functional impairment (WSAS scores > 20) performed across all four study modules (i.e., correct/correct, incorrect/correct, and other pairs of multiple-choice questions). Because some students who completed the survey did not participate in all four study modules, we compared the number of questions each student answered according to GAD-7 and WSAS cut-scores. Our results indicated that all students answered to a similar number of pairs of multiple-choice questions in all four study modules according to GAD-7 (t(26) = 0.38, $p < 0.05$; Figure 2A) and WSAS cut-scores (t(26) = 0.89, $p < 0.05$; Figure 2C).

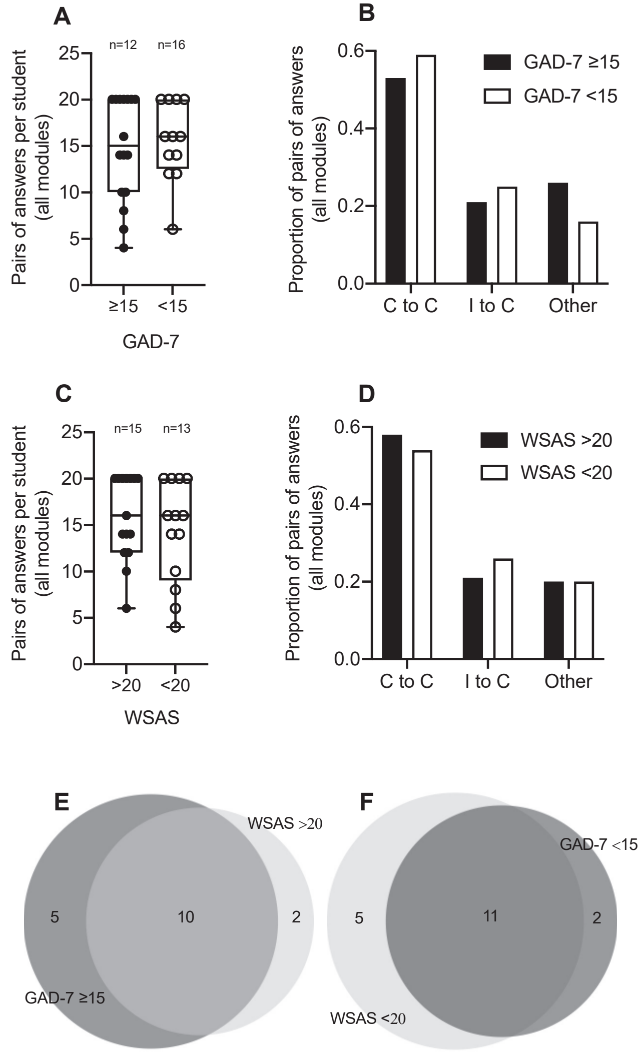

Figure 2. Profile of students' performance in pairs of multiple-choice questions according to GAD-7 and WSAS scores. Students with low anxiety scores (GAD-7 < 15; white) were more likely to answer correctly in tests, whereas students with moderate to severe functional impairment (WSAS scores > 20; black) were less likely to change from an incorrect to a correct answer in the multiple-choice test (**A**–**D**). Box plot distribution of pairs (pre- and post-test) of answers per student in all four modules (**A**,**C**) and proportion of pairs of answers of multiple-choice answers (**B**,**D**) were shown according to GAD-7 and WSAS severity cut-scores. Correct to correct (C to C), incorrect to correct (I to C), and other combinations (both correct to incorrect and incorrect to incorrect) were represented in the histogram chart. GAD-7 scores $\geq$ 15 and WSAS > 20 (black) cut-scores show moderate to severe anxiety and functional impairment indicators. Venn Diagrams (**E**,**F**) show the proportion of students categorized in the cut-score psychometric instruments and the overlap of GAD-7 $\geq$ 15 and WSAS > 20 scores and GAD-7 < 15 and WSAS < 20 scores.

A chi-square test of independence was performed to examine the relationship between pairs of answers and GAD-7 or WSAS. The relation between pairs of answers and GAD-7 was significant (χ^2 (2) = 6.77, $p < 0.05$), indicating that students with GAD-7 scores < 15 were more likely to be able to identify correct answers, to change from an incorrect to a correct answer, and to make more minor mistakes (i.e., change from correct-to-incorrect or incorrect-to-incorrect answers) in pairs of multiple-choice questions (Figure 2B). The relation between pairs of answers and WSAS was not significant (χ^2 (2) = 1.25, $p < 0.05$; Figure 2D). Venn diagrams indicate participants' relationship with the study sample with scores above (Figure 2E) and below (Figure 2F) GAD-7 and WSAS cut-scores.

There was no correlation between GAD-7 scores and answers to pairs of multiple-choice questions (Table 1). Interestingly, there was a negative correlation between WSAS scores and the percent of answers to pairs of pre- and post-tests that were changed from incorrect to correct (Table 1), suggesting that higher WSAS scores impact students' ability to learn new content.

3.5. Students' Perception of Learning Strategies

Students were asked to rate five questions relating their perceptions of the benefit and usefulness of assigning pre- and post-test multiple-choice questions in online lectures in structuring or advancing their learning. Most students considered their experience with this methodology as positive (Figure 3). Overall, students either agreed or strongly agreed that the teaching method helped develop study skills. They reported that multiple-choice questions helped guide the essential concepts in the lecture, and they felt they learned more when answering the questionnaires.

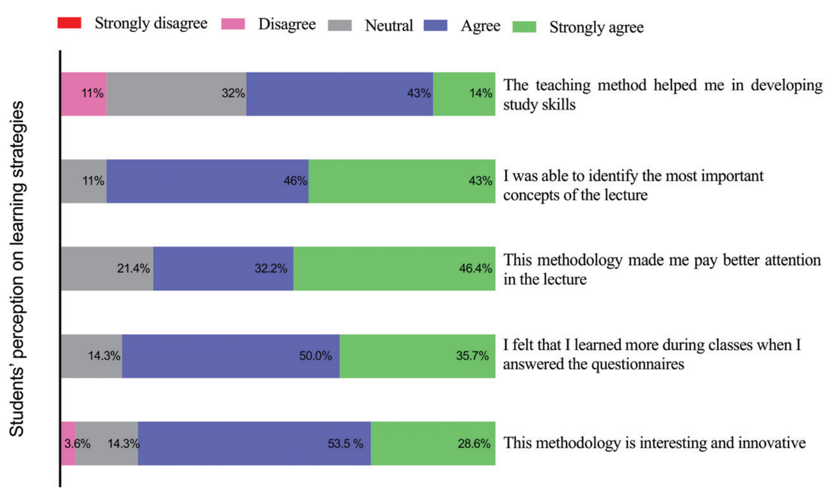

Figure 3. Most students considered the ICT methodology a positive experience in structuring or advancing their learning. Students were asked to rate their perceptions through a 5-point agreement scale, ranging from strongly disagree to strongly agree, in questions regarding the methodology, including the teaching method, the use of multiple-choice questions, and the synchronous online lectures.

4. Discussion

This study examined the impact of ICT on students' learning during a remote psychopharmacology college course during the COVID-19 pandemic and its relationship with students' mental health. A high proportion of students were under elevated anxiety levels and functionally impaired at the end of the academic year during the COVID-19 pandemic. Multiple-choice questionnaires showed that students could still learn new content during remote learning. Remarkably, psychometric measures of generalized anxiety (GAD-7) and functional impairment (WSAS) were associated with lower performance in measures of learning. Our study highlights the importance of investigating anxiety and functional impairment indicators during COVID-19 pandemic remote learning. According to students' perception of learning strategies, it is likely that the use of active learning methodologies (i.e., the teaching method, the use of multiple-choice questions, and the synchronous online lectures) was able to encourage students' engagement. Different from the passive learning approach, active learning strategies contribute positively to remote teaching. Brazil has the world's highest prevalence of anxiety (WHO, 2017). The COVID-19 pandemic aggravated the symptoms of anxiety and distress in the Brazilian population [3,16,17]. Specifically, women and young adults were amongst the most affected groups [3,6–8]. Studies conducted with college students in Brazil and other countries demonstrated higher anxiety, depression, and stress levels. Therefore, the COVID-19 pandemic has had a negative psychological impact on students.

4.1. The Impact of Psychological Distress and Anxiety on Students' Performance in Pairs of Pre- and Post-Classes Multiple-Choice Questions

The CAS-BR is an important psychometric instrument to measure coronaphobia in Brazilian adults. It can be used as a parameter to estimate the psychological and psychiatric impact of the COVID-19 pandemic on the Brazilian population. The CAS-BR items (dizziness, sleep disturbances, tonic immobility, appetite loss, and nausea/abdominal distress) represent physiological symptoms related to clinically elevated fear and anxiety [9]. CAS-BR scores in this study sample were very similar to what we observed in our previous study [3]. Our data demonstrated that CAS-BR scores correlated positively with generalized anxiety (GAD-7), functional impairment (WSAS), and fear about the coronavirus. Unexpectedly, there was a lack of correlation between the CAS-BR scores and coronavirus preoccupation. This finding was also reported in another study and might suggest that our sample shows a more complex behavioral manifestation [4]. Therefore, the results of our study demonstrated that CAS-BR scores were related to adverse psychological effects of the COVID-19 pandemic and support the construct validity of the CAS-BR and replicate previous findings.

According to the original study [11], GAD-7 cut points ≥ 15 can be interpreted as representing severe anxiety levels. Our study demonstrated that 42.9% of the students were likely to exhibit generalized anxiety symptoms according to this cut-score. A high proportion of students (53.6%) also presented moderate to severe functional impairment indicators according to WSAS scores ≥ 21 [14]. This result indicates that the significant distress due to the pandemic could contribute to functional impairment. Students showed high anxiogenic and dysfunctional scores, but an overlap of these psychological states is further represented by a significant correlation between the GAD-7 and WSAS scores. Functional impairment is often considered in tandem with anxiety during clinical assessment. Despite the multidimensional nature of the first, it is argued that GAD-7 seems to be more deeply related to the social dysfunction dimension [18]. However, extremely high scores on the GAD-7 scale may be related to a decline in overall functional status [11]. Surprisingly, in our study, most of the participants reported they have never been diagnosed with anxiety disorder, and healthy controls usually present low scores on these scales [19]. WSAS and symptoms-based instruments are often combined in primary care mental health [20], but WSAS seems to address a more general aspect that is responsive to diagnostic scales [20,21].

A recent study in the US also showed that anxiety, depression, and anger symptoms predicted significantly more work and social adjustment problems in WSAS [22]. It has been shown that the GAD-7 and the WSAS scale items reveal a clear bi-factor pattern (general trait measured by the test overall, as well as specific or secondary traits measured by the subscales), with medium to high loadings on both general and individual factors. Those psychometric instruments enable assessing negative experiences that can include both anxiety and depressive states [20]. Therefore, our data add to the discussion that WSAS is a screening tool sensitive not only to clinical change but to different clinical subgroups, representing different levels of severity of mental distress.

We verified if exacerbated signs of generalized anxiety and functional impairment would impact students' performance at the end of the academic year. Overall, students showed a good performance in multiple-choice questions on all four study modules. The high percent of pairs of correct answers detected in both pre-test and post-test (56.4%) suggested that students engaged in active learning and consulted the available online material one week before the online lectures. This observation is also supported by the fact that many students agreed that “I always studied the suggested material before classes.” We also found that 23.5% of the responses to pairs of pre- and post-tests were changed from incorrect to correct, indicating that students could learn new content during remote teaching. Learning can be verified when the learner can present behavior that he did not present before the teacher’s intervention [23]. Therefore, the difference between the learner’s performance before and after the teacher’s intervention is a valuable measure of learning and suggests that students learn new content [24].

It is broadly accepted that emotional context modulates action–outcome contingencies in an uncertain environment. Previous studies demonstrated that disrupted learning ability is present in high trait social anxious individuals [25,26]. In addition, chronic stress is known to impair retrieval and working memory and contribute to the development of anxiety [27]. Considering the great adversities imposed by the pandemic and the highly dysfunctional scores, many students still cope with learning. The methodology we used likely contributed to overcoming dysfunctional and anxiogenic states and contributed to the learning process.

Even though most students learned despite the high dysfunctionality, lower GAD-7 scores were associated with better learning performance in pairs of multiple-choice questions. We also found a negative correlation between WSAS scores and the percentage of pairs of pre- and post-tests that were changed from incorrect to correct. Taken together, our data suggest a negative association between anxiety-related psychological distress and students’ ability to learn new content. Therefore, this data highlights the need to investigate the impact of anxiety and dysfunctionality on students’ learning during remote teaching.

4.2. Protective Factors That Can Contribute to Effective Learning in the Context of Remote Education

Anxiety disorders are related to disrupted learning in uncertain environments [28,29]. A large-scale longitudinal epidemiologic assessment of college students in China demonstrated that mental health concerns significantly increased throughout the pandemic [30]. Anxiety levels were mapped in medical and non-medical students during remote and hospital classes in the United Arab Emirates during the pandemic. Interestingly, non-medical students reported higher levels of anxiety before and after online learning than medical students. While medical student anxiety levels decreased following online learning, non-medical students’ anxiety levels increased [31]. These results could foster discussions on protective and teaching strategies that support education in contexts of adversity.

As a strategy to keep the fundamental interactions and the exchange of experience in the virtual environment, the importance of tutorial mediation and the strengthening of the self-learning process associated with the mediation should be highlighted. Following up student activities, motivating learning, guiding, and providing conditions for autonomous learning could significantly contribute to student engagement and functionality in this new college format [32].

Educators, more than ever, are struggling to adapt to remote classes and keep a supportive and engaging learning environment [33]. Online platforms and learning tools became essential in higher education to establish active communication between students and educators [2,33]. Therefore, a dynamic learning environment is necessary for proper content delivery and strengthening social ties during social distancing. Even though face-to-face teaching is irreplaceable, it is needed to explore ICT in the learner–content interaction, learner–instructor interaction, and learner–learner interaction [34]. Formative assessment in higher education is essential to enhance teaching and learning practice, especially in a remote environment. Educators need to adopt personalized, self-tailored, active methodology strategies to build contextualized active and meaningful learning. Unlike the traditional education model based on passive content exposure, active learning can increase cognitive flexibility and overcome rigid mental models associated with inefficient automatic responses [35]. Therefore, when students are encouraged to learn autonomously and actively, they are more likely to connect with new knowledge to previous knowledge and acquire new problem-solving skills.

Students should be the protagonists of their learning to develop socioemotional skills such as critical thinking, problem-solving, cooperation, mutual respect, perseverance, and flexibility [36,37]. Online interaction is an essential resource for communication between professors and students, and, if used correctly, it can maintain or even strengthen social bonds during the physical distancing period. Thus, the combination of active teaching methodologies (including those mediated by ICT), immediate feedback during remote teaching, and test-taking strategies can be influential protective factors for the psychological instability generated by the pandemic in the educational field.

It is possible to assess the effectiveness of the teaching method by applying the same multiple-choice questions before and after each class using software that provides real-time feedback. The first round of questions is applied before the lecture and can access students' previous knowledge. In a well-designed methodology, correct and incorrect answers guide the professor on concepts to emphasize during teaching. On the other hand, the second round of the same multiple-choice questions provides the students' performance and the ability of the instructor to teach the concepts he considers relevant to a particular topic [38]. Therefore, learning can be verified when the learner can present behavior that he did not present before the teacher's intervention [23]. Furthermore, the difference between the learner's performance before and after the teacher's intervention is a valuable measure of learning [24].

Although this study was conducted in a small sample, educational technologies based on active methodologies favored the educational process more effectively and autonomously. This observation is supported by the fact that many students had a very positive impression of strategies used in the classes. Because students have different learning rates, it is essential to allow sufficient time to access the learning materials. Flexible schedules, follow-up activities, and student development should be considered to minimize the psychological impact caused by the COVID-19 pandemic. In other words, the educational process should focus on human development. Strategies to increase interactions within the virtual learning environment, tutorial mediation, and strengthening the self-learning process should also be used. Follow-up activities, tutorial guidance, and autonomous learning could significantly contribute to students' engagement and functionality during remote learning. In addition, it is suggested that incorporating students' perspectives (such as interests, tastes, and expectations) contribute to the learning process [39]. Collectively, these results presented here show the importance of adaptations of teaching-learning methodologies during the pandemic period and demonstrate that online classes cannot be a repository of digital content.

Our study has several limitations. First, we evaluated a small sample in a particular context of remote learning. Therefore, generalization of the results requires future studies. A control experiment conducted in a non-pandemic period would help to understand better the impact of psychological distress and teaching methodology in remote learning. Second, we were unable to map differences across gender and ages. Third, despite the general satisfaction with the methodology, we cannot exclude potential failure problems in delivering learning content. Nevertheless, this study has several strengths. Although we collected data in a small sample, we were able to run within the experimental design and correlate students' performance in multiple-choice questions with psychometric tools. It is worth noting that when we look closely to the student sample in our previous study [3]; n = 104; age: M = 24.50, SD = 5.63), CAS-BR (M = 2.53, SD = 2.88), GAD-7 (M = 11.42, SD = 5.29), and WSAS scores (M = 17.50, SD = 9.81) were very similar to the sample used in the current study (n = 28, see Table 1).

5. Conclusions

In conclusion, psychometric measures of generalized anxiety and functional impairment were associated with lower performance in measures of learning. Therefore, the data presented here highlight the need for college institutions to investigate how psychometric instruments relate to learning in disruptive situations such as the COVID-19 pandemic as part of the remote-learning curriculum. Furthermore, according to students' perception of learning strategies, we conclude that active learning strategies could support students and promote psychological protection in adverse contexts. Even teachers who already used online environments in their practices had to abruptly adapt to the new teaching context with the advent of emergency remote education [40]. Thus, there is a need for a more in-depth discussion on teacher training and the role of pedagogical practices for remote teaching. On the other hand, new contexts and necessities in education generate learning communities that facilitate and perpetuate learning. Interaction and collaboration between educators and learners must occur in a dynamic, flexible, and adaptable fashion.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data of this article will be made available by the authors without undue reservation.

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Thoughts on the Future of Higher Education in the UK: A Personal View with a Historical Context

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Abstract: Before the effect of the COVID-19 Pandemic, there had been continued debate about the future of Higher Education (HE) in the UK. It is now accepted that the effect of the pandemic will have a long-lasting effect on HE in the UK and elsewhere. This paper addresses the changes that are currently taking place, based on a strategy that aims to develop a future knowledge-based economy, following the UK governments 2019 landmark review of HE. It explores the underlying parallels between the current situation and certain historical events that catalysed the development of a new approach to HE in the past, which is very relevant today. In this context, the paper discusses why major changes in UK HE provision is now required as a response to the fact that although the cost of education is rising, employers are reporting that graduates are increasingly unprepared for the workplace. In this respect, the paper addresses a model for HE that focuses on 'earn-as-you-learn' apprenticeships and work-place-based learning. The key to this is the emphasis that the UK government is now placing on funding new 'Technological Colleges', in which students are trained by experts from the industry on a contractual basis, rather than by university academics with tenured positions.

Keywords: Higher Education; history of education in England; apprenticeship schemes; The Triple Helix Concept; change management; technological colleges; IT in education

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1. Introduction

Over the past few decades, the university sector has undergone a number of radical changes in which the search for an institutional competitive advantage has required new strategies to be considered [1]. However, given the economic conditions that prevail, and, in regard to the response of universities to COVID-19 [2], while the cost of Higher Education (HE) is rising, employers are reporting that graduates are increasingly unprepared for the workplace [3]. One of the underlying reasons for this is that the large majority of university staff have little or no experience in industries or the 'University of Life' that exists beyond the comfort zones of their 'Ivory Towers', leading to many universities that are not fit for purpose, e.g., [4]. Moreover, they have rarely been trained in modern teaching and training methods as is required to teach in a school, for example, and their skills base is often woefully inadequate and incompatible with industry requirements. Consequently, they are unable to move away from the rather superficial learning traditions of the past to the more in-depth training that is workplace-based oriented and employment focused. Another reason is the lack of parity of esteem that exists between vocational and university educational pathways, coupled with the poor managerial practices exercised throughout the university sector in general [5]. As a result of these issues, many governments are increasingly funding new and independent training centres that operate in close proximity to industies and the associated institutes and societies that support an industry, such as the Ada National College for Digital Skills, which opened its doors to students for the first time in September 2016 and was the first college of its type to be established in the UK since 1993 [6].

While universities have traditionally embraced the notion of continuous improvement for enhancing performance, it is now clear that new and fundamental changes involving radical innovations are required if the university sector is to come into parity with societal requirements. These changes will involve organisational strategies, investment, structure and operations in order to bring about a step change in the performance of universities and the value they serve. This is reflected in the UK government White Paper published in May 2016 and entitled 'Success as a Knowledge Economy: Teaching Excellence, Social Mobility and Student Choice' [7], which focuses on increasing employability and improved teaching methods to provide a boost to the UK economy. The plan is to incentivise universities to increase student employability as well as allowing more private organisations to award their own degrees. At the heart of the government proposals is a radical improvement in teaching quality through the 'Teaching Excellence and Student Outcomes Framework', which monitors and assesses different aspects of university teaching, including the student experience and the job prospects of graduates, aiming to encourage and reward universities and other educational establishments who improve their teaching standards and embed employability skills into the curriculum [8].

In regard to the issues discussed above, this work explores the future of HE in the UK in regard to the knowledge economy of the future. This is done by looking at some of the historical themes associated with HE, industry and workplace-based learning. In doing so, an attempt is made to formulate a model for Twenty-First Century HE, which is far removed from the present situation. The paper considers the principles of innovation dynamics as a driver for bringing about a step change in the organisational renewal of HE in which inter- and trans-disciplinary approaches become a natural manifestation of the notion that 'knowledge knows no boundaries' [9], unless that is, it continues to be embedded in a system that is based on what Karl Marx referred to as the 'Class Struggle' [10]. The basis for this is that education is an indispensable aid to economic and moral progress in society.

The paper embeds the 'solutions' considered in a historical context. This is done in order to reveal the similarities that have occurred in regard to education in the UK throughout its history since the first great reforms in education took place in the 1650s. Thus, the aim of this work is not to provide a narrative that is, in effect, a list of problems and solutions couched in the present (coupled with various forms of statistical information) but to 'paint' the issues of HE on a broad societal 'canvas' within a historical context. The purpose of this is to portray the similarities that exist between the present and the past, how education is related to the flux that exists between the two and the influx of new ideas that is predicated on the effects of multiculturalism. It is executed by introducing some important historical episodes that reflect the issues discussed. In this way, it is hoped that the views on education presented in this work are appreciated through a broader conceptual framework. The paper presents some ideas on how to 'stop the rot' and revitalise the UK HE sector for the sake of future generations and the UK economy, especially now that, following the Brexit on 1 January 2021, the country is a 'free agent'.

As the great English philosopher, Sir Francis Bacon once stated, "read not to contradict and confute, nor to believe and take for granted ... but to weigh and consider" [11]. In the context of this statement, the purpose of this paper is to provide some personal thoughts on education based on over thirty years of HE experience in the UK and overseas. In a 'nutshell', the aim of this paper is to weigh and consider the state of HE in the UK and consider the 'solutions' that are now required.

There are two principal points that should be taken into account in regard to the issues that are considered. They are as follows:

(i) University academic staff, not to mention the unions they belong to, will quite understandably vehemently disagree with the points of view discussed and the 'solutions' presented in this work. This is primarily because it is a direct threat to the status quo, their jobs and the comfort zones they inhabit, at least in the present. However, the ideas expressed in this work are not about the future of university academic staff, they are concerned with the future of their 'customers'.

(ii) Certain nation states who see fit to educate their children properly and are consequently experiencing considerable economic growth may find the material even more threatening than UK university staff. This is because they have come to understand that it is their interests that the UK carries on just the way that it is. It is this point that is significantly more important than that given in point (i) above.

2. Context

There are two specific quotes that are contextual to the themes explored in this work and express its core values. The first of these is from the 'Lord of Reason', Bertrand Russell, who said of education that: "We are faced with the paradoxical fact that education has become one of the chief obstacles to intelligence and freedom of thought" [12]. While an admirable statement, and one that probably rings true to many, especially those having to deal with the army of administrators that frequent today's universities, we must understand that this statement came from one the greatest minds of the Twentieth Century, a mind that was cultivated by the very best that any education system could offer at the time and, crucially, a mind that came from a very privileged background [13]. It is all too easy for those who have had a privileged life and achieved monumental academic success to criticise the very system that has nurtured them. On the other hand, it is the duty of those who are in such a position to do so; to point out errors in the system in order to forge solution that are for the betterment of society.

Another, which is complementary view to Russell's observations on education, is a statement from a very different source. In the 'Life of Dr Samuel Johnson' written by James Boswell in 1766, Johnson exclaims: "Talking of education, people now a-days have got a strange opinion that everything should be taught by lectures. Now, I cannot see that lectures can do so much good as reading the books from which the lectures are taken. I know nothing that can be best taught by lectures, except where experiments are to be shown. You may teach Chemistry by lectures; you might teach the making of shoes by Lectures" [14]. While one may argue that Chemistry and Cobbling are in fact very experimental and practical hands-on subjects that are not served well by lectures alone, the point that Johnson makes is well founded. It relates to the value of apprenticeships, where students learn how to actually do things and make things as opposed to being lectured to in the cloisters of a university and then being asked to sit an examination on the material that has been lectured to them. In this respect, the German-based apprenticeship scheme has been an ideal model to adopt for many years.

The strength of the German economy and its manufacturing base is well known. Consequently, Germany has the lowest youth unemployment in Europe; some 7%, which is one of the lowest world-wide [15]. Most countries now have an increasing focus on Apprenticeships. The G20 countries, in particular, have been promoting apprenticeship programs since the financial crash of 2008 in order to enhance their manufacturing industries, a correlation that is not a coincidence. The UK had been set to establish the order of three million apprenticeships by 2020 [16], a number that has failed to be achieved to date due to a range of factors, not least Brexit and the COVID-19 Pandemic.

Apprenticeship programs are nothing new. They were pioneered in parallel to the educational systems developed in communist countries after the Second World War and underpin much of the current industrial developments in China, for example. However, one of the first state-coordinated apprenticeship programs to be put into place by a government directive was in the England. The following section discusses the historical background to this, why it occurred and the effect that it had on the future development of England and the world beyond.

3. On the Revolution in English Education in the Seventeenth Century

"I beseech you, ... think it possible you may be mistaken" [17]. So said Oliver Cromwell in a letter to the general assembly of the Church of Scotland on 3 August 1650, one of England's most enigmatic and influential politicians [18]. Cromwell's statement (as given above) is arguably one of the most important of any. It applies to all aspects of the human condition, its frailty and above all, its fallibility. It is a statement that any and all scientists, philosophers and others should endeavour never to forget, irrespective of their deductive approach to experimentation and empirical data analysis and/or their induction through the powers of imagination and thought experiments. This is because it provides an intrinsic resistance to the faults that pervade human society, which is encapsulated in one of the 'Four Idols' of Sir Francis Bacon, namely, their 'Idola Specus' or 'Idol of the Cave'. This is where the problems of individuals, their passions and enthusiasms, their devotions, ideologies and theologies lead to misunderstandings in the true nature of things [19]. In regard to this particular idol, Francis Bacon could not have put it better than Oliver Cromwell: *... think it possible you* **may** *be mistaken*.

Oliver Cromwell needs no introduction; his influence and legacy is well known and documented. However, given the remit of this paper, there is an aspect of his contributions to English education that, by comparison with their other exploits, is not as well appreciated as it should be. It is for this reason that his contribution to English education is now addressed. This is not done out of historical interest alone but because this history has a close synergy to current times as shall be discussed later. However, in order to understand the effect that Oliver Cromwell had on English education, it is necessary to first of all put the times in which he lived into a more general context. This is basis for the material that now follows.

One of the most important works to influence the character of education in England was the *Novum Organum* by Francis Bacon [20] published in 1620. This work concerns the interpretation of nature and is a critical appraisal of the so-called scientific methods of the time. As Bacon states in the Novum Organum: "Those who have taken upon themselves to lay down the law of nature as a thing already searched out and understood, have therein done philosophy and the sciences great injury". In this regard, Bacon's underlying scientific philosophy was based on the principle of induction. This was the basis upon which Galileo Galilei presented the Heliocentric model in terms of a dialogue between the two opposing ideas, i.e., the Heliocentric verses the Ptolemaic Geocentric model, the latter case being the orthodox doctrine of the time. His book entitled *Dialogue Concerning Two Chief World Systems*, published in 1632 [21], led to the famous trial by the inquisition in which he was forced to recant his assertion that the Heliocentric model was superior and was consequently sentenced to life long house arrest.

The trial of Galileo Galilei represents an important icon of a 'phase transition' when the scientific traditions of southern Catholic Europe moved to northern Protestant Europe, especially in England and Holland. This is not because Catholic Europeans were innately lesser scientists, intellectuals and inferior thinkers. Far from it, in general, they were better educated and literate than most and by the very authority that perceived itself to be under the threat of modernity (a very common theme in history). It is because, having observed Galileo's difficulties with the 'Roman authorities', they became fearful of openly challenging the orthodox views of the time and the 'thought policing' that accompanied it. There is an interesting irony in regard to the phase transition that was taking place in Europe at this time. Considered in retrospect, it is an icon of the times, which occurred on Christmas day, 1642. For this was the day that Galileo Galilei died; the same day that Isaac Newton was born!

At the time of Newton's birth, the Dutch were set to become a major world player in regard to sea fairing trade. This is now called the 'Dutch Golden Age' [22]. They championed immigration of those who were under the boot of their most Catholic majesties totalitarianism, given that they had had first-hand knowledge of it themselves as a result of the 'Dutch Revolt' in the mainly Calvinist Netherlandish provinces, which led to the outbreak of the Eighty Years' War in 1568 [23]. This included the publication of new ideas that did not fit into the Catholic ideologies and doctrines of the time. It is in this context that the last great work of Galileo, which was on mechanics (and included a summary of his early motion experiments), was published in Holland in 1638 and not in Italy, the Italian publishing houses of the time considering Galileo to be black listed. In hindsight, perhaps this was fortuitous because it was probably through Dutch engineers that Galileo's works found their way to England, and, in particular, the East Anglian region of the country, which is where Isaac Newton spent the large proportion of their early life, Cambridge University being located in this region of England.

In the first half of the 1600s, many Dutch engineers had been encouraged to relocate to East Anglia to help in the drainage of the Fenlands (the low marshy lands in the east of England) to increase the arable farming potential of the area. This started before the English civil wars under the reign of King Charles I when, in addition to other Dutch land engineers and Hydrologists, Sir Cornelius Vermuyden (1595–1683) had been appointed to introduce Dutch land-reclamation methods in England, focusing on the East Anglian region [24,25]. In this way, through the books and scientific works that were brought into England by Dutch engineers, Newton would have become aware of the works of Galileo, which were arguably the precursor to his famous work 'Principia' [26], in which the Newtonian laws of motion were first established.

In regard to the English reformation [27,28], one of its major later contributors, namely Francis Bacon had died in 1626. However, their influence represented part of the phase transition that was ongoing, a transition that Galileo had prophesied, and one that we often associate with the birth of Newton. However, Newton was born into a country that was in the midst of a vicious civil war, a war that changed England and the development of science and technology more than Bacon and Newton could have ever imagined. This was due to the mindset of one of the principal characters of the English civil war [29,30], namely Oliver Cromwell (1599–1658) [31–34]. In this respect and in regard to the discussion that follows, one might associate Bacon, Newton and Cromwell as being a Holy Trinity (the father, the son and the holy ghost) of the English reformation. This is an idea that Newton himself would have reviled against, given that, as a Unitarian, he did not believe in holy trinities, conventional or otherwise—an irony, given that he was a Fellow of Trinity College, Cambridge.

After the end of the English civil wars with the parliamentarian victory at the Battle of Worcester on 3 September 1651 [35], debate continued to rage for many years on how the three kingdoms of England, Scotland and Ireland were to be governed. A so-called 'Rump' parliament had been established, which was forcibly dissolved in 1653 by Oliver Cromwell [36]. He was declared Lord Protector in December 1653, a Head of State and 'King Oliver' in all but name, a role he retained until his death five years later [18]. After his death in 1958, his son Richard assumed the title, but internal divisions among the republicans forced his resignation after just seven months. The Grandees of the New Model Army reinstalled the Rump parliament, but that too lasted less than a year, which catalysed the events leading to the restoration of the monarchy under King Charles II [37]. Nevertheless, the changes that Cromwell made in the five years he exercised full power were radical in the extreme and included a focus on the educational traditions of the time. Indeed, it may be argued that there has never been such a melting pot of radical ideas and movements in England before or since the 1650s. England was a Republic, its traditions, both political and religious, were inherently anarchic compared to the previous monarchy, and the citizens of the country were in a state of confusion. It was a period of disruptive thinking, which inspired the development of new ideas in regard to civil order, philosophy, science, theology, the nature of society and its prosperity and, above all, education.

During the Commonwealth of the 1650s, the Rump parliament and Cromwell passed many restrictive laws that sought to regulate moral behaviour. However, the most important and long-lasting effect of these times (the 1650s) is the renaissance in English education [38]. This is because control of education passed in every way from the church to the state. Calls for educational reform were inspired, at least in part, by a desire to improve the lot of the poor, who had suffered badly in the economic depressions of the 1630s and faced new problems in the 1640s and 1650s, including the failure of the harvest in five consecutive years. Puritans called for a broad range of reforms, including the provision of technological and agricultural education, a system of schools to educate all children and more financial aid for deserving students. While not as widely implemented as they might have been had the Commonwealth and Oliver Cromwell lived longer, these reforms were of significant value as a means to better the status of the lower classes.

It is often perceived that the 1650s was a time of severe religious intolerance, but that is not the case. Certainly, Cromwell considered Catholicism to be not just a religion but a political force. In this respect, he was correct, but where he was significantly 'mistaken' is to consider Catholicism as being a special case. The reality of the situation was far more complex. The religious spectrum associated with England, Scotland and Ireland was very broad. Ireland remained predominantly Catholic with elegance to the previous monarchic traditions. The Anglican church continued to flourish in England, but in Scotland, the Covenanter's (catalysed by the 'Martin Luther of Scotland', namely, John Knox [39]) continued to object the influence of both the Catholic and Anglican churches.

In to this cauldron of religious reformation came the Puritans, a bias to which Cromwell belonged. However, beyond this, a number of variations on a theme began to develop in England. Some of these are now footnotes in history, but others have stood the test of time, such as the Quaker's, sometimes referred to as histories quiet revolutionaries [40] and whose origins date back to the 1650s [41]. Thus, during the 1650s, it might be argued that the Islands of Britannia and Hibernia were the scene of more short-term variations on the theme of the Protestant Reformation than had occurred in the history of Christianity since its inception by the Roman Emperor Constantine through the Edict of Milan in February 313 AD [42]. This is why there was an attempt by Charles II, during the restoration of the monarchy in the 1660s and their successors, to bring about a sense of order and religious conformity. It was undertaken by encouraging the three Kingdoms, especially England, to come back to the fold of the Anglican church.

This incurred a level of intolerance that was, in some ways, more aggressive than Cromwell's 'adventures' in Ireland, for example [43]. An icon of this period was John Bunyan [44], a Puritan non-conformist and the author of the Christian allegory *The Pilgrims Progress* [45], who, as a product of the 1650s, was imprisoned in Bedford jail for twelve years from 1660 to 1672 for failing to abandon their freedom of speech as a Puritan preacher. Bunyan was born into desperate poverty and illiteracy, where he would have remained had it not been for the educational reforms of the 1650s. In this sense, Bunyan was just one of a number of Englishman who had tasted the fruits of literacy and liberty and was not prepared to throw them away just because of the republic that had made them had been replaced by a monarchy that deplored him.

One of the issues that underpinned the psychology of English Puritans was that, by comparison to the Old Testament, the New Testament was perceived to be some sort of papist conspiracy. The Old Testament was taken to be a more fundamental representation of Christian values and virtue, and the Torah was perceived by the Puritan movement to be an equally valued statement on instruction, teaching and law. While the attitude of English Puritan's to Catholics and Catholicism was aggressively hostile, it was positively congenial to Jews and Judaism. Consequently, a type of spiritual brotherhood was established between the Puritans and Jews even though neither community really understood the other. It was predicated on a mutual romanticism that was devoid of any pragmatic reality but was, nevertheless, a crucial aspect of the multiculturalism that developed in those times and continues to this day.

This came at a time when England, like any other nation state that sees fit to waste its treasury on all-out war, needed to find solutions to its critical financial situation. Thus, the Commonwealth of the 1650s embarked on the development of international trade, preferably through sea fairing routes that minimised social intercourse with Europe and consequently needed to re-engineer its education system in order to promote trade and industry, a situation that sounds rather familiar today, i.e., Brexit. Cromwell's government, therefore, actively encouraged the emigration of well-educated and skilled foreign nationals, which included the 'readmission' of Jews into England [46–48].

Before the 1650s, England was steeped in the traditions of an educational system that was, in effect, an insular establishment and parochial cottage industry. An illustrative statement of its condition was made by Francis Bacon, when, as a witness to both their teachers and follow students at Cambridge University, he referred to them as being like *becalmed ships, that never move, but by the wind of other man's breathe* [49]. Moreover, the educational system was steeped in medieval Philosophy, Theology and Alchemy. Even literature, music and the arts, in general, for which England had already developed a fine and respected tradition, were exercised in terms of cultural activities based on business prospects and profitability and were not an integral part of the university experience, alcohol abuse being a necessary exception! To a personality such a Cromwell, this tradition was a red rag to a bull. Consequently, he introduced a comprehensive range of new schools, colleges and academies in which the sciences and technology took a precedence. This caused considerable offence to the academic establishment of the time and was perceived as a form of subversive criticism [38].

The perceptions of the academic establishment were quite correct. Cromwell and his government were not at all satisfied with the education system that the new republic had inherited. He wanted school leavers and university graduates to be proficient in agricultural practices, ship building, the 'art' of navigation, in the developing technologies that helped industrial outputs as well as being trained for entry into the New Model Army and Navy. He promoted and financed many of Guilds in London and beyond to help increase the number of apprenticeships. In short, Cromwell set about transforming education in England from being a parasitical museum piece to one that promoted the quest for reason, literacy, science, industry and power. In this way, although he could not have known it, he catalysed the scientific, engineering and trading dominance of England in the centuries to come. Moreover, he encouraged the emerging immigrant communities, which had been invited to flourish in the new republic, to exercise their teaching traditions for which they were, then as now, highly respected, and inculcate these traditions into their new educational model. In this context, many of the Sephardic Jews who relocated to England from Holland and from elsewhere had knowledge of the traditions exercised in Fifteenth Century Spain, which involved the translation and study of ancient Greek texts brought into Spain by Muslims as early as 711 AD. They were therefore well versed and influenced by what Francis Bacon referred to as the 'Wisdom of the Ancients' [50] (such as the great mathematical treatise Euclid's Elements [51]) and had helped to develop what Jacob Bronowski referred to as the Spanish 'blueprint' for the Italian Renaissance [52]. Thus, it was not only their teaching practices that helped the English education system to flourish but what they were teaching. Furthermore, what they were teaching was fuelling the radical changes that were taking place throughout Europe, whether through the Catholic Renaissance of southern Europe or the Protestant Reformations of northern Europe.

Coupled with the growing success of the Republic before his untimely death in 1658, and, while many of the great scientific institutions such as the Royal Society were to be established later by their monarchist successor (Charles II), Cromwell seeded what later came to be known as the Industrial Revolution. This is a revolution that could never have come about had Cromwell not introduced a vision for English education that was based on teaching excellence, which focused on the approach to science and philosophy established by characters, such as Francis Bacon, in the earlier part of that century and the introduction of fresh and well-educated blood into the country [53]. It is the reason why the Industrial Revolution is first and foremost associated with England. What is more incredible is that Cromwell's influence on history, primarily through his pragmatic policies to reforming education, was exercised in such a short period of time. This can be understood in terms of the juxtaposition of two important and relevant issues:

(i) the search for a 'new order' and better prosperity of a population during a time of such unprecedented disruption;
(ii) the population were Islanders and thereby cut off from the short-term flow of influences from continental Europe at the time, other than through those that were readily accepted and content to contribute to Cromwell's 'New Jerusalem'.

Before the civil wars of the 1640s, England was a relatively minor player on the European theatre, with a hand-full of scholars and intellectuals that could rank with those scattered throughout renaissance Europe—Francis Bacon being one of them. However, after the civil war and well within 100 years of the event, the list of those contributing to the revolutions in science, technology and engineering that would forge the world in later centuries began to grow markedly, above and beyond the fame of scientists such as Isaac Newton. This effect can be directly attributed to Cromwell's investiture in apprenticeships, work-place-based learning and technical education. It is therefore interesting to note that, as will be discussed later, this is precisely the policy that is now being pursued by the UK government. However, it is not being driven by a radical such as Cromwell. At least, not yet!

It has been said that Oliver Cromwell was 'God's Englishman'; the 'greatest Englishman to ever walk the face of the earth' [31]. Certainly, his influence has been fundamental to the development of England since the 1650s. He was both the best and the worst of men. However, either way, he was driven by the realisation that it is not what you think or say that matters; it is only what you do that counts. In this context, what he did was drain the 'Whitehall swamp' of their time and oxygenated the pond. Furthermore, the better part of this oxygenation was the education of the land, and in their time and for that period of history, that land was England.

4. Apprenticeships in the UK: A Historical Perspective

The development of technical and scientific education in post-civil war England is well known, as discussed and referenced in the previous section. Those who contributed to this English scientific revolution over the centuries to come are also well known, and the products of their research form the bed-rock of science teaching throughout the world, e.g., Newtonian Mechanics, Electromagnetism, Thermodynamics and Evolutionary Biology to name but a few. It is a development that became infectious and was successively seeded into the world, starting with Scotland in the Eighteenth Century when Edinburgh became the 'Athens of the North' and where Adam Smith wrote one of the most influential books of the time, 'The Wealth of Nations' in 1776 [54]. In the latter part of the same century, France and America began to focus on science and technology to industrialise and develop a trading infrastructure, especially after their ideological and political revolutions in 1783 and 1792, respectively. In the mid-Nineteenth Century, the German speaking peoples began to contribute to the scientific revolution, and in the latter part of the same century, this was followed by Italy, Czechoslovakia, Russia and Japan, for example, who 'caught the bug'. In all cases, these transformations were necessarily accompanied by an education system that focused on the practical skills required of the work-force and nurtured the entrepreneurial talents of the people. Similarly, the industrial, manufacturing and commercial revolution that has been observed in the phenomenal China's rise to power over recent decades was, and continues to be, based on an educational infrastructure designed by the Chinese Communist Party that would be the envy of Cromwell himself.

In addition to the industrial-based democracies of western Europe, scientific education was serving its purpose in the central and eastern European states. However, there was an important difference between the two. Central and eastern European states have been, and largely continue to be, significantly more rural and predominantly agricultural-based economies. They have historically also been a refuge for academic figures persecuted elsewhere in Europe for unorthodox ideas. This reflects the focus of their educational traditions [55]. Conversely, the UK, for example, needed to maintain what it had developed and focus on the quest for trade and industry and the manufacture of products. In eastern

Europe, there arose an 'Intelligentsia' who were free from the shackles of industrialisation and thereby had greater time to think more carefully, to educate their children more completely and, from time to time, think outside the box of industrialisation. This is why, in the latter part of the Nineteenth and early Twentieth Centuries, there developed an educational tradition that out-ranked that of the UK in subjects such as pure mathematics and theoretical physics, for example; many would argue that it still does.

It is not that the UK failed to contribute to these subjects, it did; it is that the bias towards these subjects (and many more besides) in eastern Europe was due to a lack of their industrial heritage. This provided them with the 'breathing space' to think more deeply about issues in mathematics, science and philosophy that transcended the quest of submitting patents, research grants and developing business portfolios, which has become the obsession of the Anglo-Saxon world and its capitalist quest. To this day, the issue of research in UK universities, for example, seems to have more to do with the number of short-term research grants and the overheads they attract to help fill university coffers than the quality of the intellectual work that is actually undertaken and the thought that goes into it.

Coupled with the obsession associated with the number rather than quality of the publications that are generated for the sake of various research assessment exercises, the UK university research racket appears to have failed. However, far worse than this is that the failure has come at the expense of improving and updating the curriculum of undergraduate programs, thereby depriving undergraduates of the teaching excellence they so deserve. Moreover, with dwindling state resources and significantly greater competition, the effort required to develop a research proposal with the potential to succeed in being awarded any funding often out-ranks the effort needed to conduct the research project itself.

It is arguable that the focus on encouraging the university sector to become research active and enter into the 'publications racket' was instigated by a business model introduced by Robert Maxwell and their publishing company Pergamon Press [56]. This is an example where a talented business tycoon tapped into the naivety and vanity of academics by motivating them to publishing material, often before it was worth publishing, with minimal financial return or business acumen [57]. While the Maxwell empire eventually failed in the late 1980s (a classic case of over expansion through acquisitions in the name of Thatcherism), its legacy remains and, as a result, continues to further damage the university teaching portfolio of the nation. This is exacerbated by the level of incompetence and financial mismanagement, as well as the lack of proper teacher training and appropriate and up-to-date qualifications in regard to the delivery of teaching programs. Moreover, it has become coupled with an unacceptable level of student plagiarism (e.g., [58–60]), and, in some cases, plagiarism exercised by senior staff working with reputable publishers (e.g., [61]) that has become the lot of a UK university.

There is, however, a positive component to Maxwell's legacy, which is that more and more independent publishing companies have developed that focus on open-source materials and open access journals, e.g., [62]. This has afforded scholars the opportunity to publish their work without having to be constrained by the conservatism of the more conventional journals who like to maintain their elitist portfolios and have yet to fully appreciate the importance of open access publishing. Moreover, this Maxwellian development has made the need to sustain university libraries, who often continue to manipulate their rather archaic approach to controlling knowledge, an irrelevance. This is a welcome development as businesses, such as public libraries and high street shopping, for example, no longer need to be sustained at an expense to both students and learning providers alike. Thus, university libraries are being forced to transform their modus operandi and fully embrace e-access and e-learning in which knowledge knows no boundaries (physical or otherwise) and coverts minimal control [63].

The demise of education in the UK started in the mid-Nineteenth Century when the British empire was at its zenith and started to focus on consolidating is trading dominance. This involved establishing an education system that put patronage before reason, pride before understanding and, above all, class before social cohesion. The consequences of this were that UK education had become far removed from Cromwell's original vision and was classified into two principal categories:

(i) a 'public school system' (based on very private institutions) that focused on educating the elite for the governance of a world-wide sea fairing and trading empire;
(ii) technical institutes whose purpose was to maintain the industrial infrastructure for the 'work-shop of the world' [64,65].

At the height of her imperial might and Victorian values that Britain projected throughout the world, the entire edifice was to be challenged quite unexpectedly. The effect of this was to change the emphasis of its educational infrastructure by, once again, turning to Cromwellian values, as shall now be discussed.

In the 1870s, starting in 1873, a 'Great Depression' occurred world-wide, which was particularly severe in the UK [66]. There were a number of prior events that generated not only severe economic circumstances for the UK but prompted a reappraisal of its industrial heritage. The first of these was related to the American Civil War, 1861–1865 [67]. Although the UK remained officially neutral, it indirectly supported the Southern States or Confederacy—the Confederate States of America (CSA). This was because of the UK's reliance on Cotton imports from the CSA, which sourced the textiles industries in the north of England, a highly lucrative trade due primarily to the slave economy of the southern states, which kept the price of cotton to a minimum.

As the American civil war developed, the UK looked elsewhere for its Cotton, which included developing what became a primary source in Egypt. However, as a result of the Union victory, the price of Cotton and other imports from the new world grew rapidly. However, more importantly for the UK, the American civil war catalysed an industrial revolution forged in the manufacture of arms that, by the 1870's, had begun to show its competitive advantage over the UK's ageing industrial infrastructure, which was a relatively uncoordinated complex of cottage industries dating back to the Industrial Revolution of the Eighteenth Century.

Another emerging industrial competitor of the UK at the same time, and one that was even more uncomfortable due to its close proximity to the 'home fires', was the newly formed state of Germany, which was officially proclaimed on 18 January, 1871, under the leadership of Otto von Bismarck, who was the first Chancellor of the new state until 1890 [68]. In both the USA and Germany, there were major initiatives to promote science, engineering and technology in order to support the growth of these new nation states and develop their future prosperity. In the USA, this was driven by private enterprises and entrepreneurship, the icons of which included, Thomas Edison and Alexander Bell, for example. In Germany, central government was more pro-active in launching industrialisation, which was primarily centred, then as now, in the North Rhine Westphalia and Lower Saxony regions of the country that had ample natural resources—most notably, Coal and Iron Ore (similar to the industrial north of England, involving major industrial centres compounded in cities such a Manchester, Sheffield and Newcastle, for example). This disturbed the status quo of the British establishment for similar reasons to those associated with the current emergence of China today, which is disturbing the balance of an assumed normality of a world dominated by the USA.

In order to help tame the emerging 'German Tiger' and indirectly control it, the British government covertly helped to oust Bismarck and their republican sympathies and place the control of Germany in the hands of Emperor Wilhelm II [69]. By comparison with Bismarck, a Prussian aristocrat, a graduate of law from Göttingen University and the political genius of their time, the only qualification for the position that Kaiser Wilhelm II had was being the eldest grandson of Queen Victoria. He was a psychological wreck and unfit to hold any executive office, let alone the office of head of state. However, that was not the point. The point was that he was considered by the British establishment to be a member of the 'Club' (of unelected heads of state). Thus, it may be argued that, in trying to control Germany through introducing a reflection of themselves, the British inadvertently did much to catalyse the European Civil wars between 1912 and 1989. This led to the untimely death of tens of millions of people who, had they lived, might have contributed so much to society, which might perhaps be a better part of the curriculum in our schools and universities today.

Under the leadership of Bismarck, Germany flourished in the arts and sciences and was set to becoming a major industrial and economic power, served by a progressive written constitution, a state education system with a broad curriculum and a social welfare provision that was decades ahead of the UK for the time. Bismarck was in fact the first to establish a welfare state in a modern industrial society with the social welfare legislation of 1883 [70]. The UK only developed a societal infrastructure of a similar standing in the late 1940s with the provisions of the Beveridge Report in 1942, leading to such reforms as the National Health Service, child benefit and state education [71] under the Attlee ministry, 1945–1951. However, there was one important thing that the UK did do in response to Bismarck's initiatives, which were putting the industrial infrastructure of the UK to shame. This was the development of new educational centres for technical training, the most iconic of which was the centre established in South Kensington, London, namely the Central Institute of the City and Guilds of London. This institute is now known as Imperial College (IC), which is one of the premier scientific, technical and research establishment in the world, considered to be the Massachusetts Institute of Technology (MIT) of the UK.

MIT has an unparalleled pedigree, which is well known and needs no introduction. It's motto is: *mens et manus*, meaning 'mind and hand' and is concerned with the 'pursuit of practical knowledge' [72]. In other words, MIT's primary purpose is teaching and research with relevance to practical issues and, in doing so, transforming society for the better; something that Oliver Cromwell would have no doubt, whole-heartedly approved of. This is because the outputs of establishments, such as MIT, along with the California Institute of Technology, Imperial College and many other institutes of science and technology have done more to change society for the better than the cumulative sum of most other HE establishments in the UK and world-wide.

Imperial College has an interesting history in that after developing its technical training services as a City and Guilds centre, it joined London University in 1908, only to leave the university in October 2006. This occurred under the leadership of the Rector and former chairman of GlaxoSmithKline, Sir Richard Sykes, who stated that: *Imperial has an international reputation that is independent of the University of London. It is absolutely right that we should promote our own identity and award our own degrees* [73]. Imperial College was the last college to join London University in 1908 and the first to leave it in 2006. One of the underlying reasons for this was that IC wanted to 'go back to its City and Guilds roots' [74], a model that the majority of UK universities will now have to follow. This is not the first time that the IC model has been acknowledged as a good template. In the 1960s, under the Labour government, Prime Minister Harold Wilson introduced the 'White Heat of Technology' as being the key to forging a progressive socialist society [75]. The City and Guilds heritage associated with IC was seen as being made of the right stuff (as it is today by the current government). Consequently, IC benefited from increased subsidies at the expense of many other colleges that constituted London University and, subsequently, 'went to the wall' in the rationalisation of the university undertaken in the 1980s.

The introduction of a 'mens et manus' policy will not be achievable within the current framework of British society, given the nature of those who occupy much of the academic establishment—those who rarely have any experience within industries and the 'University of Life'. The solution, therefore, requires a significantly more radical strategy. One of the better and more culturally compatible models for this strategy is ironically the same as that which created Imperial College, i.e., the German model developed under the chancellorship of Otto von Bismarck. In Germany today, over 50% of school leavers go straight into the industry and not into a university. *This is partly because of the traditional apprenticeship system, which allows young Germans who do not go to university to train and qualify in companies* [15]. By comparison, in the UK, while the cost of education is rising, employers are continually noticing that graduates are increasingly unprepared for the workplace compared to their German counterparts and are further burdened with debt. This observation warrants an obvious question, namely how can UK graduates be prepared for the workplace if they are being educated by those who have no experience in that workplace?

More and more of the primarily G20 countries now have an increasing focus on apprenticeships, and the British government stated that some three million apprenticeships should be created by 2020. This is a figure that has not been realised, and yet, the UK is luckier than most in that it has an established institution, the City and Guilds London Institute, with a wealth of experience dating back to 1881 when the British government woke up to the emerging competition in the technological prowess of Germany and the USA. Compared to Germany, there are of course less manufacturing industries in which to place school leavers since the UK has transformed into a service-based economy over the past forty years. A more subtle but equally, if not more powerful reason, is the psychology and perceptions of those that are a product of the eternal class struggle that continues to pervade British society, one which was finally and utterly destroyed for the better in Germany in 1945.

The background to this problem is perhaps well expressed in Philip Larkin's poem *This Be The Verse* [76]. For too many years, depending upon the aspirations, cultural context and class bias of the populous, parents have quite understandably sought to give their children advice in regard to their futures, including the character of their education and, critically, the subject areas in which they appear to have an interest. However, this has been and continues to be done under a fog of ignorance and prejudice. In the past (i.e., 1960–1990s), middle class students were expected to undertake a university degree in a range of often very superficial and non-technical subjects in order to mature into a career that was independent of the subject matter that had been studied. They represented a small minority of UK students that had the opportunity to graduate from HE sectors that were fully supported by the British tax payer. Working class students were typically expected to undertake training in the old Polytechnic sector or enter into the manufacturing industries available, where they had the opportunity to obtain a City and Guilds qualification, for example, as part of their apprenticeship.

The demarcation between the university elite and the polytechnic proletariat at the time was challenged by the Labour government of the mid-1960s through the establishment of the Open University (OU), which was granted university status on 23 April 1969. This was the brain child of Prime Minister Harold Wilson, who was a strong advocate of providing university education to a wider class of students and referred to it as the 'Peoples University' [77]. The OU model is now well established worldwide. However, what is more interesting is the increasing number of National Vocational Qualifications (NVQs) [78] that the OU and other universities now offer, some of them being very reputable 'Russell Group' institutes [79]. In other words, they are offering the very type of vocational City and Guilds qualifications that the OU was originally designed to help the working classes escape from and aspire to greater heights. In this regard, we are witnessing a reversal of fortunes in terms of the debt and contempt that a degree now represents and the value and respect that a NVQ is developing, especially when it is gained through an 'earn-as-you-learn' scheme through which school leavers enter the 'University of Life' [80]. It is within this context and the economic realities associated with the evolving realpolitik that schools and parents must start to advise the younger generations, lest they continue to be suckered into a university education that has passed its sell-by date. Furthermore, to the rescue should come the apprenticeship schemes and the new Technological Colleges with a largesse that is predicated on learning modes of education that work in league with industry for industry. This 'Triple Helix Model' [81], as it has come to be known, is discussed in the following section.

5. The Triple Helix Model, Leo Szilard and the Information Technology Revolution

The Triple Helix Model (THM) is one that considers the interaction between university, industry and government to be the key to innovation and growth in a knowledge-based economy. Although the phrase 'Triple Helix Model' is original, the concept is not. Moreover, while the concept continues to be debated by the executives in many UK universities, the underlying reality is that the majority of academics are not fit for purpose in regard to understanding the THM let alone endorsing it. However, they could be, if and only if they could learn to respect it rather than fear it and, because of their fear, hold it in contempt. Thus, rather than re-iterating aspects of the THM that are well known and can be better explored elsewhere, a true story is now considered that is reflective of the THM (at least for its time), which involves characters (two theoretical physicists) whose academic credentials and research portfolio were, and remain, second to none. This is to illustrate how the THM can make such an important impact on society, above and beyond the manifestations of the 'Ivory Tower'.

One of the most important icons of the Information Technology (IT) revolution we enjoy today was first established by Leo Szilard (e.g., [82,83]). This was a result of their solution to the 'Maxwell Demon' problem, a thought experiment leading to a paradox, named after James Clerk Maxwell, who unified the Physics of Electricity and Magnetism in the 1860s. Maxwell had originally proposed the thought experiment as a result of their work on the properties of ideal gases. He considered a model where gas particles are free to move inside a container and whose interactions occur through elastic collisions when they exchange heat with each other (energy and momentum being conserved). Some of these particles have low velocities, and others have higher velocities. The velocity profile of such particles was taken by Maxwell to conform to a Probability Distribution Function known as the Maxwell-Boltzmann Distribution, which has a well-defined maximum value—the 'mode' of the distribution. This is the velocity at which the majority of the gas particles move (the most probable velocity), and Maxwell showed that this velocity is related to the temperature of the gas where the most probable velocity is proportional to the square root of the temperature. The energy associated with this particle velocity (through Newton's famous energy equation) is equal to the product of the temperature and a constant of proportionality—the Boltzmann constant.

The thought experiment considers a 'Demon' operating a frictionless shutter that partitions the container into two sections. The shutter can be opened to allow particles with a velocity less than the most probable velocity to enter into one section of the container and particles with velocities greater than the most probable velocity to enter into the other section. Both the container and shutter are taken to be perfectly thermally isolated. In this way, high and low velocity gas particles are separated into the two sections of the container, preserving their velocities. Consequently, the equilibrium temperatures of the two sections become higher and lower than that of the original container.

For a classical thermodynamic process, work can only take place when there is a temperature gradient, and, for an irreversible process, the 'Entropy' (a measure of the disorder of a system) associated with that process always increases; the change in Entropy being given by the change in the work divided by the temperature. This is the basis for the second law of thermodynamics, a law that appears to be broken according to the thought experiment considered by Maxwell. This is because the Entropy of the two sections is now different, and, given that there is a decrease in temperature in one of the sections, the Entropy has been lowered without expending energy.

Leo Szilard was a classic example of eastern European Intelligentsia. Born and educated in Hungary, and, under the supervision of Albert Einstein at the University of Berlin, in their 1922 doctoral dissertation and a companion landmark paper [84], he showed how Maxwell's paradox can be solved by taking into account the fact that, in order for the Demon to open and close the shutter to let particles of different velocities through, a decision must be made. Furthermore, this decision is based on gathering information on the velocity of a particle a priori before it is let through the shutter or otherwise. The information measure is taken to provide a balance to the apparent decrease in the physical Entropy, a measure that is therefore compounded in the so-called 'Information Entropy'. In this respect, Szilard's principal contribution was to consider that the Demon must be an intelligent being that can make a decision based on a priori information on the velocity of a particle. This is an obvious but critical issue, and one that Maxwell had failed to conceive of and include in his original thought experiment.

Szilard's original concept on Information Entropy has become a fundamental basis for digital information theory. He showed that there is always an increase in the Information Entropy for any and all measurements, a concept that was independently 'discovered' by the communications engineer and cryptographer Claude Shannon in 1949 (to whom credit is usually but erroneously given) [85]. In developing a solution to a paradox in thermodynamics, Szilard introduced an idea that is arguably the single most important icon of the information revolution today. This is because Information Entropy provides the key for estimating the (average) minimum number of bits needed to encode a string of symbols based on the frequency of those symbols. It, therefore, represents a fundamental criterion—a limit—as to how much information is communicable digitally in terms of a sequence or 'string' of bits. Further, Information Entropy is a fundamental measure that can be used to determine the intelligibility or otherwise of a binary string. This is important in the search for other intelligent beings through the reception and processing of radio signals, for example [86].

What has all this got to do with the THM? Just as it is not fully appreciated that it was Leo Szilard who first developed the iconic formula for the IT revolution that dictates the ebb and flow of our lives today, so it is not appreciated that the context for their work was not an Ivory Tower in Berlin but part of an industrial problem of the time—namely, how to design and manufacture a refrigerator that satisfied health and safety requirements.

In the 1920s, the principal chemical refrigerant was Ammonia, which was used in a single-cycle design for the operation of refrigerators. It had been reported at the time that in some cases, the Ammonia had leaked through the failure of a seel, leading to fatalities. This inspired Szilard and his doctoral supervisor, Albert Einstein, to investigate available technologies in order to design a refrigerator with no moving parts, thereby improving upon the safety of a refrigerator. Coupled with Szilard's understanding of thermodynamics and Einstein's in-depth knowledge of writing and submitting patents, they filed a number of patents relating to the design of the so-called 'Einstein Refrigerator' [87]. In the context of Szilard's solution to the Maxwell Demon problem, a refrigerator can be considered a thermally insulated container with a door. The door is then equivalent to the shutter between the two 'sections' considered in the 'Maxwell Demon' problem: a section that gets colder (the interior of the refrigerator) and the section that get hotter (the room in which the refrigerator is housed).

One of their aims was to develop a business to manufacture the next generation of refrigerators, which might have been a spin-off company from Berlin University. However, an important event intervened that prohibited this, namely the 'Wall Street Crash' of 1929, which rapidly led to an economic depression world-wide that was specifically detrimental to Germany. Thus, investors were not keen to invest in a start-up company of the type that Szilard and Einstein were considering, and the business venture failed before it had even started. Nevertheless, it was in the context of the industrial and practical problems that they were attempting to solve that Szilard's thought experiment led to a deeper understanding of thermodynamics, an understanding that now underpins the basic principles of all digital processors and digital communications.

The purpose of introducing this lesser-known event in the history of physics is as follows: If intellectual elites, such a Szilard and Einstein, whose contributions to science require no introduction, considered the importance of industry-based problems, then just who do lesser rank and file academics of today think they are when they distance themselves from getting involved in industry-based problems associated with private enterprise. Their preference to remain in an 'Ivory Tower' and maintain their insular comfort zones not only limits their horizons but exacerbates a tradition that is incompatible with institutes whose purpose should be to prepare the younger generations for the 'University of Life'.

It is interesting to note that Szilard is well known for many other contributions to Physics, most notably, his concept of a neutron-induced chain reaction to sustain nuclear fission. A patent on this idea was filed in 1933, granted in 1936 and assigned to the British Admiralty to ensure its security [88]. This was many years before the experimental verification of nuclear fission in December 1938 by physicists Lise Meitner, Otto Frisch, Otto Hahn and Fritz Strassman at the Kaiser Wilhelm Institute of Chemistry in Berlin, who were not aware of Szilard's contributions at the time. Moreover, it was Szilard who wrote the letter to president Roosevelt that initiated the Manhattan project, asking his previous supervisor to sign the document because of their greater international acclaim [89].

It is arguable that Szilard never rated their earlier work on thermodynamics as, from a psychological point view, he may have associated it with the failure of the business venture he was pioneering. In this respect, it is not a coincidence that their seminal paper entitled *On the Decrease in Entropy of a Thermodynamic System by the Intervention of Intelligent Beings* was published in 1929 [84]. However, their efforts to investigate a scientific and engineering problem that was of commercial importance led to this work becoming one of the most important in the history of Physics and the digital IT-dominated world we live in today. Furthermore, this is due to the juxtaposition of academic excellence and an industrial problem that lies at the heart of the THM. For this reason, it should be more fully respected by rank and file academics and learning providers who currently frequent the UK HE system. They must start to understand the changes that are going to be imposed upon them. These changes and the THM ethos is perhaps well expressed by Wernher von Braun when he stated that *Pure research is what I do when I do not know what I'm doing*. This is the subject of the section that now follows.

6. Current Problems with UK HE

The idea that through an endless stream of government White Papers, coupled with select committees, conferences, workshops and so on, will lead to universities coming to terms with the current challenges and changes that are so urgently required, let alone implementing them, is a strategy that is doomed to failure. Its only purpose is to maintain the status quo while giving the illusion of implementing a change of direction. This is something that many university vice chancellors and staff would welcome; not the changes that is, just the excuse to talk about them. Thus, what can and should be done and what strategy can be implemented to make things happen? To start with, we must understand the nature of the rot and why it has occurred. This is discussed in the following sections.

6.1. From Grants to Tuition Fees

In the 1960s, slightly over one in ten (approximately 12%) of school leavers went to university in the UK. Sixties students did not require loans; their fees were paid in full by local educational authorities, and there was a means-tested annual grant of up to GBP 340 to cover living costs, thereby allowing students from deprived backgrounds to undertake a university education. Moreover, the remit of the degree that was awarded did not necessarily fix the nature of the career into which a graduate would embark. The university experience was perceived to be a mark of maturity and preparation for a career in a broad spectrum of activities, even if much of that experience had been infected by the values of the permissive society of the time.

In the 1970s, one in seven 18-year-olds (some 14%) entered HE in 1972. However, this percentage fell over the decade as university funding was cut, and vice-chancellors refused to reduce the amount spent on each student. Consequently, many 16-year-olds school leavers opted not to go into the sixth form because there was no guarantee that after two years of A-level studies, a place could be found for them at university. Further, there was a reasonably healthy manufacturing base for such school leavers to enter an industry.

By the end of the decade, the grant for students had increased from GBP 380 to GBP 1430 in 1980.

The 1980s produced a massive expansion in UK HE, masterminded by the Secretary for Education, Kenneth Baker. This was necessary because of the decrease in the jobs available for school leavers due to the systematic reduction in manufacturing industries and the transformation of the UK into a service industry. By 1990, one in five 18-year-olds were entering the HE sector, but the funding for each student started to be considerably reduced. In 1989, the government introduced a mortgage-style student loan scheme to compensate for any increase in the annual grant, although grants of up to GBP 2265 were made available for students from poorer families. Moreover, because the 'Cold War' came to an end in 1989 (with the fall of the Berlin Wall), the emphasis on Science, Technology, Engineering and Mathematics (STEM) to maintain the defence sector was perceived to be less important as funding for the Scientific Civil Service was massively reduced. Thus, school leavers were encouraged to undertake a university education, take out a loan and study for a degree in any subject as long as it helped reduce the youth unemployment rates of the time.

The 1990s witnessed another boom in UK HE with many of the Polytechnic's being given university status in the early part of the decade. In 1997, the new Labour government abolished the student grant, which was worth GBP 1710 and from 1998 introduced a new system involving a GBP 1000 means-tested and upfront tuition fee and low-cost income-contingent loans. By 2002, 43% of under-30's had experience of HE in the UK, and the Labour government of the time pledged to raise that to 50% by the end of the decade. Tuition fees became GBP 1100, offset by low-cost loans of up to GBP 3905.

In 2006, students became liable to pay up to GBP 3000 a year in fees paid after graduation, once they were earning GBP 15,000 a year. Repayments were made at a rate of 9% of income, with inflation-only interest payments.

In hindsight, one of the principal mistakes that was made in the early 1990s was the knock-on effect of the Polytechnics being given university status. There was nothing intrinsically wrong with this per se. What was wrong is that the new universities set about trying to copy the old universities instead of cultivating and improving upon what they were already good at and well respected for, namely technical training. Because of this, the gate was opened for companies to take advantage of what the new universities were quite literally throwing away.

The change in status of the Polytechnics included a drive for the new university sector to become research active. However, and most unfortunately, this has come at the expense of the high-quality technical educational once provided by the Polytechnics from which they were derived. This has been exacerbated by the monumental increase in bureaucracy that has constipated the operational directives that most academics have been subjected to as the student population has increased. It has led to an imbalance in the hierarchy of university structures in which the scholars have become servants of the 'Bean Counters', which has not been in the interests of the student population. The HE system has been reduced to a business enterprise culture that is dominated by staff who have become increasingly unaware of their customer's needs—something through which no state economy can thrive. An icon of the current status is compounded in the 'Mickey Mouse degree', which is introduced and discussed in the following section.

6.2. Mickey Mouse Degrees

The term 'Mickey Mouse Degree' was originally coined in 2003 by the then Minister for Education, Margaret Hodge, as part of a discussion paper on the expansion of HE. She referred to a Mickey Mouse degree course as one *where the content is not as rigorous as one would expect, and where the degree itself does not have huge relevance in the labour market* and *. . . simply stacking up numbers on Mickey Mouse courses is not acceptable* [90]. However, it is not just Mickey Mouse degrees that have flourished in the UK since the late 1990s but the large number of Mickey Mouse universities that have emerged and are now responsible for awarding them. The principal subject matter of the Mickey Mouse degree is perceived to be the Liberal Arts and Humanities. For example, President Obama joined the ranks of many who suggested that the *liberal arts disciplines do not lead to jobs* [91] and that *universities must focus on science, not 'useless' arts* [92–94]. Science and engineering degrees have also suffered from the 'Mickey Mouse Syndrome' and have been dumbed down over the years, primarily because of the lack of mathematical literacy that school leavers have.

If students graduating with such degrees were on state grants, then it would not matter so much. However, graduates of such degrees now have to borrow increasingly large sums of money to be awarded them. Consequently, they end up in a scandalously high level of debt before they have even started employment, and, should they be lucky enough to obtain a job, it is usually one that is far from the remit of the degree(s) they have taken for which there is usually an insufficient job market anyway.

The term 'education, education, education' used on many occasions by Prime Minister Tony Blair and colleagues around the time when student fees underwent a quantum leap (i.e., the Teaching and High Education Act of 1998 [95]) should be applauded. However, the underlying reality is that the 50% participation in HE vision was adopted to reduce the projected level of unemployment of school leavers as a direct result of the disestablishment of the manufacturing industry under the government of Margaret Thatcher. In short, it appears that the post-baby-boomer generation have been sold a Pup, whose increasing deficits are an indirect source of payment for the pensions and state health that the baby boomers are now receiving and increasingly requiring, respectively. This situation is another example where the younger generation and, primarily, the working-classes end up paying the price for maintaining the comfort zones to which the older generations have become accustomed.

As the Spanish philosopher, George Santayana said: *Those who do not learn from the past are condemned to repeat it* [96]. However, there is an additional fundamental reality that needs to be understood, especially in relation to the vision of globalisation. This is that those who accept, use and pay for the technology of 'others' end up having to accept the influence and control of the 'others'. A recent example of this is the growth of the 5G communications infrastructure, courtesy of the Chinese telecommunications group Huawei. The head of MI6, Alex Younger, has been one of a number who have signalled security concerns over Huawei in regard to the development of 5G in the UK [97]. However, few appear to have questioned why this relatively new communications giant has taken a pole position so quickly in a technology that is fundamental to society and why the UK, for example, has not been able to compete. The fundamental reason for this is the correlation between information communication technology, data security and education. It is because Beijing have seen fit to educate their people properly in Science, Technology, Engineering and Mathematics (STEM), while London has had a relatively laissez faire attitude to allowing Mickey Mouse degree programs to proliferate. The disparity in promoting STEM by the central governments of the UK and China has led to an inequality in technical skills between the two countries. Furthermore, this has not gone unnoticed by those nation states who realise that it is now in their best future interests for the UK to carry on just the way it is, or at least, has been doing. In other words, used discretely, Mickey Mouse can be used as a powerful weapon, especially when he is encouraged to proliferate covertly throughout a nation state, given that he is not perceived by the status quo to be threat. This has been realised by an increasing number of overseas students, who no longer consider UK HE to be value for money and have reported this back to those who are often paying their exorbitant fees.

6.3. On the Incompatibility of Linear Growth Models with Reality

We are quite naturally and psychologically attuned to the idea, and indeed, the desire, for continued growth and prosperity in the future. This 'growth' is often perceived to have a linear progression in time where performance (which represents the growth in society, its industries and intuitions we relate our careers to, our contributions to them, our promotion prospects, financial rewards and so on) increases subject to the resources that are invested. Thus, as time increases, it is normal for us to perceive our roles within a 'system' whose performance is associated with greater prosperity. The rate of increase in this performance/productivity typically depends on incremental improvements that are driven by competitors. This leads to the generation of performance gaps that are filled through increased work under a controlling framework (central and local government) that is designed to maintain the long-term future direction of the system within the democratic traditions (or otherwise) of a given nation state [98] (Based on some of the ideas introduced by Professor Calie Pistorius during his seminar 'Bringing about a Step Change in the Organisational Renewal of Universities', at the University of KwaZulu-Natal, South Africa, 6 May 2016.).

The simplistic and naive description given above is entirely incompatible with reality, especially the realities associated with the growth of organic 'systems'. Whether the 'system' is a bacterial colony, a simple or complex animal or the behavioural dynamics of a group of animals, including human beings, its dynamic behaviour is usually governed by four fundamental phases. These phases are, in order of occurrence, the developmental phase, the growth phase, the saturation phase and the death phase. Given that the death phase is rarely fully completed (as it would lead to extinction), the cycle repeats itself. Each time this cycle occurs, mutations take place that promote the evolution of the system, conditioned according to the environmental circumstances that filter those mutations through which the cycle can grow 'stronger'. However, the time scales over which these cycles occur are very broad. This is why, when the time scales of the cycles are much larger than the average life time over which they can be observed, they are not always so easy to appreciate. Nevertheless, any dynamic behaviour that exhibits similarity over different time scales is an example of a self-similar process, and such processes are fundamental to the 'Fractal Geometry of Nature' [99] and systems thereof. Education systems are no exception.

Ignoring prior developments (and certain characteristics in regard to their continuity), the post-war HE system in the UK has undergone three of the four phases discussed above. The development phase started in the 1960s under a Labour Government when a range of Colleges of Arts and Technology throughout the UK were given university status. This included their development in terms of building infrastructure and the recruitment of staff, many of whom had an understandable allegiance to the socialist values of the time. Some of these 'Red-Brick' universities focused on science and technology and have secured excellent reputations. Other universities developed to sustain reputations in the arts and humanities, while others opted for a mixed portfolio determined by the traditions and continuity of the biases reflecting the characteristics of the Vice-Chancellors and the executive governance of the institutes.

In the early 1990s, the growth phase was initiated when, under a conservative government led by Prime Minister John Major, numerous Polytechnics and FE institutes were provided with university status. This was necessary in order to increase the university provision of a generation (the children of the baby boomers) that required a higher level of education than was previously needed. More importantly, it served to decrease the growing youth unemployment due to the severity of the financial rationalisations undertaken in the 1980s, which dramatically reduced those industries that had previously been able to offer school leavers employment and/or an apprenticeship. This is a process that continues to this day, and, in the space of some thirty years, the rate of growth in universities has been considerable. However, the nature and quality of the education that they now offer has become suspect, one that has been increasingly predicated on attending to the financial realities required to sustain their existence rather than attending to the welfare of their customers through relevant technical education. Furthermore, this is why the system has now entered its third phase, namely the saturation phase. Another less palatable word for this phase, but one that is perhaps a better description of the current reality, is ' stagnation'.

The current conditions have been brought about, not by the success of the HE system to stave off youth unemployment of the future but, its failure to adapt to the realities of that future. This is partly due to a lack of vision in that future, compounded in the technical and managerial inexperience, incompetence and unprecedented self-indulgence of university executives. However, there may also be a deeper reason for this, which is a natural reaction to the fall of the Berlin Wall in 1989, when a highly educated population developed to sustain the great socialist experiment were responsible for dismantling that experiment as a result of being so well educated. This is a correlation (i.e., the correlation between a quality education system and the effect it can have in forging changes that are not necessarily in the interests of the government that developed the system) that the western democracies would have observed and understandably compensated for, lest they also end up making the same 'mistake'. Whatever the principal reason for the age of stagnation in UK HE (and perhaps there is no one principal reason but a confluence of many), the ramifications and scandalous reality of the current situation is well served by the cartoon given in Figure 1.

So what can be done to rectify the problem expressed in Figure 1? The most important thing is to understand the nature of the strategy for change management in HE that is now required. This is discussed in the following section.

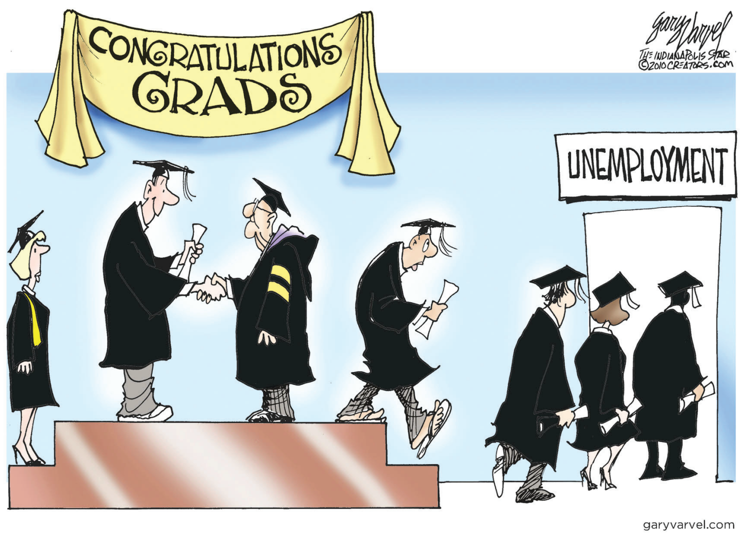

Figure 1. 'Degree, Dole and Debt [100]. A cartoon [101] illustrating the 'flow' of UK graduates from a graduation ceremony to unemployment after having been burdened with an average debt of the order of GBP 50,000 in student fees, accommodation and other living costs, often for the privilege of being able to receive nothing more than a 'Mickey Mouse Degree'.

7. Strategy for Change Management in Higher Education

Organisational reviews have and continue to keep on being undertaken at all levels of management within HE, but few of them appear to be of fundamental significance and are understandably based on treading water while maintaining an eye on what might emerge from the current 'season of mists and mellow fruitfulness'. There are some basic issues that should be considered if such reviews are to be of any consequence. One of the most important is that knowledge knows no boundaries, whether it be physical, intellectual or digital. In this respect, the academic renewal that is so urgently required in UK universities that they must cater for an international mind-set, an organisational revival and the interdisciplinary virtues that necessarily reflects the reality of future generations and their working environment. Thus, the traditional and parochial 'Silo Mentality' must be outcast, competitive advantages developed and the drive for economies of scale realised. Examples of how this can be achieved include restructuring the academic enterprise by converting university faculties into multi-disciplinary schools instead of single-discipline departments and establishing inter-disciplinary research institutes that cut across all faculties, for example.

What are the factors that are driving the organisational renewal that universities are faced with? A fundamental, and crucial factor, is the development of the virtual campus and distance learning. More and more competitors are emerging from organisations that are driving the agenda of distance learning, e.g., 'Arden University', the 'Online University Experts'. Not only are their degree courses consistent with the operating conditions of the working classes, but they endorse the concept of work-place-based learning and employability with significantly more experience and positivism than conventional universities.

Coupled with organisations, such as the City and Guilds London Institute, and others institutes that focus on industry-based apprenticeships, these universities are capable of introducing new interdisciplinary curricula and endorsing continuous change that transcends the traditional HE sectors. Furthermore, it is the 'products' (i.e., the graduates) of these new drivers in HE that employers are increasingly looking for. Above all, it is these initiatives that are helping to abolish Mickey Mouse degrees in Mickey Mouse disciplines from Mickey Mouse universities and driving the need to introduce a high-quality technical education in STEM. The issue is whether the current university sector is fit for a change where Twenty-first Century HE workers (not conventional academics) need to have:

(i) worked in and been successful in the respective industry;
(ii) regulated qualifications reflecting their training in teaching and learning;
(iii) obtained leadership and management training and qualifications thereof, especially at the executive level and not on the basis of having acquired a ten-a-penny MBA or attending a short course, especially if it has taken place at a university.

What is the strategy that is required for doing this? In order to address this issue, let us consider the following scenario. Suppose that a new appointment is made to the position of Minister of HE for the UK. Further, suppose that such a minister opted to make an unorthodox approach, whereby he or she embarked on regular fishing trips to see the vice-chancellor's and their executives on location in each university. One can imagine that in each case, they would be given the 'red-carpet treatment' and entertained with a range of excellent presentations and executive summaries where positivism was mandatory. This would be coupled with a wealth of statistical evidence quantifying developments in teaching practices, research, buildings infrastructure, quality control, the Centres of Excellence that have been created and so on. Even the finger sandwiches would be freshly prepared, no doubt in some Centre of Excellence for catering.

At the end of such events, it is usual for a ministerial visitor to provide feedback and to give an overview on the broad directions associated with a government manifesto on education, current White Papers and pending or current legislation. Suppose that, for each vice-chancellor and the assembled executive team, the minister was to read the riot act in regard to HE not providing what industries want and what the UK economy requires based on an evaluation from employers. The reaction from any vice-chancellor would quite naturally be defensive. This is understandable, and it is not entirely the fault of the executive of a university but rather the legacy of the staff they have to manage, whose experiences are often woefully incompatible with the way of the future.

It is of course all too easy to criticise the academic fraternity of UK universities. They have been subject to one initiative and policy change after another, relating to changes in strategy, as directed by Whitehall, but with little direct control from Whitehall, UK universities tend to be autonomous. This is a situation that is not replicated in continental Europe, where HE institutes are not conducted by a central government, but where university administrators are relatively few in comparison with the UK and fully understand that the 'few' are the servants to their academic masters.

By and large, UK university academics have tried hard to accommodate the change management that has been imposed from Whitehall. Perhaps they have not tried hard enough or not put up as much resistance as they might have, but that issue is now a technicality. Either way, with the sum total of the developments that have taken place, coupled with the economic realities of the past few decades, and compounded by the current COVID-19 Pandemic, the system has become akin to a brittle metal, whose malleability is at a minimum and is therefore destined to shatter. What then is the right strategy for change management that should now be adopted? This is discussed in the following section.

8. The Solution in a Nutshell: A University Hopping Strategy

While the conflict in Europe during the Second World War was well-defined geographically, the Pacific conflict was not. This is because after the pre-emptive attack on Pearl Harbour on 7 December 1941 by the forces of the Imperial Japanese Navy, the Japanese Army initiated an invasion of numerous countries in South East Asia in order to secure sources of oil and raw materials. By the end of 1942, in addition to their occupation of large regions of China and Manchuria, the Japanese Empire had expanded to include major industrial, economic and distribution centres, including Hong Kong, Singapore and the Philippines, for example. They had also occupied numerous Islands throughout the Pacific, many of which were not of any strategic significance in terms of the coming conflict with the USA. This situation and the realities of dealing with it were exploited in the strategy developed primarily by the Commander in Chief of the US Pacific Fleet, Admiral Chester Nimitz and General Douglas MacArthur in the Pacific War, 1943–1945, and was referred to as the 'Island-Hopping' or 'Leapfrogging' strategy [102].

The rationale for the Island-Hopping strategy was not to spend time, money and blood in taking back a complex of Pacific islands just because they contained a Japanese garrison. Instead, strategically important islands were targeted, in particular, those that could support a growing air force consisting of the new Boeing super-fortress under the supreme command of General Curtis LeMay. The purpose of this was to bomb Japan in to an oblivion until its government opted for unconditional surrender. This was achieved, the finale culminating in the use of the world's first nuclear weapons that devastated Hiroshima and Nagasaki in August 1945.

In regard to the Japanese forces that remained scattered throughout numerous pacific islands while the Island-Hopping strategy was being implemented, it was a question of letting them 'wilt on the vine'. In other words, the approach considered by the Americans was not to confront the problem everywhere but to go around the problem and focus on the key objectives that enabled dominance of the air to determine the outcome of the war. This has a clear and unambiguous synergy to the approach taken by Oliver Cromwell in the 1650s, as discussed earlier. Discontent with the academic traditions and institutes associated with English education at the time, he chose to establish brand new schools, academies and colleges that focused on technical training rather than non-technical conservatism, allowing many of the existing institutes to fade away organically. Furthermore, this is the strategy that is now being followed in the renewal of HE in the UK. It is based on starting with a clean slate by introducing and funding a new set of Technological Colleges that are characterised by the 'Solution in a Nutshell', as compounded in the following points:

(i) The new technological colleges, which in time will replace the rank and file universities, are administered by a small cohort of professionally trained managers, preferably those with an industrial, commercial and/or military background. Either way, such administrators must have significant experience in project and program management with appropriate vocational qualifications to match. In each case, a maximum three-year contract is provided, which is renewable upon completion, satisfactory performance and student evaluation. A primary object of such administrative staff is to minimise the administrative load(s) of teaching consultants and learning providers.

(ii) The new technological colleges have financial advisors and accountants with solid and proven experience in the management of funding for the sole benefit of college customers; all other investment portfolios being prohibited.

(iii) Conventional academic staff are replaced with industry consultants. The trainers that students come into contact with are respected experts in the field through their work with industry and, without exception, contracted to provide teaching on a per module basis. If the student evaluations are negative, then the module contract is not renewed. All trainers are, by default, expected to have undertaken a T3 (Train the Trainer) course and continuous T4 programs to introduce state-of-the-art teaching techniques and technologies.

(iv) Colleges focus on the National Vocational Qualification award scheme working with institutes, such as the City and Guilds, on developing opportunities for their students to enter earn-as-you learn schemes with local industries as apprentices in relevant technologies, ideally leading to the award of professional qualifications by relevant institutes.

(v) Research funding is only provided to specialist research institutes that are independent of a university or are centres for research excellence established within a university. Research contract overheads are set to a minimal level compatible with the infrastructure (physical and managerial) required. The projects are taken to be highly focused and the number reduced so that there is no proliferation of Mickey Mouse research grants in addition to Mickey Mouse qualifications across the sector. Research is also encouraged to take place elsewhere, not on the basis of securing government funding but on an individual philanthropic basis.

Examples in the realisation of points (i)–(v) above, which are taking place, are considered in the following section. For now, it is important to stress that this 'University Hopping Strategy' has a very positive function. It provides a solution to the 'Angry Dinosaurs Problem'. Having to explain the nature and effects of an approaching asteroid to the dinosaurs is just a waste of time. This is because they will not understand it, and even if they could, what can they really do about it? It is better to let nature take its course by virtue of customer (student) choice, especially once that choice has been established, e.g., [103–105].

For the universities that remain from the fallout to come, there is a further advantage that is related to the fast tracking of degree programs. For some time, many reputable UK universities have been recognising NVQs and introducing what are, in effect, fast track degrees, whereby a student with an appropriate NVQ can enrol on a one- or a two-year degree program in order to graduate with a Bachelors degree. This has the effect of reducing the fees that students have to pay to couple vocational qualifications to conventional degree programs and thereby integrate separate streams of qualifications relevant to the THM. There is also a positive knock-on effect for those universities that survive this reformation in English HE, which is that mainstream university academics will have significantly more time to undertake their research in an appropriate and multi-disciplinary research institute. This will also enable the 'Medici Effect' [106] to come to fruition when exciting things happen at the interfaces and intersections between different disciplines by exposing different fields of interest to one another and provide inter-disciplinary cross-pollination. In this regard, a problem-focused rather than a discipline-focused approach is required that can provide stimuli for academic renewal and act as a ' Silo-killer'.

9. On the New Age of the Technological College

In this section, two examples are considered that are representative of the new age of the Technological College that is evolving in the UK. They are illustrative of the realisation that a university degree is 'not the only route to success' and the recent announcement of plans to reform post-16 education in order to give employers the skilled work force that is needed [107], following the UK governments 2019 landmark review of HE [108].

In 2014, Microsoft identified the order of 100,000 technical, programming and IT-related jobs in the UK that could not be filled for lack of appropriate skills of UK graduates. Consequently, and after significant irritation in regard the matter, in December 2014, Prime Minister David Cameron announced the establishment of the first new college of its type since 1993. The Ada National College for Digital Skills [6] opened its doors in September 2016 with the following mission statement: *The mission of the College is to work with industry* *to design and deliver an institution that provides the education and support needed for all its students to progress into highly skilled, computing-related roles*.

The focus of this college is to provide a broad portfolio of students (from school leavers to more mature students seeking a career change) with the hands-on skills required to enter the digital technologies job market. This is a very relevant example of the strategy discussed earlier and is a quintessential case study of history repeating itself when, under the leadership of Oliver Cromwell, the stagnant education system of the times was replaced by new schools, academies and colleges.

The learning providers that work with the National College for Digital Skills are not traditional academics but industry-based experts with a wealth of practical experience in digital technologies from basic computer programming skills to current advances in Artificial Intelligence, Robotics and Machine Learning, for example. It is an example of a new college that provides an essential contribution to filling the job roles of the future that are associated with the so-called 'Big-data Society'. The type of industries that relate to this society have and will continue to drive progress in the communications infrastructure of the UK, data management and security, financial management and trading using cryptocurrencies, new health care technologies and personalised medicine, renewable energy, and, given the current COVID-19 pandemic, biosecurity and public health management.

Another example of the new age of the technological college is the Institute of Digital Technology at Bletchley [109], which is part of the Milton Keynes College [110] and opened its doors in September 2021. The aim of the College is to once again focus on developing the hands-on programming and technical skills required by an industry where the industry works hand-in-hand with the Institute by designing the modules and their curricula, presenting the material and tutoring students who have gained apprenticeships through the earn-as-you-learn schemes. This is an example that reflects the UK governments drive to by-pass the traditional university sector in terms of focus and funding. In this case, the aim is to reflect the work undertaken at Bletchley Park during the Second World War when scientists and engineers developed the bed-rock of the IT revolution. This is because it was at Bletchley Park that the worlds very first (partially) programmable computer—the *Colossus*—was designed, built and operated.

The Colossus project was undertaken by the practically minded telecommunications engineer, namely Thomas Flowers and his team. Flowers was a post-office engineer working for the Post-Office Research Station and an expert in the design of the electro-mechanical switch gear required to operate the telephone exchanges of the time. It was because of this knowledge that he was in a position to build a machine that, then as now, is essentially composed of a large set of switches. Installed at Bletchley Park in June 1944 and reconstructed in the mid-1990s, the Colossus 'read' the encrypted information communicated by the German high-command from the Normandy landings on the 6 June 1944 until the end of the war in April 1945.

It is most appropriate to praise and recall the work of the Cambridge academic Alan Turing who was recently, through a public poll, accepted to be the face of the new GBP 50 note. Turing was a crucially important figure in the development of digital computing (at least, from a theoretical point of view) and single-handedly improved upon the Enigma decryption techniques originally developed in Poland during the 1930s. However, the aim of the Institute of Digital Technology at Bletchley is to produce graduates with the technical skills of Thomas Flowers and not just the theoretical ideas of Alan Turing. Such aims are not designed to necessarily inhibit individuals from contributing the incredible originality and long-term influences of Alan Turing, merely to provide the technical excellence required by a society that has evolved to become reliant on the legacies of both Alan Turing and Thomas Flowers and many other scientists and engineers besides.

Alan Turing obtained prestigious qualifications from Cambridge University. By comparison, Thomas Flowers had qualifications from the City and Guilds London Institute. The work undertaken at Bletchley Park during the Second World War is illustrative of the fact that both such qualifications are important and must be respected in equal measure, lest the distinctions between a university (Cambridge or otherwise) and the City and Guilds become distorted through a clash between reality and the class struggle.

In 2011, the author of this article published a book entitled 'Cryptography and Steganography' [111] through the Erasmus Mundus teaching programs being undertaking at the time in the Centre for Advanced Studies at the Warsaw University of Technology, Poland, who published the work in their 'Lecture Notes Series'. The material focused on the development of new algorithms and applications in data security and was aimed, then as now, at encouraging students to develop their own software to test out the algorithms being considered using a 'hands-on approach'. Upon returning to the UK, the work was passed on to a senior academic at a highly reputable UK university who was responsible for teaching Cryptography. The reaction to the material presented in the book was that it was 'far too practical' to be of relevance. In light of this statement, one might wonder whether if Station-X at Bletchley Park had taken a similar attitude during the Second World War, this article might have been written in German!

10. On the Impact of Information Technology on Education

By considering Einstein's evolution equation for a Lévy distributed system, it can be shown that the Continuity Equation reduces to the Diffusion Equation subject to the Central Limit Theorem [112]. For a social system, this result can be interpreted as follows: Given sufficient time, the continuity of one idea will reduce to the diffusion of many ideas, providing a disruptive technology can be developed to 'open' the system and 'catalyse' the process. Further, once this reduction has matured, the diffusion of many ideas within the system will generate more and more disruptive concepts. The continuity of one idea is described by the Continuity Equation, which defines the conservation of mass or charge, for example. The Diffusion Equation (which governs the distribution of heat in a material over time, for example) describes the interaction and exchange of ideas between peoples from different backgrounds and cultures. The issue of providing 'sufficient time' (which is an ill-defined statement) relates to the governance of the Central Limit Theorem, where the linear aggregation of random systems (irrespective of their initial statistical distributions) tends to reduce to a system that is characterised by a normal distribution. The use of a Lévy distribution in regard to Einstein's evolution equation is consistent with the concept of introducing a disruptive technology to 'open the system' and initiate the process that takes place afterwards.

In 1439, a disruptive technology was conceived that had a huge influence on society. This was the printing press, which was developed in Mainz, Germany, by Johannes Gutenberg [113]. It played a key role in the development of the Renaissance and the scientific and engineering revolutions that followed. It was the basis for modern knowledge-based economies and the spread or diffusion of ideas into the mass populous. Thus, it was arguably the first technology of its type that may be identified with the concept of information distribution.

A consequence of the introduction of this disruptive technology was the dissemination of the disruptive concepts attributed to Martin Luther in Wittenburg from 1517, which catalysed the Protestant Reformation and the Age of Reason and Enlightenment [114]. Luther was a highly well-educated and prolific writer and had it not been possible to print his books, papers and pamphlets through the disruptive technology of his time, then his ideas might have remained closed to the populous. Although very limited compared to now, the fact that he could distribute his views throughout the German speaking peoples and beyond, led to developments in education and the broad spectrum of cultural activities that accompanied it. For example, Germany is considered, and rightly so, to have the longest continuous and uninterrupted tradition in the development of western music and to an extent that overshadows all other nation states. Why should this be? Because Martin Luther had written extensively on the importance of music in Christian worship, which was to be inclusive of the 'audience'. Thus, when Johannes Sebastian Bach wrote his contiguous stream of Cantatas along with a wealth of other music, he was doing more than earning a living. He was doing his master's bidding, a bidding that was expected within the cultural framework of his time. Bach's influence on musical form and its development is unprecedented in the history of western civilisation, but this is not what he had in mind at the time. In his mind, he was contributing to the Reformation; one that was made possible through the printing of his scores and in so doing, led to the development of musical notation in an attempt to minimise the costs associated with the printing techniques of the time. Thus, in more ways than one, the printing press provided the route through which Europeans were able to more fully appreciate the meaning of the phrase, 'Veni Creator Spiritus' (Come, Spirit of Creation).

In 1985, Michael Gorbachev became the eighth and last leader of the Soviet Union. He was the General Secretary of the Communist Part of the Soviet Union from 1985 to 1991. Upon coming to power, it is said that he told his wife that he was now in charge of the largest and best-educated country in the world and yet people could only talk about life in the kitchen. Actually, the kitchen is not a bad place to discuss life; second only to the pub and the bedroom but not necessarily in that order! Shortly after becoming leader of the best-educated country in the world, he introduced their policy of openness or 'Perestroika'. He also embarked on a policy of positive discrimination in which those who were not part of the old establishment were promoted to positions of prominence in all aspects of society. These policies were examples of disruptive concepts and led directly to the fall of the Berlin wall in 1989 and the collapse of communist systems the world over except in China. This is because by then, China was pursuing a route to enlightenment based on a principle introduced by Deng Xiaoping, namely *it does not matter whether a cat is black or white, as long as it can catch a mouse* [115]—preferably a mouse with more than a Mickey Mouse degree!

The collapse of the communist system in the USSR and the Warsaw pact was catalysed by Gorbachev's disruptive but necessary policies. However, they could not have been effective or influential if it had not been for the development of another disruptive technology, namely the early stages of those technologies associated with the Internet in the 1980s and the World Wide Web in the 1990s, which we now take for granted. In this sense, and, if a parallel can or should be made in respect of Gutenberg and Luther in the Sixteenth Century, then it is, respectively, Sir Timothy Berners-Lee and Michael Gorbachev in the Twentieth Century. The Internet aside, more conventional information technology was used to catalyse the coming changes for the communist block, such as the distribution of advanced printing facilities by the CIA into Poland in order to aid the development of the Solidarity movement during the 1980s; Poland being the very first communist domino to fall. Thus, the distribution of information using old, new or emerging information technologies is a critical source of disruption that has seeded and continues to disseminate disruptive concepts and a hunger for change. Furthermore, now that hunger is set to significantly change the modus operandi of HE, an effect that has been understood for some time and will lead to a dim future for any and all universities that fail to accommodate [116].

In both cases, i.e., the introduction of the printing press in the 1520's and the creation and development of the WWW in the 1990s++, the technologies associated with the distribution of information to the populous has driven the radical changes that are reflected in the continuity of one idea transforming to the diffusion of many. It is possible that, in a broad societal context, this process is as natural in a social system as it is in a physical or biological system. Coupled to this possibility, however, is the inevitable resistance to change by the established authorities of the time, who fail to understand some of the basic laws of statistical physics and the dynamical process of all organic systems (including their own).

In the appalling scenes that took place in Washington on 6 January 2021 [117], one of the flags that was waved stated 'No more Bullshit'. While the behaviour of this form of support for President Trump was entirely reprehensible, the sentiment associated with this statement is not, irrespective of the individual who encouraged it. Unless this sentiment, and what it represents in the larger societal context, starts to be appreciated by current and future governance, the rift that has been initiated will continue to grow, especially in the younger generation who perceive that they are being used—they are, especially in regard to the educational provision they are being provided with.

It would appear that Donald Trump has opened a 'Pandora's Box'. In this respect, the educational fraternity that has seen fit to deprive emerging generations of a future that is commensurate with parental expectations, guidance and advice, has become responsible for its own demise; such is the reality of the flow of digital information that will continue to ensure that no one trusts anything and everyone questions everything. It is in this context, and that of the COVID-19 pandemic, that the next revolution will come into effect, a revolution concerning the effect of IT on education, a revolution that, like the age of enlightenment, will radically change society.

By way of an example, the author of this article has been involved in IT, Computer Science and, more latterly, Cryptography for over 30 years. A life-long Fellow of the British Computer Society, the author has developed a number of spin-off companies, all of which related to the author's research in areas such as Computer Vision and Artificial Intelligence. The knowledge gained to do this is not owed to any university or academic institute and their convoluted approach to managing computer centres, for example. Instead the author's knowledge of computer science is a direct result of the efforts of an entrepreneur who never bothered graduating from a university, namely, Lord Alan Sugar, whose business efforts provided the opportunity for the author to purchase a personal computer, an Amstrad 640, in 1988. This gave a level of independence that was devoid of interference from lecturers in computing, computer managers and the like and facilitated the chance to learn how to program a computer through practical experience using the relatively limited literature available at the time without being confused by self-serving academics. Consequently, it was Alan Sugar who did more for the author's education and professional development than any university did then or could do now.

This recollection highlights a current problem that has been exposed as a result of the COVID-19 Pandemic effect on education. This is the issue of 'Digital Poverty'. With the increasing focus in regard to online learning, Digital Poverty is set to limit the training and education of learners more fully than any other educational policy. Furthermore, the cost associated with solving this problem compared to the combined salaries of university academics is surely minimal. In short, having a personal computer and access to the internet can do more for the education and skill development of younger generations than any university. Thus, just as Alan Sugar provided the author and many others with an affordable facility to develop hands-on IT skills, so too should current and future governments do more for education by eliminating Digital Poverty than anything else.

11. Concluding Remarks

The current crisis in UK HE is compounded in what current employers of its graduates are constantly saying, namely that while the cost of education to both the state and students alike is growing, graduates are increasingly unprepared for the workplace. Thus, both parents and schools alike should therefore start to encourage school leavers to enter the 'University of Life' through earn-as-you-learn apprenticeships. This approach should be nurtured on the basis that:

(i) In the short term, more and more universities (at least those that remain in business) will offer fast track one- or two-year (maximum) degree programs that are predicated on an increasing recognition of and respect for an NVQ.
(ii) Such fast-track degree programs will be integrated into online learning schemes, especially in light of the fact that the COVID-19 Pandemic has forced the issue and shown that this mode of teaching is not only possible but desirable, especially in regard to cost effectiveness.
(iii) The current lack of parity of esteem between vocational and university educational pathways due to the class struggle will become dissipated.

It is point (iii) above that is the more difficult issue to resolve, as it represents a deeply embedded social reality in the UK, more so than in many other countries and societies.

On the other hand, if the middle classes in the UK want to continue to do their children the disservice of limiting their future prosperity by being a sucker to educational values that have passed their sell-by date, then perhaps they should be encouraged to do so. This is because it will provide a new window of opportunity for the coming technically competent proletariat to influence the future prosperity of the state; something that Oliver Cromwell himself may have understood in his vision for the new English republic and perhaps, if he had lived long enough, might even have discretely encouraged.

After decades of rapid expansion in UK HE and the current period of stagnation that it is now experiencing, STEM has acquired a pole position in HE (world-wide). Nevertheless, the provision of STEM must start to focus on moving away from superficial learning to more in-depth training and become work-place-based and informed by industry experts. The growing number of new technological colleges are free to implement this approach as they are not constrained according to the contractual obligation of academic staff with tenured positions, whose mentality was moulded by a society of excess that no longer exists. This is why more and more state funding is set to be channelled into the development of the academies and technological colleges as it was in the 1650's to produce an educational wealth that was common to all the people of the Commonwealth and the 'New Jerusalem' they yearned for.

Even though the new technological colleges will have greater freedoms than the old and new university sector, their teaching and research programs must come to be based on continual developments in the curriculum and teaching practices that are based on the 'pursuit of practical knowledge' and the motto of the Massachusetts Institute of Technology, 'mind and hand'. Moreover, they must continually take into account that 'Shift Happens' in respect of the impact of IT on education and that *for students starting a three-year degree, half of what they learned in the first year may be out dated by the time they have completed their studies* [118]. On the other hand, this is a reality that will become null and void as the university sector starts to focus on fast-tracked final year degree programs predicated on a NVQ awarded by institutes, such as the City and Guilds London Institute, through the UK Academies [100,119] and the new Technological Colleges.

One of the reasons for the current need and inevitable future success of the new technological colleges is the knock-on effect of the UK Polytechnics being given university status in the 1990s. There was nothing intrinsically wrong with this. What was wrong is that the new universities set about trying to copy the old universities instead of cultivating and improving upon what they were already good at and well respected for, namely technical training. Because of this, the gate was opened for the private sector to take advantage of what the new universities were quite literally throwing away through disregarding their raison d'être.

Today, the situation is reversed, and UK universities, both old and new, are waking up to the fact that their degree programs are increasingly out of date and out of sync with current and future generations. When they are not trying to sell their Mickey Mouse degrees abroad, they are now attempting to cash in on the NVQ programs. Both approaches are symbolic of the HE system having been reduced to a business enterprise culture that is dominated by staff who have become increasingly unaware of their customers needs—something through which no state economy can thrive. Furthermore, until university academics are prepared to find a way to change accordingly, they will not be fit to manage the education of future generations. For the world is a very different place to that when many senior university academics were themselves educated, and the economic dominance of the free world is being challenged on all fronts. In order to develop further, that free world must rapidly engage in freeing future generations from a system that has created a populous that is dumb and in debt, thereby protecting itself from the implosion suffered by the old communist world as a direct result of providing its citizens with a free and comprehensive education in science and technology. The transitions that are going to take place should be understood in terms of a stark evolutionary fact, namely that it is not the strength in a tradition which matters, it is the ability for any and all traditions to be able adapt to the changing circumstances that forge the future which counts.

12. Some Final Thoughts

Given the change management that is required in HE, whether it be in the UK or elsewhere, is there another governing issue that is taking place throughout society, and, if so, how should education, in the broadest context of the word shape the future? The changes that took place in Europe from the Renaissance of the Sixteenth Century onwards have moulded society into the world order that currently exists. The word Renaissance means quite literally Re-birth; a re-birth of what? A re-birth, and, as of now, an all-out revival of the Greek view of life and Hellenistic culture. Hellenism is a culture that is arguably influencing current times in a more profound way than it did in the earlier part of the re-birth of Europe.

Hellenism is not only continuing to influence the future of society, it is actually accelerating society into that future. In this respect, the practices, traditions and all-out superstitions of the medieval mind have and continue to give way to the enlightenment of the ancient Greek and Roman civilisations. It is upon these civilisations that the underlying flow of modernity is based but not always accepted. This is due to the monotheistic cultures that emerged in Europe when Rome morphed from being a Pagan to a monotheistic society. In this respect, it may be surmised that the order of 1500 years went by when Greek philosophy lost out the monotheistic theology and for this reason alone, the post pagan Roman period before the Renaissance of the Sixteenth Century is deserving of the title, the 'Dark Ages'. For this was an age when people lived and died according to the whims and fancies of unelected heads of state, some of whom lost their heads!

Above and beyond developing a new class of technological colleges that focus on STEM, what should be the broader aim of education? What should, if any, be the ultimate goal? Surely, it should be something along the lines of constructing a society that gives opportunity to all in a way that harmonises their life-long quest for continued education and in doing so, yields a culture where judgement is based on, to paraphrase the words of Martin Luther King, *the content of their character and not the colour of their skin*. It is therefore worth noting that beyond the contributions and, in many cases, the inventions made by the ancient Greeks and Romans to Philosophy, Mathematics, Medicine, Politics, Music and Literature to mention just a few, the great virtues of their society were intrinsic multiculturalism and multi-theological tolerance. It was a society that was intrinsically devoid of any form of racism or sexism; the greatest empire of all—an empire of the mind.

In 1889, the great Russian writer, Anton Chekov, published one of their many essays and short stories for which he is now famous. It is entitled 'The Bet' [120], and it is an example of a time-honoured and quintessential Russian tradition in regard to asking but not necessarily solving the more important questions and issues of life. As such, this short story takes the reader on a fascinating journey in which the forced isolation and self-education of a young and idealistic lawyer leads to an evaluation of society that is far from that which he perceived before he became so well educated. Like many other Russian writers of the time, Chekov's rendition of how education can provide an individual with a level of freedom that transcends the trappings of a society with an out-dated modus operandi reflected a vision for the future that he could not have imagined but was nevertheless catalysed throughout their country in 1917.

The Russian revolution, its causes and its long-term effects have been studied and commented on by historians for decades. However, there is one thing about it that is undisputed. This is that it had the effect of draining the 'Petrograd Swamp', inclusive of changing the name of the city (which had originally been built on a swamp anyway). Furthermore, in doing so, it provided the potential for countless illiterate individuals to contribute their scientific, engineering, artistic and humanitarian talents to a new society. One such individual was Michael Gorbachev who managed that society through its final phase transition—from the saturation phase and time of stagnation through to the death phase. That this society, like any other, underwent its initial, interim and final phase transitions is not important, but the manner in which the death transition occurred is. Under the governance of a lesser well-educated and well-balanced individual, this paper might not have materialised, and, even if it had, there might be few people, if any, able or interested in reading it. This conclusion is something that the UK might do well to contemplate in regard to the phase transition that it is now entering; a transition that, above and beyond the education system it has conceived for its people, is going to become increasingly dependent upon a radical change in that system.

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Article

Exploring Faculty Perspectives during Emergency Remote Teaching in Engineering at a Large Public University

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Abstract: In Spring 2020, the College of Engineering at San José State University (SJSU) conducted a comprehensive analysis of the impact of COVID-19 on faculty who were forced to transition to an online learning environment. The purpose of this study is to assess the impact of COVID-19 on faculty teaching methods, assessment methods, and personal well-being. The study was a combination of a quantitative survey and a qualitative study using interviews of engineering faculty teaching in Spring 2020. In the first part, we surveyed all faculty teaching during Spring 2020 in the SJSU College of Engineering about their experiences after the move to 100% online instruction in March 2020. In the second part of the research, we interviewed 23 faculty members to obtain a more in-depth understanding of their experiences during the move online in Spring 2020. Overall, 98 faculty participated in the survey: lecturers (58), tenure-track (18), tenured (13), adjunct (1), and Teaching Associates (1). The faculty reported being worried about their family and their students' well-being. In addition, 65% of faculty members reported either a moderate or a great deal of stress related to the shelter in place, and this percentage was higher for female faculty (74%) and for tenure-track faculty (83%). Overall, faculty members felt that they had their classes under control most of the time and that the transition to online teaching was positive, even if they felt they had too much work to do and felt always in a hurry and under pressure. From a teaching perspective, the interviews highlight that faculty members' main concerns focus on testing and assessment and students' engagement. Overall, SJSU College of Engineering faculty members felt under stress in the transition to online teaching, especially the tenure-track faculty members, but were able to transition their classes with ease.

Keywords: distance learning; faculty attitudes; emergency online teaching; engineering; COVID-19; higher education; survey; interviews

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1. Introduction

The California State University system, the largest four-year public university system in the United States, was among the first to call for an immediate transition to online learning in Spring 2020 across the whole 23-campus system. It was also the first system across the country to announce that both the Fall 2020 and Spring 2021 semesters would remain primarily online, with limited hybrid course offerings. These early decisions prompted a group of faculty members in the College of Engineering (COE) at SJSU to survey students and faculty members to better understand their experiences as a result of the sudden shift to online learning due to the shelter-in-place order, with the intent to better prepare for Fall 2020 and Spring 2021 online instruction. The rapid switch to online instruction in March 2020 did not allow faculty members to train, plan, and reflect upon the best teaching modes for online instruction, unless they had previously taught an online class. Therefore, as with many other researchers [1], we consider the Spring semester to be an example of emergency remote learning rather than planned online learning.

Online education (also called online learning, remote learning, distance learning, or e-learning) has grown in popularity across the U.S. over the last 10+ years, with increased online options across all universities, including public, private, non-profit, and for-profit institutions. Online learning is defined as education that takes place online, either synchronously and/or asynchronously. In Fall 2018, approximately 35% of undergraduates in U.S. two and four year colleges took at least one online course [2].

One consistent factor for effective online learning is the recognition that quality online education requires careful and effective design, delivery, and assessment that goes beyond shifting in-person practices to an online environment. The need for high quality online education tools is greatest when student populations are underserved or at-risk, including students who are low-income, first-generation, and persons of color [3] The students of the College of Engineering and SJSU are diverse, with a significant number of students identified as one or more "at-risk" markers including first-generation college students, low-income students, and underrepresented students. Table 1 presents demographic data for SJSU and the College of Engineering.

Table 1. Demographic data for the College of Engineering and the University in Spring 2020 [4].

	College of Engineering		SJSU	
	Headcount	**Percentage**	**Headcount**	**Percentage**
American Indian/Alaskan Native	1	0.01%	18	0.06%
Asian	2136	33.5%	10,221	33.3%
Black or African American	107	1.7%	986	3.2%
Hispanic/Latinx	974	16.8%	8292	27%
Native Hawaiian or Other Pacific Islander	19	0.29%	136	0.44%
White	799	12.5%	4728	15.4%
Two or More Races	208	3.3%	1393	4.5%
Non-Resident Alien	1895	29.7%	3669	11.9
Unknown	233	3.7%	1266	4.1%
Total	6371	100.00%	30,709	100%
Persons of Color	3445	54.1%	21,046	68.5%
Pell Recipient *	1444	22.7%	9991	32.5%
First Generation Student *	2281	35.8%	13,733	44.7%

* Pell recipients are used by SJSU as a measure of low-income status. A First Generation student is a student who is the first in their family to attend college.

Online course offerings are an important component of higher education. However, online education, similar to other major transitions in higher education, has been met with resistance from instructors [5]. Administrators who promote online education are accused of prioritizing cost over quality, student outcomes, and faculty expertise [6]. In engineering, there are few online courses or degrees available in the U.S.; however, online engineering courses are more available at the graduate level.

Online instruction, which has grown in popularity in the last decade in the US, requires thoughtful instructional design, delivery, and assessment. Online instruction is different from teaching in-person and requires skills and expertise that are generally not part of faculty members' education and experience. Use of technology, which is of paramount importance in online instruction, can be a barrier to some of the faculty members.

Generally, online learning comprises of a combination of synchronous (real-time) and asynchronous learning (on-demand). Most common pedagogies in online teaching include discussion boards, audio and video submissions, text-based assessment, collaboration, emails exchanges, text-based chat, audio and video conferencing, real-time polls, real-time collaboration, and real-time assessment [7,8]. These teaching modes can be classified as "surface structures" (pedagogies that transmit the information between the teacher and students), "deep structures" (pedagogies that encourage higher order thinking and problem-solving), and "implicit structures" (pedagogies that develop a moral dimension in terms of professional values and attitudes). According to Eaton et al. [7], some teaching activities in the online environment have "the potentials to cultivate deeper learning experiences, but they can fail to do so if activities are not designed and implemented properly".

Since the emergency move online in Spring 2020, there have been several surveys of faculty to ask them about their experiences. The Higher Education Data Sharing Consortium (HEDS), in their survey of faculty, received responses from 4000 faculty from 28 different colleges [9]. The faculty felt overwhelmed in Spring 2020 by the increased amount of work in the newly online classes, with 61% of faculty indicating they had too many things to do, 55% felt that they were in a hurry, and 51% felt under pressure from deadlines.

A second survey of university faculty in Spring 2020 was done by Tyton Partners, in conjunction with Every Learner Everywhere [3]. Nearly 5000 faculty from over 1500 institutions responded. This survey found that almost all faculty (91%) had to move online in Spring 2020 because of COVID-19. Fewer than half of the faculty had ever taught online. The Tyton study also found that faculty had difficulties in engaging and motivating their students after the move online. Faculty also indicated that child or elder care was a significant challenge for 40% of faculty, with women and tenure-track faculty more likely to report this concern. In addition, research indicates that many faculty had technical issues after the move online [10], such as lack of reliable internet connection, no access to a webcam or camera for use during online instruction, and no access or technical difficulties with online writing tools.

Faculty challenges with the emergency remote learning include a decreased interaction with students during class time and decreased students' engagement [11,12], increasing concerns about students well-being [13], and a general feeling that their course quality has decreased [12]. In addition, faculty members needed to juggle work with personal needs. Some of the strategies that faculty members adopted to adapt to the remote environment include modifying or dropping assignments and exams and lowering their expectations about the quantity and quality of the work performed by the students [14]. Despite the challenges, according to Williams [12], faculty members had a positive experience in teaching remotely in Spring 2020.

Almost all faculty members in the United States were required to shift their pedagogy in Spring 2020, in what has probably been the quickest shift in teaching pedagogy that the academic environment ever experienced. In order to understand the underlying assumptions that drove faculty members in re-evaluating their teaching practices and adapting them to the remote environment at the end of the Spring 2020 semester, Deters et al. [15] conducted semi-structured interviews of three mechanical engineering faculty members and eight students. This study identified three main core beliefs that motivated faculty members' decision: fear of cheating, valuing of hardness, and views on flexibility. The personal challenges that faculty members experienced likely influenced their ability to effectively shift their pedagogy and testify to the resilience of the faculty body. Morelock et al. [16] created a novel research platform to collect the experience of students, faculty members, and staff (for a total of 70 participants, of which 25 were faculty members). The study identifies that students and instructors struggled to recover a sense of connectedness in a remote environment, as well as a disconnect between faculty members' and students' experiences. Students and faculty members faced a range of COVID-19-related challenges within and outside of academia.

There also has been increased stress reported by faculty after the move online because of COVID-19 [17–19]. For example, Bizot et al. [19] found that over half of the computer science faculty who responded to the survey had used active learning before the move online. However, 34.9% of the faculty discontinued their use of active learning after the move online, while 43.4% made minor changes and 21.3% made significant changes. Bizot also found that the Computer Science faculty had higher levels of stress after the switch online because of COVID-19.

In October 2020, the Chronicle of Higher Education conducted a survey among faculty members at U.S. institutions to gain insights into how the pandemic affected faculty members from a mental and emotional perspective [20]. A total of 1122 faculty members responded to the survey from four-year and two-year universities. The analysis of the data highlights that the majority of faculty members experienced elevated levels of frustration, anxiety, and stress as they struggled with increased workloads and a deterioration of work–life balance. This is especially true for female faculty members. The survey also highlights that more than two-thirds of all faculty members were discouraged enough to consider retiring or changing careers and leaving higher education, with tenured faculty members even more likely to retire than others. In addition, tenure-track faculty had some of the highest levels of stress and fatigue. Faculty members faced a multitude of challenges at the same time: abruptly changing their work strategies and habits, learning new technologies, job insecurity due to the economic challenges of higher education, worries about the health and well-being of their families as well as students, and losing collaboration opportunities. The Chronicle of Higher Education's survey, however, did not explore the experiences of the faculty members from a teaching perspective.

This paper is part of a larger study completed at SJSU which looked at the impact of COVID-19 on students and faculty members [21–24]. We surveyed all the faculty members that taught a class in the College of Engineering at SJSU in Spring 2020 (more than a hundred of responses) and interviewed 23 of them. In addition, we surveyed all the students enrolled in the College of Engineering at SJSU in Spring 2020 and interviewed 40 students [22,23]. This paper presents a comprehensive description of the results of the survey and of the set of interviews with engineering faculty members at SJSU University after the end of Spring 2020 semester and explores faculty members' experiences as well as the novel teaching approaches they used in the emergency remote environment.

This paper is organized as follows: there is a description of the research questions in Section 2, the methodology for the survey is in Section 3, and the methodology for the faculty interviews is in Section 4. The results of the survey and interviews are presented in Section 5 and extensively discussed in Section 6, followed by a conclusion section (Section 7). A discussion of the limitations of the approach is presented in Sections 8 and 9 discusses possible future work.

2. Research Questions

The current article describes the results from the faculty survey and the faculty interviews. The research questions of the study are:

- Did faculty experience pressure and stress during the COVID-19 transition to emergency online learning?
- What challenges have faculty identified during the online transition and how do they plan to improve instruction?
- Is there a difference in the effect of COVID-19 among tenured faculty and tenure-track faculty and lecturers?
- What are the impressions of faculty members to the learning environments in engineering courses after the switch to emergency remote learning in Spring 2020?
- What was the impact of the switch online in Spring 2020 to lab classes?

3. Materials and Method: Faculty Survey

The research team based the surveys on the questions that were developed by researchers at Georgetown [25] and HEDS [9] to survey the student population, and modified them to be relevant to the faculty participants. In designing our students' survey, we used questions from the Georgetown survey that related to the students' personal experiences with life during COVID-19, including questions about the students' medical situation, living situation, financial situation, and perceptions about the future. We added questions from the HEDS survey about student worries including stress levels, satisfaction with institutional responses to COVID-19, and intent to return. The research team also added questions that investigated student access to resources, student communication with instructors, the availability of faculty for office hours, experiences with controlled testing environments, and specific questions related to laboratories and project-based classes that are relevant to the engineering classes at SJSU. As much as possible, the faculty survey asked similar questions as our student survey. We mirrored the questions for the faculty survey from the Georgetown [25] survey, which related to personal experiences with life during COVID-19 including questions about the faculty member's medical situation, living situation, and financial situation. We also mirrored the questions about stress from the HEDS [9] student survey for the faculty survey. The team submitted an IRB application, and it was approved on 28 May 2020.

The survey design was based upon the Lazarus' Theory of Stress: "psychological stress is a particular relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well-being" ([26] p. 19). This theory is defined as a transactional theory of stress and coping and is related to other constructs in psychology including locus of control [27] and self-efficacy [28]. Existing research has shown that the COVID-19 pandemic was stressful to many colleges students and faculty who underwent changes that taxed their resources. According to Lazarus and Folkman, there are two phases in psychological stress: appraisal and coping. An individual in a potentially stressful situation first appraises the situation in relationship to their own sense of well-being: "Primary appraisal is an assessment of what is at stake: "Am I in trouble or being benefited, now or in the future, and in what ways?" If the answer to this question is yes, then people categorize the situation as being a threat, a challenge or a loss." [29]. Coping relates to a secondary appraisal of the situation and the individual's self-confidence to have the resources to deal with the situation. The resources can include physical, social supports, or financial or psychological resources. According to Lazarus and Folkman [26], coping has two major purposes. First, it regulates the negative emotions that relate to the stressful situation, in this case, the COVID-19 pandemic. Second, individuals can manage the problem by attempting to change the stressful situation. In the COVID-19 pandemic, since the situation was not usually able to be managed by some faculty and students, most of the coping relates to faculty and students attempting to regulate their emotions or distress caused by the pandemic.

Coping with the COVID-19 pandemic was a unique experience for most faculty members students and challenged their regular patterns of coping behaviors. Most faculty and students were not prepared for the lifestyle and education changes initiated by the pandemic and found they lacked the coping strategies to deal with it. "If the individual does not believe he or she has the capacity to respond to the challenge or feels a lack of control, he or she is most likely to turn to an emotion-focused coping response such as wishful thinking (e.g., I wish that I could change what is happening or how I feel), distancing (e.g., I'll try to forget the whole thing), or emphasizing the positive (e.g., I'll just look for the silver lining)" [30].

3.1. Recruitment

The survey was distributed to all lecturers and tenured/tenure-track faculty using the SJSU College of Engineering email distribution list. An email distributed to all faculty teaching in Spring 2020 contained a link to the faculty survey. About one week after the initial email, a reminder was sent to the faculty who have not filled out the survey or have not finished it. A final reminder was sent in week 3. One of the last questions in the survey asked for volunteers to participate in an interview.

3.2. Participants

There were 288 faculty (lecturers, tenure-track and tenured) that taught a class in the College of Engineering at SJSU in Spring 2020. Overall, 98 faculty completed this survey, which represents 34% of the faculty population and equates to a confidence level of 95% with a margin of error of 8%. Because of this low margin of error, the research team is confident that this survey is representative of the faculty teaching in the College in Spring 2020 [31].

The majority of the respondents who answered the question about rank were lecturers (58); there were fewer tenure-track (18), tenured (13), adjunct (1), and Teaching Associates (1) responding. Of the faculty who identified their gender, 66 were men and 27 were women. It is interesting to note that there were more responses from newer faculty; 45.1% of the faculty responses were from faculty with five or fewer years teaching at SJSU (see Table 2). Before Spring 2020, only 26 of the 88 respondents had taught a course online. Of the faculty who previously taught online, only seven had taught online for five or more years.

Table 2. Reported number of years teaching at SJSU for Faculty Responding to the Survey.

Answer	Headcount	Percentage
0–5 years	41	45.1%
6–10 years	15	16.5%
11–15 years	12	13.2%
More than 15 years	23	25.3%

Faculty from every department in the College responded to the survey. The survey respondents were generally representative of the faculty in the College of Engineering with the exception of the faculty in Computer Engineering and Chemical and Materials Engineering who were under-sampled and the faculty in Civil and Environmental Engineering and General Engineering who were over-sampled, as shown in Table 3.

Table 3. Comparison of the total number of Faculty in the SJSU College of Engineering (SJSU Institutional Research, Spring 2020) to the Survey Respondents.

	SJSU Data		Survey Respondents	
Department	Headcount	Percentage	Headcount	Percentage
Aerospace Engineering	15	4.9%	8	7.7%
Aviation and Technology	40	13.5%	11	10.6%
Biomedical Engineering	10	3.3%	3	2.9%
Chemical and Materials Engineering	27	8.9%	5	4.8%
Civil and Environmental Engineering	30	9.9%	15	14.4%
Computer Engineering	63	20.7%	12	11.5%
Electrical Engineering	30	9.9%	13	12.5%
General Engineering	33	10.8%	16	15.4%
Industrial and Systems Engineering	21	6.9%	6	5.8%
Mechanical Engineering	35	11.5%	11	10.6%
Other/NA	1		4	
Total	305		104 *	

* The number of faculty in the departments is greater than the total number of faculty respondents (n = 98) because some faculty members in the COE work for more than one department.

About half of those who responded to this question (48.9%) did not work outside of SJSU in Spring 2020; however, a significant number, 27 faculty members (31%), worked full-time outside of SJSU in Spring 2020.

4. Materials and Method: Faculty Interviews

4.1. Recruitment

A final question in the faculty survey asked for volunteers to participate in an interview. All volunteers were contacted by the research team to conduct interviews, except for faculty members that were currently acting as Department Chair in the college. A total of 23 faculty interviews were conducted.

4.2. Interview Protocol

Our interview protocol was informed by the interview protocol that was used by Pawley [32] at Purdue University. The interview consisted of two questions: "How did you do in your classes in Spring 2020?" and "How did SJSU as an institution do in this transition?". According to Pawley, these open questions allow "participants to tell their stories in whatever way they chose". Some participants asked for more guidance in answering the questions, and the research team therefore developed a variety of prompts such as "Tell me a little about yourself. Tell me about your experiences at SJSU after the transition to 100% online instruction. Has COVID 19 made any impact on your life? Let's talk about that for a minute; Tell me more about that; So, just to clarify . . . How did you learn about this? What was important to you? Any regrets? Anything you wish you had done differently? Anything else you would like to tell me?".

The interviews lasted about 20–30 min. The interview recordings were completed through Zoom cloud and Zoom automatically created a transcript of the recording. The research team reviewed the transcripts and recordings together for typos in the transcript and words that the transcriber misheard or misunderstood. The research team then pseudonymized the transcripts, masking names, places, ages, organizations, ethnic groups (replacing them with broader racial categories), nationalities, languages, and religious affiliations or communities for those participants who desired it and the names of people participants mentioned. The participants were then sent both the original transcript (for their records) and the pseudonymized transcripts to review for inaccuracies or things they regretted saying.

At this point, the revised transcripts were coded by two members of the research team, a faculty member and a graduate student [33]. An iterative inductive stage was used that involved several close readings of the transcribed interviews to code the results. This reading provided a holistic perspective of the responses. At this stage, points of interest and interpreted significance were coded by the two coders, respectively, who then compared and arbitrated their results until they achieved a valence of consistency that approximated near complete calibration. The coding was defined using NVivo 12, a qualitative data analysis tool, to code responses and identify outstanding themes of perceived in the student and faculty interviews. Once the codes were arbitrated and calibrated, the team completed a step-by-step analysis that went into the description of the analytic themes previously derived that culminated into a rich description of the phenomena from the participants' point of view and a subsequent conceptual interpretation conducted by the team.

4.3. Participants

The research team conducted 23 interviews with faculty of the SJSU College of Engineering of which six identified as female, 16 identified as male, and one identified as unassigned. Most of the participants were lecturers (18 out of 23), with two tenure-track faculty and three tenured faculty. Of these, nine participants have been teaching at SJSU less than five years, six participants for 6–10 years, two participants for 11–15 years, and six participants for more than 15 years, as shown in Table 4. All departments in the college were represented across the participants. Department data has been excluded from the reported data out of concern of identification due to the small number of teaching faculty in many departments. Each participant was assigned a pseudonym, taken from the Atlantic Tropical Cyclone Names [34] for 2020 and 2021 to limit any potential bias that could arise from the research team choosing random pseudonyms.

Table 4. Interview faculty participants identified by their pseudonym, gender, status, and time teaching at SJSU.

Participant	Gender	Status	Years Teaching at SJSU
Josephine	Female	Lecturer	6–10 years
Dolly	Female	Lecturer	more than15 years
Hanna	Female	Tenure-track	0–5 years
Laura	Female	Lecturer	6–10 years
Paulette	Female	Lecturer	6–10 years
Vicky	Female	Lecturer	11–15 years
Kyle	Male	Tenured	more than15 years
Arthur	Male	Tenured	0–5 years
Isaias	Male	Lecturer	0–5 years
Cristobal	Male	Lecturer	0–5 years
Edouard	Male	Tenured	more than15 years
Victor	Male	Lecturer	6–10 years
Gonzalo	Male	Lecturer	0–5 years
Peter	Male	Lecturer	11–15 years
Nicholas	Male	Lecturer	0–5 years
Omar	Male	Lecturer	6–10 years
Marco	Male	Lecturer	more than15 years
Larry	Male	Tenure-track	0–5 years
Henri	Male	Lecturer	0–5 years
Bill	Male	Lecturer	more than15 years
Fred	Male	Lecturer	more than15 years
Wilfred	Male	Lecturer	0–5 years
Bertha	Unassigned	Lecturer	6–10 years

5. Results and Discussion

5.1. Survey Results

The survey explored two main themes. Initially, faculties reflected about their personal experiences and psychological well-being in Spring 2020, including the stress and pressure that they experienced. Then, the survey explored the pedagogies and tools that faculty adopted in the transition to emergency online instruction.

5.1.1. Personal Experience and Psychological Well-Being

Several faculty members (29 responses out of 92 responses) are living with someone over the age of 65 or who has a risk factor for COVID-19, mostly lecturer and tenured faculty. In addition, 34.8% of faculty (32 faculty members) either had to care for children or elderly people either full-time or part-time during the shelter-in-place in Spring 2020 (see Figure 1 and Table 5). A higher number of faculty (39%) who had taught less than five years had to care for children or elderly people either full-time or part-time, although this was not significant. Slightly more lecturers (36%) and tenure-track faculty (38%) had to care for children or elderly people either full-time or part-time than tenured faculty (30%). As could be expected, female faculty had much higher care responsibilities than male faculty; 59% of all female faculty had to care for children or elderly people either full-time or part-time during the shelter in place compared to 24.6% of the male faculty.

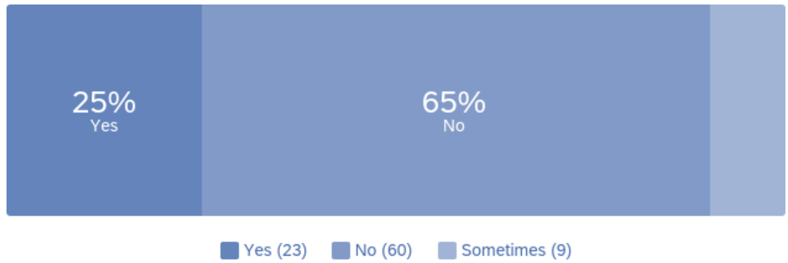

Figure 1. Responses to the question "Do you currently have to care for children or elderly while under quarantine?" for all faculty members.

Table 5. Responses to the question "Do you currently have to care for children or elderly while under quarantine?" broken down by faculty rank and gender.

	Yes	No	Sometimes
All faculty	25% (23)	65% (60)	10% (9)
Female:	52% (14)	41% (11)	7% (2)
Male:	14% (9)	75% (49)	11% (7)
Tenure-track	39% (7)	61% (11)	0% (0)
Female:	50% (5)	50% (5)	0% (0)
Male:	25% (2)	75% (6)	0% (0)
Lecturer	22% (12)	64% (35)	15% (8)
Female:	46% (6)	38% (5)	15% (2)
Male:	14% (6)	71% (30)	14% (6)
Tenured	31% (4)	69% (9)	0% (0)
Female:	75% (3)	25% (1)	0% (0)
Male:	11% (1)	89% (8)	0% (0)

Several faculty members reported difficulties in traveling (22 faculty), changes in their living situations (5), and adverse discrimination (2) since the shelter-in-place in March 2020. With respect to all three of the five questions relating to different aspects since the shelter-in-place, faculty reported that their ability to socialize with peers (89.5%), ability to socialize with friends (91.9%), time management (43.2%), and overall psychological well-being (47.7%) was worse or much worse since the shelter-in-place began. Most faculty reported feeling more stress as a result of COVID-19, in particular tenure-track faculty (see Table 6. In addition, tenure-track faculty and female faculty experienced higher stress levels than other faculty groups; 83% of tenure-track faculty reported a moderate or a great deal of stress compared to 63% of lecturers and 46% of tenured faculty. Moreover, 73% of female faculty reported a moderate or great deal of stress compared to 63% of male faculty.

Table 6. Responses to the question: "Overall, how much stress are you feeling about the consequences of COVID 19?" for all faculty members and broken down by gender.

	A Little or no Stress	A moderate Amount of Stress	A Great Deal of Stress
All faculty	34% (30)	57% (50)	8% (7)
Female:	27% (7)	62% (16)	12% (3)
Male:	38% (23)	56% (34)	7% (4)
Tenure-track	18% (3)	71% (12)	12% (2)
Female:	22% (2)	67% (6)	11% (1)
Male:	13% (1)	75% (6)	13% (1)

Table 6. *Cont.*

	A Little or no Stress	A moderate Amount of Stress	A Great Deal of Stress
Lecturer	37% (19)	59% (30)	4% (2)
Female:	38% (5)	54% (7)	8% (1)
Male:	37% (14)	61% (23)	3% (1)
Tenured	54% (7)	38% (5)	8% (1)
Female:	0% (0)	75% (3)	25% (1)
Male:	78% (7)	22% (2)	0% (0)

A large number (31) of faculty members provided comments about their quality of life. As Figure 2 shows, the most common words mentioned were work, home, and stress. Some faculty comments from the survey are below, which are deidentified as "Faculty A", "Faculty B", "Faculty C", "Faculty D", and "Faculty E".

Figure 2. Word frequency cloud from comments to the question: "Please help us understand the diversity of experiences by sharing any further information on your quality of life here".

Faculty A: "*Spending all my time on the computer, dealing with email and Zoom meetings, is draining. There were a lot of additional workloads to put together a strong online class in addition to extra administrative workload and stress.*" (Female—Tenured)

Faculty B: "*Making the change in pedagogy with little notice and not being able to do anything about mine or student's issues with the internet, or feelings of isolation, lack of engagement, etc. and inadequate communication from all SJSU leaders regarding the COVID situation added a lot of stress.*" (Female—Tenured)

Faculty C: "*During the semester, I felt completely stretched thin. Everything was a tradeoff between taking care of myself and fulfilling my responsibilities. I frequently felt like I was failing at both.*" (Male—Lecturer)

Faculty D: "*I feel I am on call 24/7 and it is difficult to take a break. Summer is the time I revamp my courses, work on educating myself and other personal development routines; However, because I feel that I am on call 24/7, I am unable to do those.*" (Female—Lecturer)

Faculty E: "*It has been extremely difficult to maintain the normal pace and responsibilities of this job while caring for two young children full-time at home. After mid-March, there was no childcare available for either, and we as faculty were expected to continue making progress, meeting deadlines, and fulfilling all our normal job responsibilities as if nothing had changed.*" (Female—Tenure-Track)

Faculty reported that both their expenses (41%) and their income (20.7%) had decreased since the shelter-in-place. The survey asked faculty to reflect on five areas that could lead to stress. The responses show that there are a significant number of faculty who were worried about the health and well-being of their families, friends, and students. Additionally, they worried about doing their job well despite the changes made to classes when the classes moved 100% online (see Figure 3).

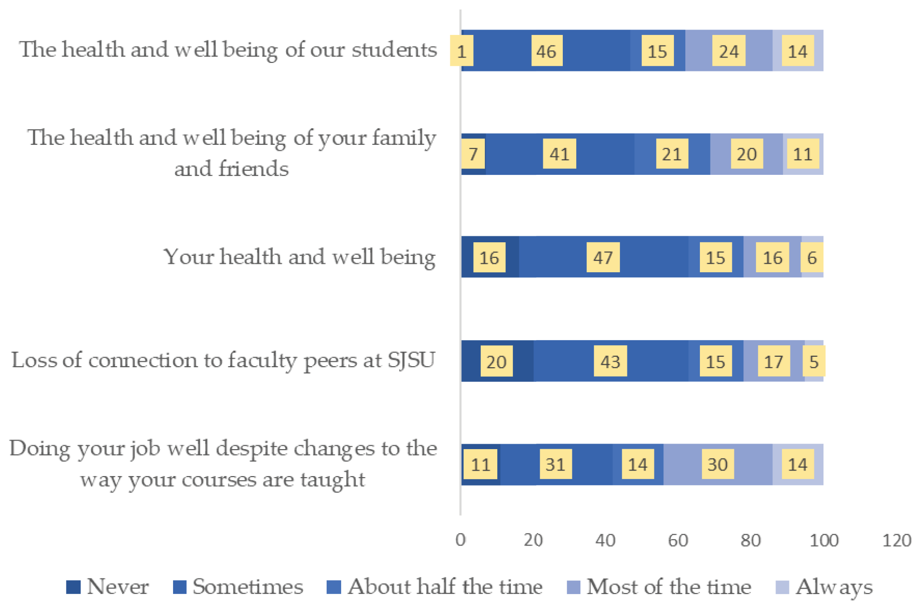

Figure 3. Responses to the Question: "Given the changes in your classes in Spring 2020 and the shelter in place, how often do you worry about the following?" for all faculty.

When asked about several areas of potential stress/pressure, most faculty (64.8%) generally felt that they had everything under control, although they also felt that there was too much to do in their classes (55%) and they were under pressure from deadlines in their courses (48.9%). When analyzing these questions by gender, we found some differences; 50% of the female faculty felt they had things under control compared to 70% of male faculty. In addition, fewer male faculty (37.7%) felt they were under pressure from deadlines compared to female faculty (77%), and female faculty felt they had too much to do in their classes (76%) compared to male faculty (47%). Since female faculty reported higher stress levels and more care responsibilities (see Section 5.1.1 above), it is not surprising that their work responsibilities also were affected. All responses to this question are shown in Table 7 as well as in Figures 4–9.

Table 7. Faculty responses to the Question: "Since SJSU made the decision in March 2020 to move to 100% online instruction, how often have you (Never/Sometimes/About half of the time/Most of the time/Always [%])".

	Had too Much to Do for Your Courses	Felt You Were in a Hurry	Felt You Were under Pressure from Deadlines	Felt That Work Was Piling up so High That You Could Not Finish It	Felt That You Had Everything under Control in Your Classes
All faculty	15/30/22/23/10	18/35/13/19/15	18/33/16/19/14	32/31/13/16/9	9/26/15/36/14
Lecturer	17/35/23/13/12	21/42/10/13/13	21/42/10/13/13	38/30/12/12/8	6/19/19/38/17
Tenure-track	6/13/13/50/19	6/24/12/29/29	6/12/24/29/29	12/29/12/29/18	12/53/6/24/6
Tenured	15/31/0/38/15	15/31/31/23/0	15/31/31/23/0	31/38/8/15/8	15/31/0/38/15
Female faculty	1/5/8/7/4	1/6/7/6/6	0/6/7/7/6	3/11/3/5/4	3/11/3/5/4
Male faculty	13/25/19/20/9	15/31/11/17/13	15/29/14/17/12	27/27/11/14/8	8/23/13/31/12

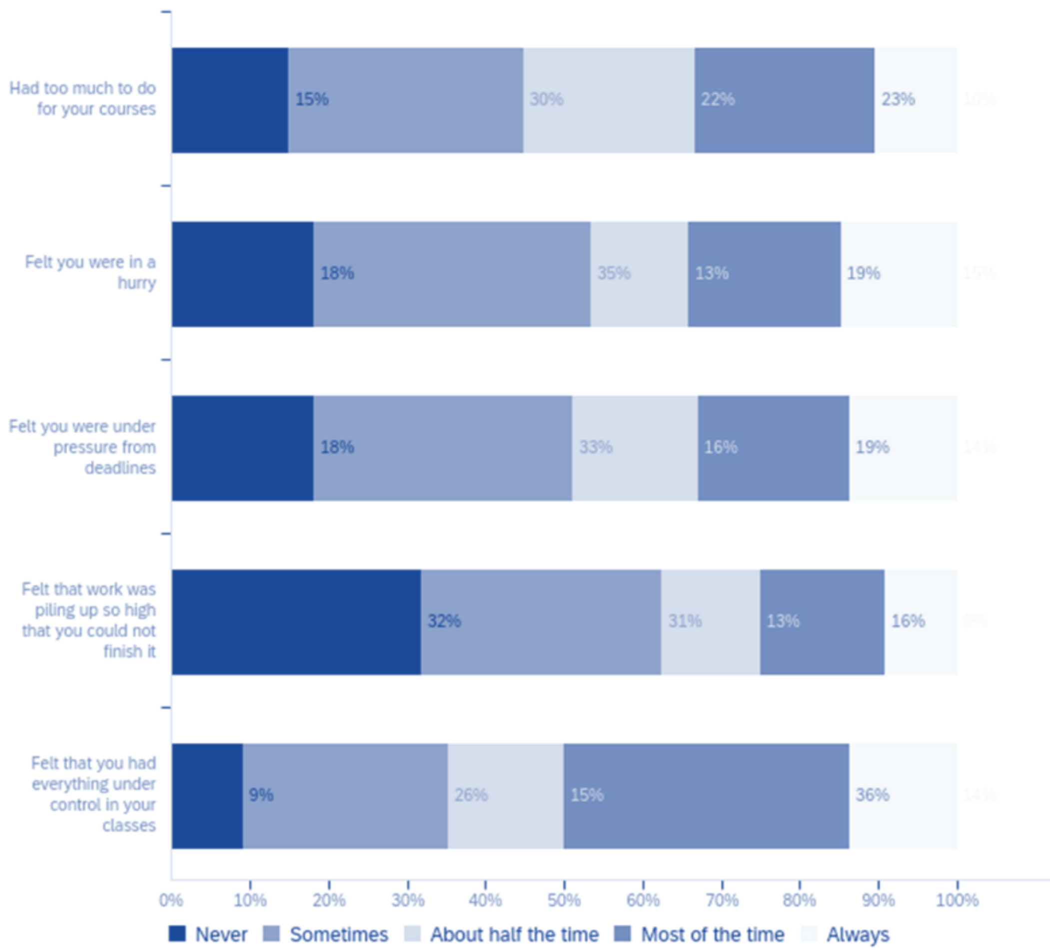

Figure 4. Faculty responses to the Question: "Since SJSU made the decision in March 2020 to move to 100% online instruction, how often have you".

Table 7 and Figures 4–9 show that the perception about the Spring 2020 transition was felt differently by faculty of different ranks. Overall, tenure-track faculty were more likely to report negative feelings than both lecturers and tenured faculty. For example, 33% of all faculty (Figure 4) felt they had too much to do for their courses all or most of the time, but this percentage increases to 69% for tenure-track faculty and 53% of the tenured faculty (Figure 5). Moreover, 58% of tenure-track felt they were in a hurry as a result of online instruction (Figure 6), in contrast with 34% of all faculty (Figure 4). Lecturers were the least likely to feel hurried, as 68% reported they never or only sometimes felt this way. Similarly, 33% of all faculty (Figure 4) felt under pressure from deadlines all or most of the time; this percentage rises to 58% for tenure-track faculty (Figure 7). Additionally, only 25% of the entire faculty (Figure 4) felt that work was piling up so high that they could not finish it all or most of the time, but the same answer was given by 47% of the tenure-track faculty (Figure 8). In terms of teaching, 35% of the entire faculty (Figure 4) felt they were in control of the class only sometimes or never, but this same feeling of loss of control was felt by 65% of tenure-track faculty member (Figure 9).

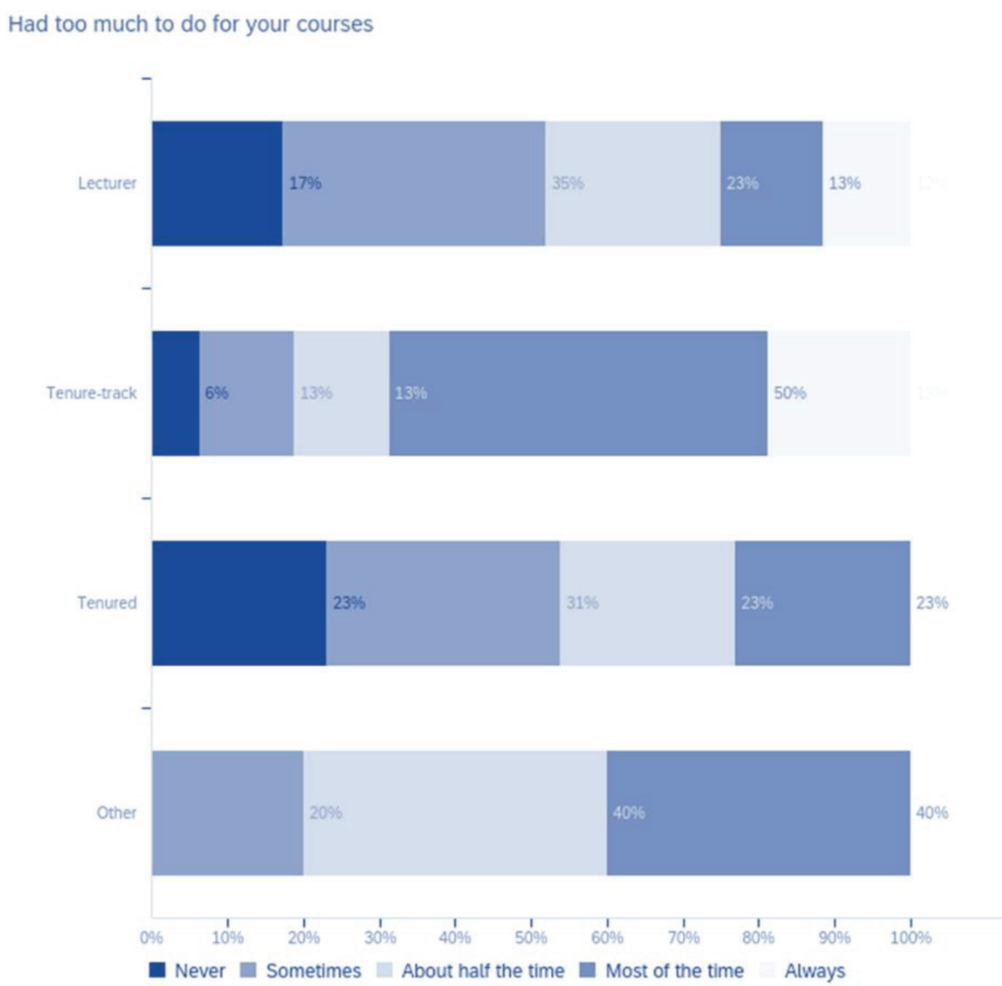

Figure 5. Faculty responses to the Question: "Since SJSU made the decision in March 2020 to move to 100% online instruction, how often have you had too much to do for your courses?" divided by faculty rank.

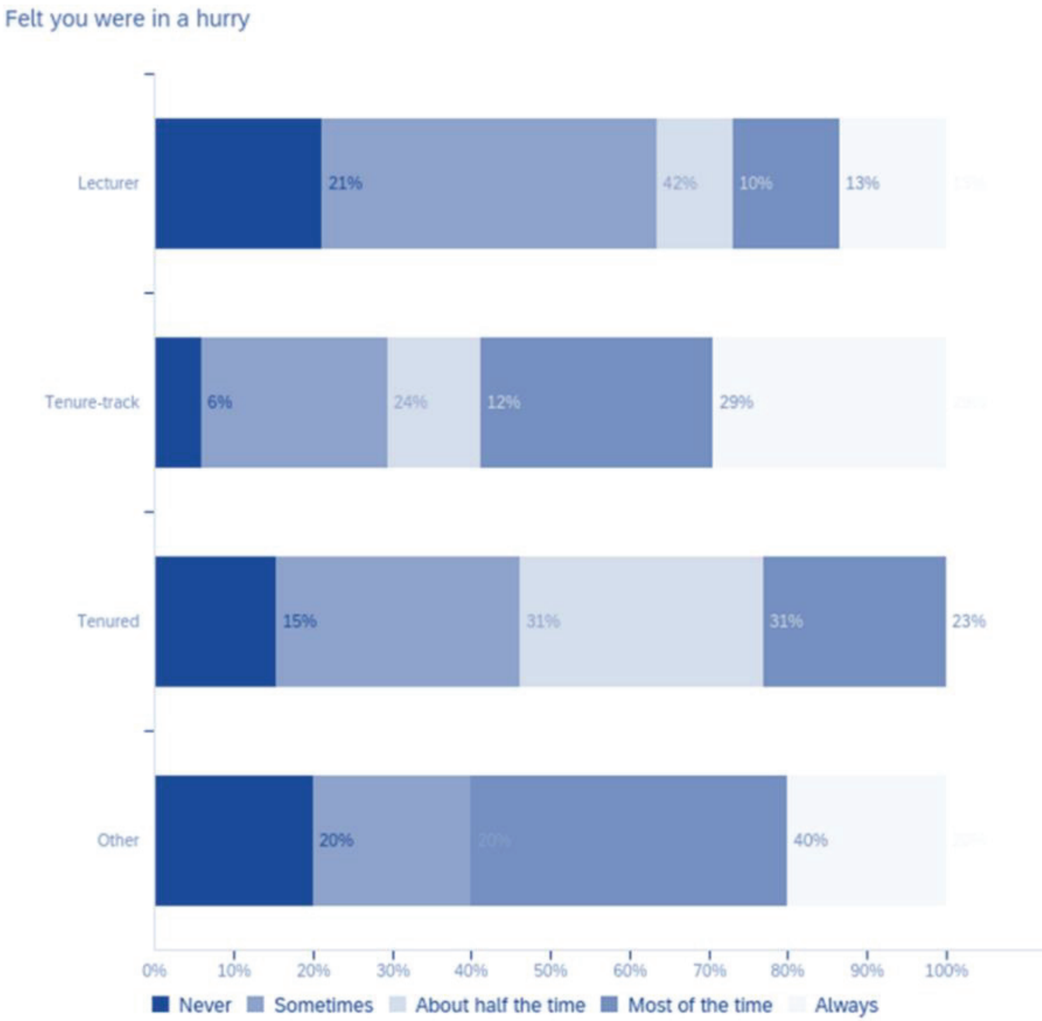

Figure 6. Faculty responses to the Question: "Since SJSU made the decision in March 2020 to move to 100% online instruction, how often have you felt you were in a hurry?" divided by faculty rank.

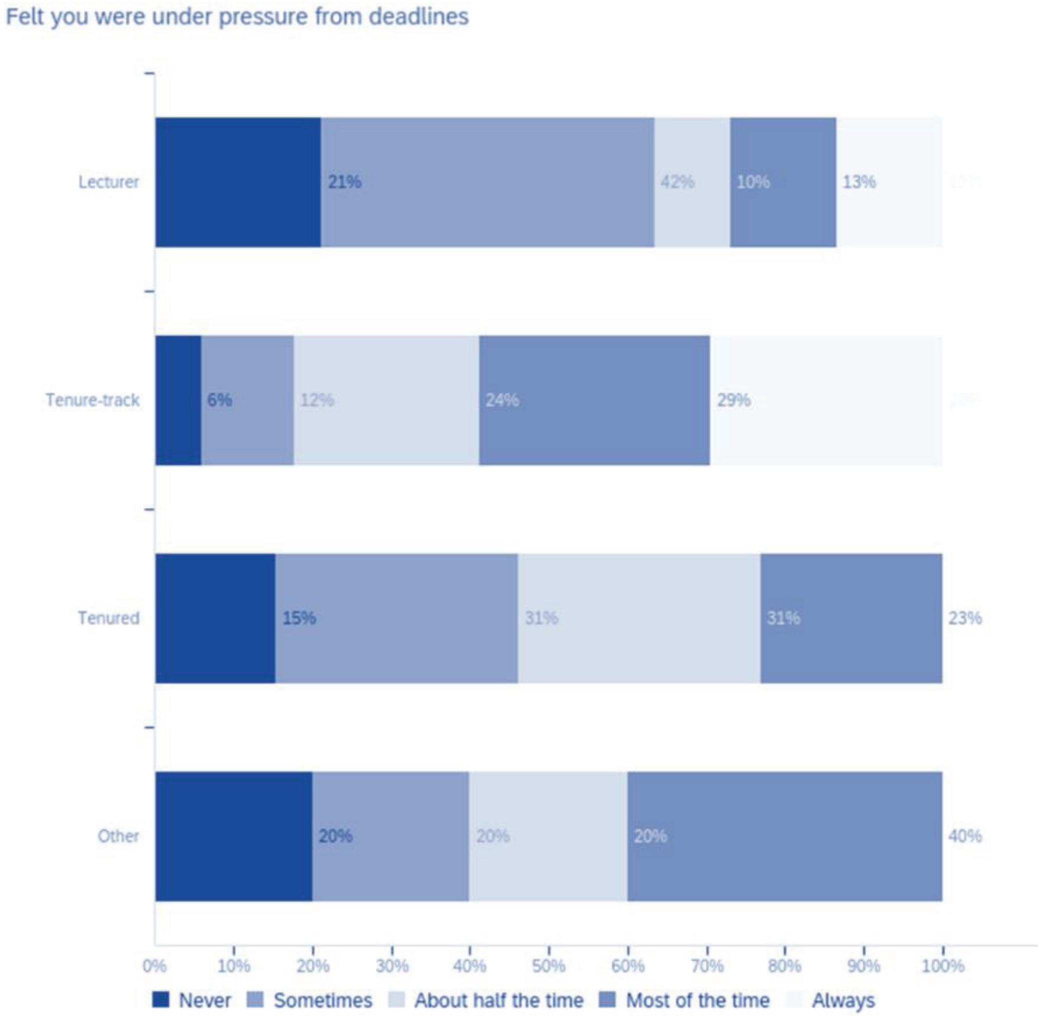

Figure 7. Faculty responses to the Question: "Since SJSU made the decision in March 2020 to move to 100% online instruction, how often have you felt you were under pressure from deadlines?" divided by faculty rank.

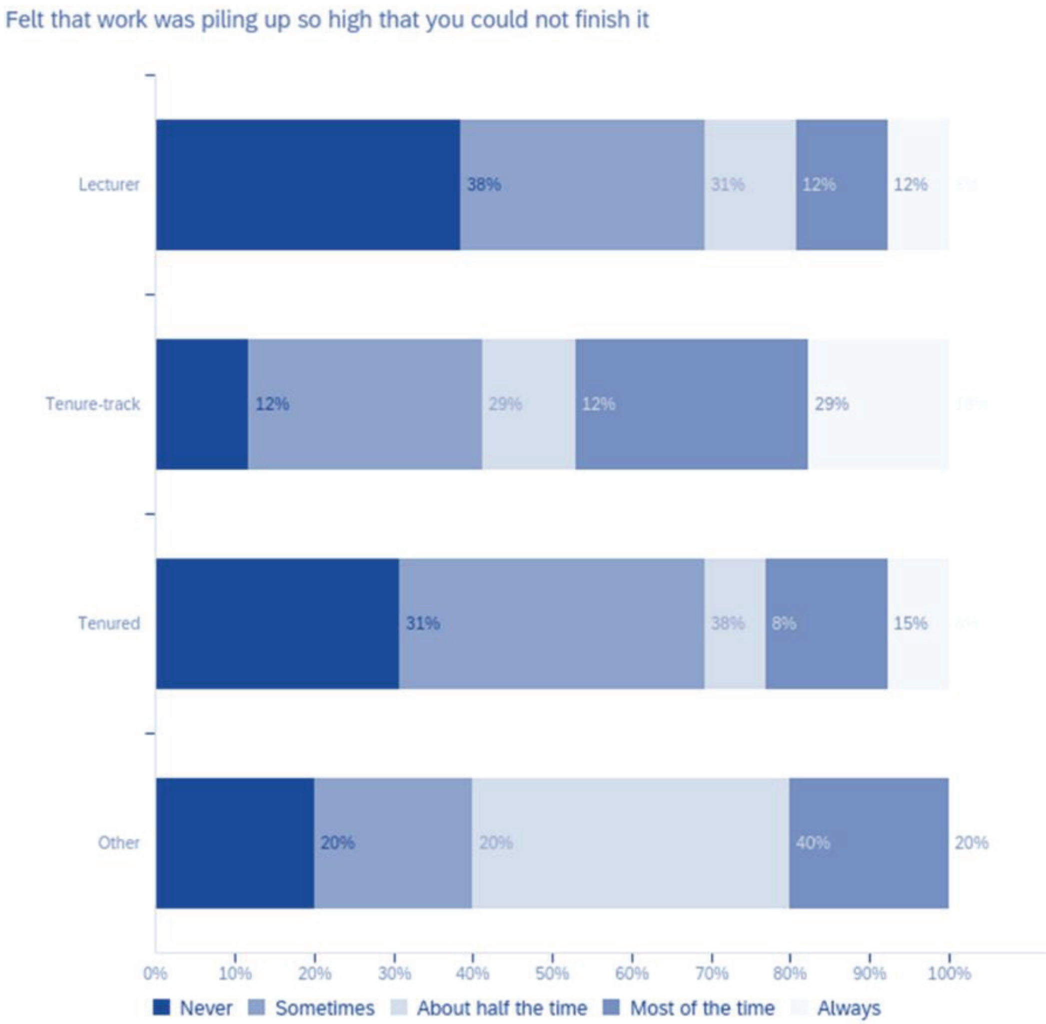

Figure 8. Faculty responses to the Question: "Since SJSU made the decision in March 2020 to move to 100% online instruction, how often have you felt that work was piling up so high that you could not finish it?" divided by faculty rank.

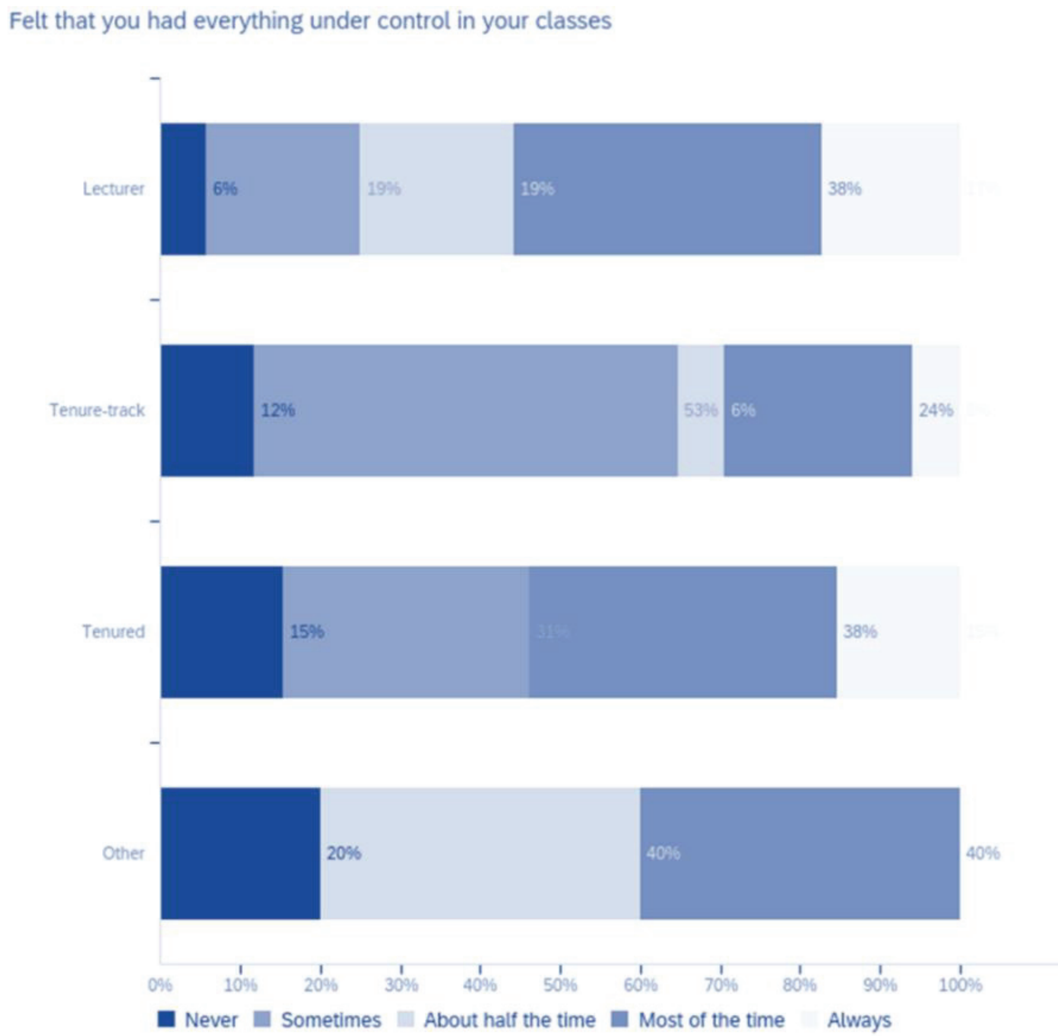

Figure 9. Faculty responses to the Question: "Since YYY made the decision in March 2020 to move to 100% online instruction, how often have you felt that you had everything under control in your classes?" divided by faculty rank.

5.1.2. Online Instruction

The research team was interested in seeing how many faculty members had ever used active learning in their in-person courses. Research has shown that integrating active learning techniques into STEM classes has produced gains in student learning. A study completed by Hake [35] in Physics showed that when active engagement methods were used, students' scores on a Force Concept Inventory (FCI) were higher than students in traditional classrooms. Hake's research is supported by research by ENGAGE that shows that faculty–student interactions increase student retention rates in STEM courses [36]. At Purdue University, large STEM lecture courses were redesigned to include active learning strategies in STEM classes; this is part of the Purdue Academic Course Transformation program (IMPACT) [37]. As a result of IMPACT, overall student retention increased by 1%, while retention in their respective STEM courses increased by 2%. After the redesign, the student GPAs of those taking IMPACT made a significant increase, making a significant difference between non-IMPACT and IMPACT classes. Freeman et al. [38] conducted a meta-analysis of 225 studies that compared student performance in undergraduate traditional lecture classes with active learning classes in STEM. They found that the failure rate in lecture classes was 1.5 times that of active learning classes. Theobald et al. [39] also performed a meta-analysis, but it was focused on comparing the achievement levels of underrepresented students and majority students in STEM classes; they analyzed student examination data from 15 studies and student failure rates from 25 studies (a total of 53,844 students). Theobald et al. found that "active learning reduced achievement gaps in examination scores by 33% and narrowed gaps in passing rates by 45%".

The number of engineering faculty using active learning is lower than other fields: a national survey of engineering faculty [40] found that only 47% of engineering professors use active learning in their classrooms. Indeed, Borrego et al. [40] found that, although 83% of engineering chairs were aware of active learning techniques, only 36% of engineering faculty were using them. In Fall 2011, SJSU surveyed the faculty in the Colleges of Science and Engineering to gauge the instructional methods used. Using the Survey of Instruction and Assessment Strategies (SIAS) that was developed by the NSF-funded *Louisiana Collaborative for Excellence in the Preparation of Teachers* (LaCEPT) [41], and the results indicated that 71% of the SJSU science and engineering instructors gave lectures for the majority of the class periods. This survey was repeated in Spring 2016 and Spring 2019. In Spring 2019, the number of SJSU engineering faculty using some active learning in their classes increased to 60%.

The results of this survey showed that most SJSU faculty (70.5%) used active learning in their in-person classes although this number was slightly higher for female faculty (77%). In addition, most faculty (60%) took training to learn about online tools; the most common training was for audio or video conferencing tools, Canvas, controlled testing environments, and online videos or tutorials. Figure 10 displays the most common active learning pedagogies used by survey respondents. Most faculty were satisfied with the support they received from SJSU after the shelter-in-place with 63% of the faculty indicating that they were moderately or extremely satisfied with the support.

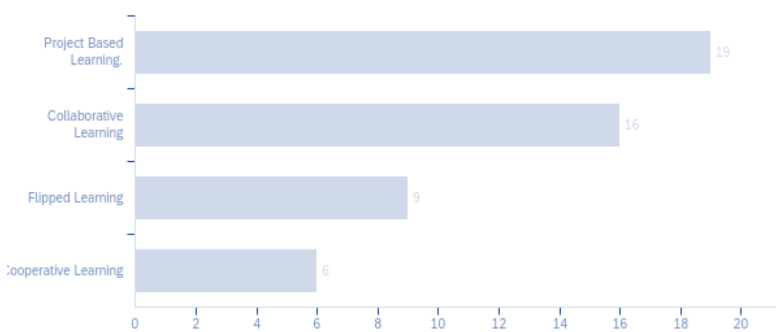

Figure 10. Faculty responses to the Question: What active learning pedagogies have you used in your classes?

Faculty reported using a wide variety of online tools since the move online in March 2020. Prior to the shelter-in-place, almost all faculty reported using Canvas and online videos and tutorials in their in-person courses (see Table 8). After the shelter-in-place and transition to online learning, faculty understandably reported using different online tools and more online tools than with in-person classes. After the move to online learning, more faculty reported using audio and video conferencing tools (90.6%), webcams (77.3%), online videos or tutorials (68.8%), and YouTube (50%) (See Table 9).

Table 8. Online tools that faculty report having used in their in-person classes.

Tools	Never Use		Sometimes Use		Always Use		Sometimes & Always Use	
Canvas	3	4.4%	2	2.9%	64	92.8%	66	95.7%
Online videos or tutorials	9	13.6%	38	57.6%	19	28.8%	57	86.4%
YouTube	14	21.2%	36	54.6%	16	24.2%	52	78.8%
Collaboration tools (Google Docs or other collaborative tools)	21	35.6%	30	50.9%	8	13.6%	38	64.4%
Audio or video conferencing tools (Google Hangout, Zoom, Microsoft Teams, etc.)	23	37.7%	15	24.6%	23	37.7%	38	62.3%
Real-time polls	26	41.9%	28	45.2%	8	12.9%	36	58.1%
Discussion boards	27	43.6%	24	38.7%	11	17.7%	35	57.4
Text-based chat	31	53.5%	21	36.2%	6	10.3%	27	46.6%
Controlled online testing environments (ProctorU, Proctorio, LockDown Browsers, etc.)	40	63.5%	15	23.8%	8	12.7%	23	36.5%
Video editing software	43	70.5%	17	27.9%	1	1.6%	18	29.5%
Digital whiteboard apps	47	75.8%	8	12.9%	7	11.3%	15	24.2%
Podcasts	53	94.6%	0	0.0%	3	5.4%	3	5.4%

Table 9. Online tools that faculty have used in their online classes after the shelter-in-place.

Tools	Yes, Tool Used		No, Tool Not Used		Sometimes		Not Needed	
Computer or laptop	83	96.5%	2	2.3%	1	1.2%	0	0.0%
Canvas	80	96.4%	3	3.6%	0	0.0%	0	0.0%
Audio or video conferencing tools (Google Hangout, Zoom, Microsoft Teams, etc.)	77	90.6%	7	8.2%	0	0.0%	1	1.2%
Webcam	58	77.3%	10	13.3%	2	2.7%	5	6.7%
Online videos or tutorials	55	68.8%	13	16.3%	5	6.3%	7	8.8%
YouTube	39	50.0%	18	23.1%	13	16.7%	8	10.3%
Text-based chat	37	49.3%	21	28.0%	9	12.0%	8	10.7%
Collaboration tools (Google Docs or other collaborative tools)	35	46.7%	23	30.7%	9	12.0%	8	10.7%
Controlled online testing environments (ProctorU, Proctorio, LockDown Browsers, etc.)	37	45.7%	27	33.3%	7	8.6%	10	12.4%
iPad or tablet	32	42.1%	32	42.1%	5	6.6%	7	9.2%
Real-time polls	32	42.1%	28	36.8%	7	9.2%	9	11.8%

Table 9. *Cont.*

Tools	Yes, Tool Used		No, Tool Not Used		Sometimes		Not Needed	
Scanner	30	41.1%	31	42.5%	7	9.6%	5	6.9%
Discussion boards	28	35.9%	29	37.2%	8	10.3%	13	16.7%
Digital whiteboard apps	26	34.7%	33	44.0%	3	4.0%	13	17.3%
Video editing software	19	26.0%	37	50.7%	6	8.2%	11	15.1%
Document camera	15	20.8%	42	58.3%	2	2.8%	13	18.1%
Podcasts	3	4.3%	46	65.7%	2	2.9%	19	27.1%

Faculty responses were mixed when asked about concerns related to privacy and security of online tools, with 44.6% indicating they were concerned, 42.2% indicating that they were not concerned, and 13.2% indicating they were unsure. Most faculty (70.4%) spent more hours than usual on course preparation after the shelter-in-place. All the female faculty who responded to this question indicated that they spent more hours than usual on course preparation. The additional hours spent on course preparation by faculty were significant with 41% of the faculty reporting spending 5 or more hours per week for online instruction as compared to their normal course preparation for in-person classes, with female faculty spending about the same amount of time as male faculty.

Faculty reported that students indicated they had issues with several digital technologies after classes moved online. More than two-thirds of students had problems with Internet connectivity either always or sometimes during Spring 2020. In addition, as can be seen in Table 10, more than 50% of the students had issues with a physical space for studying and webcams.

Table 10. Faculty responses to the Question: "Have your students indicated that they have issues with access to any of the following after the move to 100% online instruction in March 2020?"

Issue for Students	Yes	Sometimes	No	Not Needed	Total
Enough internet access for doing your classwork online	32	22	26	0	80
Physical space for studying and doing assignments	26	14	38	1	79
Webcam	23	17	34	4	78
Computer, laptop, or tablet	16	16	48	0	80
Library resources (including books, articles, etc.)	14	5	53	3	75
Scanner	10	2	50	12	74
Printer	6	8	48	15	77

5.2. Analysis of the Interviews

Interviews were conducted throughout Summer 2020, with the majority of them occurring in late July and early August. The analysis of the interviews is divided into four main themes: "Testing and assessment", "Experience", "Teaching approach", and "Hands-on laboratories".

The majority of the interviewed faculty reported never having taught online before Spring 2020, and they were therefore required to transition to the emergency online format with very little preparation and formal training. Courses were canceled for 4 days after the shelter-in-place announcement in mid-March to allow faculty time to transition to online instruction. Faculty needed to quickly get up to speed in online teaching and were able to attend brief trainings offered by the college and university, receive one-on-one support from IT and instructional designers, and collaborate with other faculty members skilled in online instruction. This model of just-in-time support continued through Spring 2020.

In preparation for Fall 2020, which had been announced to be primarily online in late May, the university utilized federal funds received from the CARES Act to offer training to all faculty in Summer 2020. More than 1000 faculty remotely attended a 3-week course in online teaching and assessment offered by the university's Center for Faculty Development and eCampus.

5.2.1. Testing and Assessment

Testing and assessment was the main point of discussion during the faculty interviews. The research team associated the following codes with the "Testing and Assessment" category:

- Online testing: 15 out of 23 faculty;
- Concerns about cheating: 9 out of 23 faculty;
- Grading issues: 8 out of 23 faculty;
- Students had higher grades: 6 out of 23 faculty;
- Students had lower grades: 4 out of 23 faculty;
- Faculty made more exceptions to students: 3 out of 23 faculty.

Faculty members in Engineering were highly concerned about finding assessment tools that were meaningful and allowed them to assess both lower taxonomy and higher taxonomy skills [42]. When planning for online testing, the majority of the interviewed faculty changed their assessment strategies, moving from traditional closed book exams to open books exams. They also reported experimenting with different types of assessment methods, such as open-ended exams, multiple choice exams, or asynchronous "take-home" exams. Kyle, for example, discusses the need to experiment with different types of online assessment strategies during the semester:

> *"The exam I mean that that was a little bit difficult experience the exam, the first exam, which we did we use Zoom [...] Now the second exam that I use a different process. I use the lockdown. [...] And then I change it to a multiple-choice question and now with the multiple choice question the computer can generate the answers randomly."* —Kyle

Many faculty members reported being concerned about students cheating and academic dishonesty and were not very confident in their ability to truly assess individual students' skills:

> *"I think testing in an online environment is very, very difficult. [...] I think testing is a real, real challenge for the engineering curriculum, to be honest with you. [...] Students are cheating. I'm not saying that at all. I think I think exam integrity is a big, big challenge, for engineering for the engineering curriculum."* —Peter

To minimize cheating, some faculty experimented using video proctoring during assessment, either using software such as LockDown browser, ProctorU, and Impendus, or monitoring students using synchronous Zoom meetings. In some cases, these monitoring techniques resulted in students' push back, with faculty feeling under pressure about their assessment strategies:

> *"And they were saying like why I'm only using this because many other faculties are giving take home exam and I'm the only one who does like who tortures them you know like basically, they felt that way a little bit, and I tried to compromise with them. [...] they were like trying to push me even say that they even send email to our chairs if there is a way to do not have tests online. [...] from one side, I felt like they were under the stress and I understand that situation, but at the same time, they just wanted to take advantage of it."* —Hanna

Faculty felt responsible for preventing cheating, but in many cases, they were not sure about best practices for online testing or found that it took excessive faculty time to prepare the assessment:

> *"On exams, there was a lot of rampant cheating. [...] some of the students are, you know, told me that they were constantly you know messaging, or, you know. How are you going to you know stop it without making faculty responsible for them not to cheat? [...] So, I, I don't know. I mean, you cannot make you know 10 different question papers. I mean, that will be ridiculous, right. So, I just don't know how to do it. And if you don't go the traditional testing route, you know, how would you test them? Is it more pop quizzes and giving more weightage to those? I don't know, So, if you can come up with some guidelines and those, and how to, you know the, the whole academic integrity and how do they, how, you know, how do you make them responsible for the learning, I think, I think that would be important"* —Arthur

5.2.2. Experience

Faculty experience was reported as positive, with faculty generally finding it easy to transition to emergency online instruction. The following codes were associated with this category:

- SJSU acted appropriately as an institution: 14 out of 23 faculty;
- Positive experience: 14 out of 23 faculty;
- Online teaching and learning difficulties: 13 out of 23 faculty;
- Faculty found it easy to transition to online teaching: 11 out of 23 faculty;
- SJSU should provide more support: 6 out of 23 faculty;
- Faculty SOTES: 3 out of 23 faculty.

Faculty, in general, reported having a positive experience teaching in an online environment and defined the transition as easy. Online teaching was found by some faculty to be convenient. The transition to emergency online teaching was reported by the interviewed faculty as "smooth," "seamless," "pretty easy," "not that hard," "not as challenging," and "convenient":

> *"I feel like Spring was a fairly seamless transition, as seamless as it could have possibly been"* —Cristobal

> *"I just continued with the lectures, you know, didn't really skip a beat and it went well and went really well. [...] It was good. [...] With respect to the class. I think, I think it went fine. [...] I was able to get through those this time so I did find the online format, more efficient and it was definitely easier for me. You know, I didn't have to drive commute to nest apart didn't have to walk over to the class set up the audio visual. [...] So I, I liked it."* —Fred

> *"I think, I think it worked out very well for me. It, I was very happy like I'm now comfortable teaching online or in-class. Both are okay with me."* —Isaias

At the same time, faculty noted that they were faced with challenges in their teaching approach during the transition to emergency online teaching. They reported challenges with grading and assessment, forming a personal connection with the students, listening and supporting students who were struggling because of their personal situation, maintaining students' engagement, and "Zoom drain." Faculty noted that students were struggling because of the difficult situation, as described by Vicky below:

> *"They [students were thrown into this mess. They had family problems and stress because people were losing the jobs. It was just a mess. [...] But it was so there was a lot of stress, our students suffered a lot of stress, more than I thought would happen. [...] I didn't realize that they would be out of work or the parents would have been laid off. Then they felt the stress that they had to work to help their families. I really had never seen anything quite like it. [...] And then, as I said, I think I don't know what caused some of them I reached out to them. Never heard back for them just to drop be gone. And what one of them was even my best student, I mean, he was a solid A up to that point. And because of family pressure. He had to quit. That one broke my heart."* —Vicky

For some faculty, meeting students' needs came at a cost of personal well-being:

> *"That it helped them, but it was incredibly draining for me because I would be on Zoom for five hours every Monday and Wednesday. I have, a five-minute break here and there they go get another drink and use the facilities and rush back and get started again. So, the Zoom drain was incredible. And I would basically I'd be done for the rest of the day I interact with my family but mentally I was just put. And my students seem to have very similar reactions to having to be engaged with their classes online, whether it was my class or another class but many times I heard that they were struggling to keep up with the dates, because there wasn't always that engagement directly with their instructors and even with the engagement with me. It was hard for them to keep up."* —Josephine

Some faculty noted a discrepancy between their experience as a faculty and the students' experience:

> *"It turned out that, I thought okay, I thought in terms of delivery from my side, I did not see any difference. But then students did not like it at all. [...] They had difficulty and I had to a lot of times I had to go over things repeatedly, they wouldn't get it so it take, it's, most of them did not like that."* —Arthur

SJSU, as an institution, was reported to be effective in how it responded to the difficult circumstances. Many faculty members praised the IT team for the quick transition and the many trainings offered regarding online teaching resources and software offered to faculty members:

> *"I thought they did a great job in the way they handled everything because it had to happen so fast, especially the training that was available."* —Bertha

> *"I feel like the IT people did a wonderful job of helping get everyone up to speed as best as possible with Zoom and remote learning technologies."* —Cristobal

> *"It's actually hard for me to imagine anything that could have been done better. It doesn't mean that things were great, but this is catastrophic. This is before all of this happened. I think what is happening is beyond all of our imaginations."* —Laura

> *"I'm really grateful and happy that the prompt response from SJSU. In terms you know again, limiting the exposure to the students and myself by making that early call of just transferring everything online."* —Wilfred

At the same time, some faculty noted that SJSU could have been more supportive of their faculty and students by asking faculty what they needed and how they could be best supported in their teaching, by promptly providing devices needed to teach (laptops, tablets, printers, scanners, etc.), and by providing some guidance and best practices for grading and assessment strategies:

> *"So, I really feel that it was a lot of scrambling that was doing a lot of, some faculty members were allowed to do things that I found unacceptable, like one faculty member I know decided they weren't going to have any Zoom, they weren't going to have any anything, and they just assigned homework. [...] So, I think that that's where the university really let faculty down. Is they did not have a collective effort where they said, okay, we're taking this week off and basically, they said we're taking this week off so you can get your act together. [...] there was never anything that went out and said, how can we support you?"* —Dolly

> *"We need more support from the university to the student [...] Okay, so, if a faculty doesn't have a computer. Then this is a problem. The second thing a faculty need a scanner and I need a, I need a scanner and then needs a printer. Well, I do have a printer. Okay. And it's a fast printer. I didn't have a problem. I did have a page-by-page scanner but I have one at work, which is a fast, fast scanner, you can do 50 pages per minute."* —Kyle

> *"I wish that the purchasing for things would be a little bit easier I requested to get like a tablets that I could work through some laboratory problems and structures, just to be able to write and draw. Because if not, I'm gonna have to set up a camera"* —Nicholas

> *"Effort by the university to help us on the testing side to you know, some kind of guide that they can they can provide that would help all the professors with testing and how to maximize exam integrity look even in the classroom."* —Peter

5.2.3. Teaching Approach

Many participants discussed how their teaching approach changed in the transition from in-person to emergency online classes. The following codes were identified as part of this theme:

- Faculty used PowerPoint: 9 out of 23 faculty;
- Faculty recorded classes: 9 out of 23 faculty;
- Use of technology in the classroom: 9 out of 23 faculty;
- Faculty changed teaching approach in online class: 8 out of 23 faculty;
- Faculty lectured entire time: 8 out of 23 faculty;
- Faculty assigned project: 7 out of 23 faculty;
- Faculty run office hours: 6 out of 23 faculty;
- Internet or connection issues: 5 out of 23 faculty;
- Faculty used active learning: 4 out of 23 faculty;
- Faculty taught synchronously: 17 out of 23 faculty;
- Faculty taught asynchronously: 3 out of 23 faculty;
- Students were highly engaged during class: 6 out of 23 faculty.

In many cases, faculty changed their teaching approach "*a whole 180 degree*" (Dolly) as they recognized that the emergency online format required different strategies to keep students engaged. Some faculty reported decreasing the pace of the class and the quantity of material covered, while other faculty were able to cover a bit more material:

> *"I had to make changes to the material to make it … work better with the, you know, online delivery. … And also, I had to … learn, of course, the tools, getting the ins and outs of Zoom. I was only … casually familiar with Zoom before that. So, I didn't know the … screen sharing and breakout rooms and … all the other good stuff that that we need to know for a good teaching experience. And … then in terms of some of the deliverables, the assignments, I had to make some changes to … make sure that they are compatible with online and the biggest challenge was with one of our hardware labs, which required … holding things in your hand and doing things."* —Bill

The majority of the interviewed faculty taught synchronously with the same schedule as during in-person teaching, used PowerPoint slides to present their lessons, recorded their lectures and made them available to students, and had office hours. A large number of faculty lectured for the entire class time, finding it difficult to incorporate active learning activities to keep students engaged.

> *"That remained mostly unchanged with the exception of not having, probably if I had to estimate, 20 to 25% of the time in the, of the lecture before people working through a problem in like a small group or something like that, which really I didn't judge is feasible with remote lecture via Zoom and that was discontinued when classes went remote"* —Cristobal

A few faculty were instead able to incorporate active learning into their online classes, taking advantage of the digital environment they were suddenly teaching in:

> *"Later, what I did is beforehand the students need which readings, they needed to cover, so I enforce the concept with announcements, say, hey, heads up, we're covering this material this week, make sure you're ready, we will do exercises first and so, implement the flipped learning Idea and concept right and approach. […] The students beforehand they will know or they knew what things they will be working on. And right at the beginning of the class. I'm just giving them a quick introduction […] Then ask some questions to engage and to get an understanding of what the general where the class was in terms of their understanding to the concept […] I did use polls. […] So, asking*

> *those questions that will get a baseline for the class and understanding. [. . .] Then I'll give them exercises without, without covering the material myself like because the expectation was you already learned this material. So, now you go and try it out. [. . .] So, then I'll jump. Probably for about 45 min, at the beginning of the class I will separate the class into groups, then I'll be joining each of the rooms in a rotating manner, and I'll go and you know ask questions and see if they were struggling with the material. [. . .] I will create another poll and run a comparison between this is where you started in class."* —Wilfred

Some of the faculty found that students were highly engaged during their online classes, and this was especially true for faculty who experimented with active learning:

> *"The engagement in the class was much higher that's compared to the beginning of the semester."* —Wilfred

5.2.4. Hands-on Laboratories

In the SJSU College of Engineering, many classes have hands-on activities and laboratories incorporated into the schedule. Transitioning laboratory activities to an online format was reported to be particularly challenging given the sudden transition and the inability to provide hardware or materials to students because of the campus closure and safety concerns.

Faculty used different strategies to conduct their laboratory activities, such as using *"a simulator" (Larry) or* conducting demonstrations (*Cristobal*):

> *"then for the labs, I used a simulator. Yeah, So the good thing about SJSU is that I could use simulator . . . For SJSU and YYY, I use Multisim."* —Larry

> *"So, what I did is I personally went to the lab, took the data for them, took images of the setup, and went through my normal in text format, my normal spiel that I would give to them at the beginning of the lab. You know, generally what we're doing what we're looking for, etc. And basically, handed the photos and the data off to them for them to process as they normally would and write a report on it. [. . .] As they normally would, if it weren't in person thing. So, really, the part that got lost in that was they weren't physically there to see the setup themselves or actually run the equipment. And ideally, I would have liked to actually record the entire process of the lab. But because it was basically required that I'd be the only one in the lab for that. That really wasn't a practical possibility with the ad hoc nature of the online transition."* —Cristobal

Some faculty discussed their frustration on the inability to conduct labs in a safe environment:

> *"What I'm saying is, is if my karate studio can open up with social distancing, why can't, I mean my lab would have like one person per area and if you wear the mask and you do all this business. It's not like Texas reopening with like no rules. No, we're, we're in a lab. I mean, the people who run labs"* —Edouard

5.2.5. Preparing for the Next Semester

Many of the faculty (11 out of 23) discussed their plans for their Fall 2020 online instruction. They planned to make changes after the lessons they learned in Spring 2020 in delivering the class material and their teaching approach, as well as in conducting laboratory activities:

> *"I'm going to be teaching the same class and I am actually making fairly extensive changes to the way it's being taught and part of that is based, it's . . . because of the experiences in the spring. . . . I'm making it a lot more interactive. [. . .] And then the lab part that I mentioned earlier, the hardware lab revamping that so instead of building it ourselves, . . . I've identified a piece of hardware that they could order on the web, which is just as cheap, if not cheaper. So, I think that would be that would also be a little, should run a little, more smoothly."* —Bill

Some faculty planned to move to an online "asynchronous" flipped classroom approach, so they could prepare their class material and videos beforehand and then use class sessions to engage students in problem solving activities, answer questions, or meet in small groups to review projects:

> *"But as far as, you know, fall is concerned, I'm going to make asynchronous lectures, make it available at least a week in advance and then use the sessions more for you know, you know, a lot of problem solving"* —Arthur

> *"Okay, I'm going to teach online, but now it will be asynchronous. So, what I'm doing now I'm spending all the time to do some lectures and it will be posted on YouTube. And then I download it to Canvas and then I'm going to make, make some meetings with them because this is a design class. So, I have to see how do they do? So, it will be regular meetings with each group. So, I, I will have next semester 12 groups. So, that will be 12 meetings for these groups."* —Omar

Faculty also planned to incorporate more active learning strategies, such as synchronous group activities, using breakout rooms and *"to really do more to encourage discussion amongst them, and with me" (Gonzalo)*:

> *In terms of testing and assessment, faculty planned to be clearer with the students from the beginning of the semester with respect to their expectations, particularly if they planned to use video proctoring.*

6. Discussion

For the discussion, we related the results of our interviews back to the research questions. We will summarize the results in this manner.

Research Question 1: Did faculty experience pressure and stress during the COVID-19 transition to emergency online learning?

Faculty members, in general, had a positive experience teaching in the online environment and defined the transition as easy. For some faculty members, online teaching is convenient. The transition to online teaching was defined by the interviewed faculty members as "smooth", "seamless", "pretty easy", "not that hard", "not as challenging", and "convenient".

Most faculty reported feeling more stress as a result of COVID-19, in particular tenure-track faculty, as described in Table 6. A large number (31) of faculty members provided comments about their quality of life. As Figure 2 shows, the most common words mentioned were work, home, and stress. These findings agree with those of other researchers [13–15]. For example, Bizot et al. [19] found that over half of the computer science faculty who responded to the survey had used active learning before the move online. However, 34.9% of the faculty discontinued their use of active learning after the move online, while 43.4% made minor changes and 21.3% made significant changes. Bizot also found that the Computer Science faculty had higher levels of stress after the switch online because of COVID-19.

In the Higher Education Data Sharing Consortium (HEDS) survey of faculty [9], faculty felt overwhelmed in Spring 2020 by the increased amount of work in the newly online classes, with 61% of faculty indicating that they had too many things to do, 55% felt that they were in a hurry, and 51% felt under pressure from deadlines. A second survey, the Chronicle of Higher Education faculty survey [20], also showed that faculty were experiencing elevated levels of frustration, anxiety, and stress and were struggling with increased workloads and a deterioration of work–life balance. These findings agree with our survey of faculty. However, in our survey, there was a gender difference in stress levels and in the pressures experienced by faculty. Female faculty experienced higher stress levels than male faculty; 73% of female faculty reported a moderate or great deal of stress compared to 63% of male faculty. In addition, fewer male faculty (37.7%) felt they were under pressure from deadlines compared to female faculty (77%), and the female faculty felt they had too much to do in their classes (76%) compared to male faculty (47%).

Research Question 2: What challenges have faculty identified during the online transition and how do they plan to improve instruction?

The Chronicle of Higher Education survey of U.S. faculty [20] also showed that faculty faced a multitude of challenges at the same time: abruptly changing their work strategies and habits and learning new technologies. Our survey also documented that faculty used new online tools after the switch to a remote learning environment. After the move to online learning, more faculty reported using audio and video conferencing tools (90.6%), webcams (77.3%), online videos or tutorials (68.8%), and YouTube (50%) (See Table 9).

Most faculty (70.4%) in our survey spent more hours than usual on course preparation after the shelter-in-place. All the female faculty who responded to this survey indicated that they spent more hours than usual on course preparation. In addition, faculty members in Engineering were highly concerned about finding assessments that are meaningful and allow them to assess both lower taxonomy and higher taxonomy skills. The interviewed faculty members changed their assessment strategies, moving from traditional, closed book exams to open books exams, and experimented with different types of assessment strategies such as open-ended exams, multiple choice, or take-home exams. Kyle (see comment above), for example, discussed the need to experiment with different types of online assessment strategies during the semester. This finding agrees with other research on the impact of COVID-19 on assessments which showed that faculty members adopted new strategies to adapt to the remote environment including modifying or dropping assignments and exams and lowering their expectations about the quantity and quality of the work performed by the students [10,14].

Most of the faculty members in SJSU engineering have always viewed online teaching with skepticism, and prior to Spring 2020, very few classes in the STEM disciplines were taught fully online. The traditional teaching approach was completely shifted by the COVID-19 pandemic and all engineering classes at SJSU transitioned to online learning in Spring 2020, with limited training and planning for the faculty members. As a result, faculty members experienced an increase in workload at a time in which many also experience an increase in personal needs. Faculty members were also challenged to keep students engaged online and by the organization of hands-on laboratories in a fully online environment.

The survey would have been strengthened if we had asked faculty more details about specific challenges they had during the move to remote learning in Spring 2020. Other studies have shown that faculty challenges with the emergency remote learning include a decreased interaction with students during class time and decreased students' engagement [11,12], increasing concerns about students well-being [13], and a general feeling that their course quality has decreased [12]. We did not include questions that asked faculty about these issues specifically in our survey.

Research Question 3: Is there a difference in the effect of COVID-19 among tenured faculty, tenure-track faculty, and lecturers?

Table 7 and Figures 4–9 show that the perception about the Spring 2020 transition was felt differently by faculty of different ranks. Overall, tenure-track faculty were more likely to report negative feelings than both lecturers and tenured faculty. For example, 33% of all faculty (Figure 4) felt they had too much to do for their courses all or most of the time, but this percentage increases to 69% for tenure-track faculty and 53% of the tenured faculty (Figure 5). Moreover, 58% of the tenure-track faculty (Figure 6) felt they were in a hurry as a result of online instruction, which is in contrast with 34% of all faculty (Figure 4). Lecturers were the least likely to feel hurried, as 68% reported they never or only sometimes felt this way. Similarly, 33% of all faculty (Figure 4) felt under pressure from deadlines all or most of the time; this percentage rises to 58% for tenure-track faculty (Figure 7). Additionally, only 25% of the entire faculty (Figure 4) felt that work was piling up so high that they could not finish it all or most of the time, but the same answer was given by 47% of tenure-track faculty (Figure 8). In terms of teaching, 35% of the entire faculty (Figure 4) felt they were in control of the class only sometimes or never, but this same feeling of loss of control was felt by 65% of tenure-track faculty members (Figure 9).

Few other studies look at the differences between faculty ranks. The Chronicle of Higher Education survey of U.S. faculty [20] found that tenure-track faculty had some of the highest levels of stress and fatigue. Our faculty survey agrees with this finding. Tenure-track faculty in our survey experienced higher stress levels than other faculty. In addition, 83% of tenure-track faculty reported a moderate or a great deal of stress compared to 63% of lecturers and 46% of the tenured faculty.

The survey by Tyton Partners, in conjunction with Every Learner Everywhere [3] included some analysis of the differences among different faculty ranks. The Tyton Partners survey found that child or elder care was a significant challenge for 40% of women faculty members, and tenure-track faculty were more likely to report this concern. In our survey, slightly more lecturers (36%) and tenure-track faculty (38%) had to care for children or elderly people either full-time or part-time than the tenured faculty (30%).

Research Question 4: What are the impressions of faculty members to the learning environments in engineering courses after the switch to emergency remote learning in Spring 2020?

Overall, despite the challenges, at the end of the semester faculty members shared a positive experience in how they were able to transition their classes despite the fact that the majority of the interviewed faculty reported never having taught online before Spring 2020 and were therefore required to transition to the emergency online format with very little preparation and formal training. The general positive experience identified by the engineering faculty members is in clear contrast to the experience described by the students in the transition to online learning, who struggled both from an academic and non-academic perspective [22,23]. Most faculty (64.8%) in our survey generally felt that they had everything under control in the remote environment although they also felt that there was too much to do in their classes (55%) and they were under pressure from deadlines in their courses (48.9%). When analyzing these questions by gender, we found some differences; 50% of female faculty felt they had things under control compared to 70% of male faculty.

Our faculty interviews showed that faculty reported that they were faced with challenges in their teaching approach during the transition to emergency online teaching. The faculty reported challenges with grading and assessment, forming a personal connection with the students, listening to and supporting students who were struggling because of their personal situation, maintaining students' engagement, and "Zoom drain." In many cases, faculty changed their teaching approach "a whole 180 degree" (Dolly) as they recognize that the emergency online format required different strategies to keep students engaged. Some faculty report decreasing the pace of the class and the quantity of material covered, while other faculty were able to cover a bit more material. The majority of the interviewed faculty taught synchronously with the same schedule as during in-person teaching, used PowerPoint slides to present their lessons, recorded their lectures and made them available to students, and had office hours. A large number of faculty lectured for the entire class time, finding it difficult to incorporate active learning activities to keep students engaged. Both the surveys and the interviews of engineering students point to a large disconnect between the faculty members and students' experiences in remote learning in Spring 2020 with the students describing their experiences as more negative. Some faculty noted a discrepancy between their experience as a faculty and the students' experience although one of our faculty interviewees (Arthur) noted that students pointed out to him that their perceptions of the Spring were much different than his. Our faculty interviews also indicated that faculty members generally were unaware of best practices in teaching online including best practices in terms of presentations, grading, and assessment strategies. This aspect is fundamental in an online environment, in which visual clues are eliminated and the student–faculty contact time is diminished.

Research Question 5: What was the impact of the switch online in Spring 2020 to lab classes?

The faculty members interviewed found that moving laboratories to a remote mode was difficult. Specifically, the faculty members found it challenging to provide hardware to the students because of campus closure and safety concerns: Faculty members used different strategies to conduct their laboratory activities, such as using "a simulator" (Larry), and conducting demonstrations (Cristobal). In addition, some faculty members discussed their frustration on the inability to conduct labs in a safe environment (Edouard).

We did not ask any specific questions related to the impact of remote learning on labs in our faculty survey. This, in introspect, would have given us more insight to the experiences of a larger number of faculty than our faculty interviews about the impact of the COVID-19 shelter-in-place on instruction in labs.

7. Conclusions

Most of the faculty members in engineering have always viewed online teaching with skepticism, and prior to Spring 2020, very few classes in the STEM disciplines were taught fully online. The COVID-19 pandemic has completely shifted the traditional teaching approach, forcing all engineering classes at SJSU to be taught in an emergency online mode. Faculty shifted their classes in a matter of days; as a result, they felt under stress and under pressure from the work piling up, from deadlines, and from the lack of training in teaching in an online environment. Faculty members were worried both for their families and their students and experienced an increase in workload at a time in which many also experience an increase in family responsibilities. Tenure-track faculty members were impacted the most. Challenges that faculty have identified focus on testing and assessment, which found many faculty members unprepared and quite a bit at loss in dealing with suspected cheating and new testing formats. Faculty were also challenged to keep students engaged online and by the organization of hands-on laboratories in a fully online environment. Overall, at the end of the semester faculty share a positive experience in how they were able to transition their classes.

8. Limitations

The main limitation of the current analysis stands in the limited number of participants, which represent a small portion of the total number of faculty members in the college of engineering at SJSU. In addition, the participants were self-selected and not randomly selected, as we interviewed all the volunteers that offered to participate in the interview process. These limitations are common practice for qualitative analysis. To our knowledge, this study represents the largest qualitative study of the experience of engineering faculty members during the online transition due to the coronavirus pandemic. All interviews were conducted by one author, who is a white female engineering educator, an engineering education researcher, and an advocate for active learning and active communication. The epistemological commitments and positionality of the interviewer might have affected the follow up questions asked to the participants, although the interviewer kept the follow-up questions as consistent as possible.

9. Suggestions for Future Work

The emergency move to online learning in Spring 2020 caught many faculty unprepared. SJSU, as well as many other institutions in the U.S., planned to continue with most classes taught online in Fall 2020 and Spring 2021. It would be interesting to determine if faculty had less stress during Fall 2020 and Spring 2021 and used better pedagogical techniques in their online classes.

After the pandemic has ended and instructors are teaching again in face-to-face instruction, additional research could be done comparing stress, working conditions, and pedagogy and compare these results to our interview and survey as well as to other completed research. Despite increasing research on active learning, the teacher-centered lecture model still persists in STEM fields [43]. Although the number of faculty using active learning (or student centered) methods has increased in the last ten years, the Higher Education Research Institute survey of faculty in 2016–2017 showed that about half of faculty participated in teaching-related professional development opportunities [44]. After the changes in pedagogy that arose from the emergency remote learning in Spring 2020, more research could be conducted on the number of Engineering faculty who pursue faculty development to improve their delivery of courses and change their pedagogical methods. Research into professional development programs for engineering faculty [45] indicates that single seminars or trainings are insufficient to promote change in pedagogy. Therefore, more research should be done on the type of training that the engineering faculty receive and how it impacts their teaching.

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Article

A Survey Study on U.S. College Students' Learning Experience in COVID-19

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Abstract: COVID-19 affected various aspects of our life. Many college students were forced to take courses remotely. It was not clear how they adapted to this new environment and how their mental health was affected. The objective of this study is to understand college students' learning experience one year after the outbreak of COVID-19. An online survey was developed to investigate students' overall learning process, mental health, perception of the learning community and student support. Sixty-two college students in the U.S. were recruited through an online survey platform. Findings of this study revealed: (1) improved mental health of college students compared to the beginning of the pandemic; (2) an overall positive learning experience and perceived belongingness to their learning community, as well as high satisfaction with the student support; (3) the major hindrance in the online learning environment was the lack of interactions with teachers and classmates; (4) a relationship between family income and perception of the learning community was discovered, and the students from low-income families were found to feel more belonging to the learning community; (5) hybrid was the optimum learning mode during COVID-19; (6) on-campus students perceived more student support than off-campus students. These findings provided a guideline for future research to further explore, and improve, the online learning environment.

Keywords: college student; learning experience; COVID-19; survey; anxiety; depression; learning mode

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1. Introduction

The novel coronavirus SARS-CoV-2, known as COVID-19, is a disease that outburst from Hubei Province of China to the world at the beginning of 2020. The World Health Organization (WHO) declared a global health emergency for containment of this disease on 30 January 2020 [1]. By 23 March 2020, there were approximately 353,000 positive cases and more than 15,000 deaths globally [2]. According to [3], approximately 138 countries closed up their schools by March, which instantaneously affected about 80% of students worldwide.

As a result, alternatives to onsite learning were necessary [4]. In the U.S., remote online learning was initially a major alternative since March 2020. With the improvement of the COVID-19 situation and the opening of college campuses to students since the winter semester 2020, three alternative learning modes emerged: in-person, hybrid, and remote.

In-person learning allows the richest teacher-student and student-student interactions, but the uncertainty of COVID-19 spreading and insufficient social distancing in classrooms may cause certain levels of anxiety and depression to students. Remote learning is considered the safest mode, but the lack of in-person interaction between teacher-student and student-student may lead to loneliness, even anxiety, or depression. Hybrid, as a tradeoff between safety concern and in-person interaction, might provide the best learning mode for college students, but most colleges and universities were not able to support it due to insufficient on-campus resources.

In fact, due to the different sanitation conditions of the college, the combinations of learning modes and places were complicated. For example, some private colleges allowed students to stay on campus to learn in-person, but students were not allowed to go outside the campus once they were admitted to the campus. They needed to run weekly COVID-19 testing in order to stay on campus. Some colleges, such as Harvard, allowed students to stay on-campus but study remotely. Students also need to be tested weekly to ensure the safety of the dorm. Some public colleges, such as The City University of New York (CUNY), only allowed students to study remotely. The campus was completely closed.

To react to remote learning, some students chose to stay on campus, while others chose to live off-campus with friends. When students stay on campus, they could still have some levels of in-person interactions with peers outside the classroom. When students live off-campus with friends, they avoided an intense dorm environment and thus, reduced the risk to be affected by COVID-19.

The complicated learning system was indeed a challenge for both students and faculty, since neither of them was familiarized with remote learning. It had strong effects on student's learning experience and mental health: whether a student chose to stay on-campus or learning from home, many of them had experienced the different extent of mental health problems. For example, college life requires student interaction, but the social distancing during COVID-19 limits the chance of getting face-to-face contact, which causes anxiety for students. While both students and faculty learned to adapt themselves for the changes during COVID-19, it is crucial to investigate college students' learning experience one year after the outbreak of COVID-19. Will students still demonstrate similar levels of depression and anxiety at the beginning of COVID-19 [5,6]?

The objective of this study was to discover college students' learning experience and, in particular, perception of the learning community, satisfaction level, hindrance that they had encountered, and mental health, including their anxiety and depression level, one year after the outburst of COVID-19.

The rest of the paper is organized in the following way. In the literature review, related research on remote learning and mental health issues are reviewed. In the method, research questions, participant information, procedure, survey design, and data analysis plan are explained. In the results, it starts with the results of demographic information and reliability analysis, followed by descriptive analyses of survey responses corresponding to five research questions, and inferential analyses of impacts of students' grade (freshman, sophomore, junior, senior), gender, ethnicity, family income, learning mode, and learning location on their learning experience and mental health. In the discussion, five themes out of our results were elaborated. Finally, the conclusion section summarized major findings, limitation of the study, and future research.

2. Literature Review

In this section, academic coping strategy to COVID-19 was first reviewed, followed by introduction of remote learning, and previous questionnaires related to learning experience. The section ended with a review of research on health issues related to COVID-19.

2.1. Academic Responses to COVID-19

According to [7], all states in the United States were well prepared for implementing remote learning by 31 March 2020. The overall goal was to continue the education in the lock down period. Although the purpose was the same, the different universities developed different coping strategies for remote learning based on their condition. For example, when the shortage of online learning equipment (iPad, laptop, desktop) appeared, non-digital alternatives (such as mailing print textbooks or handout) were offered. On the other hand, the adjustment of curriculums and the grading policies were needed as well. The equality of special populations, such as ENL (English as a New Language) and handicapped students, was another challenge that universities faced. While continuing on the education through online learning mode, it is more important for the state education agencies to acknowledge the difficulties of students in this period, and it is critical to pay close attention to student support that helps them to get away from stresses [7].

According to [8], the Chinese Ministry of Education implemented a policy of suspending classes without stopping learning in response to the school's closures during COVID-19. They encountered many obstacles in delivering remote learning. For example, the heavy use of the internet caused regional network crashes. In addressing the problems of the inexperienced teachers and the lack of the online learning resources, the Chinese Ministry of Education integrated national resources (such as ordered the major communications companies to maintain a stable internet connection), trained the teachers online, and created platforms for students and teachers to share their online learning/teaching methods and experiences. Because of the unequal development of infrastructure in many provinces, localized strategies for remote learning were also developed based on their local conditions. In particular, the mental and physical wellness of students was paid special attention to in preparing for reopening schools after a pandemic [8].

2.2. Remote Learning

Remote learning, known as e-learning, online learning, or distant learning, was an innovative learning method being introduced in the twentieth century. One great example is the massive open online courses (MOOCs). It is an online platform that provides regular courses which can be accessed from anywhere in the world. Compared to the ordinary in-person classes, some students favor its self-paced learning style that promotes their learning motivation and comprehensiveness. However, some students who were less familiar with using computers and the internet to take courses appear to be uncomfortable and reject the use of e-learning because they are afraid that it would decrease their course performance [9]. During the pandemic period, when college students were forced to take their courses remotely, they reported both technology difficulties and resources challenges [5,6].

There are two major learning modes in remote learning: hybrid and online. In contrast to online learning, where students take courses completely online, hybrid remote learning refers to a combination of in-person and online class meetings. Through a semester, students are required to take a certain number of in-person classes while taking the rest of classes online. Hybrid mode allows students to have in-person interactions with peers and the instructors, and also saves students travel and commuting time when they take classes online, thus hybrid is considered as a good choice for remote learning.

2.3. Learning Experience Measurement

In the following, various survey instruments were reviewed regarding four facets of learning experiences: online learning experience, satisfaction, motivation, and learning strategy, and emotion.

2.3.1. Measure of Learning Experience in Online Learning (OLEQ, DLQ)

Online Learning Experience Questionnaire (OLEQ) was developed for measuring students' experience of online learning based on an evaluation framework. It consists of 27 items, exploring 6 aspects of the online learning experience: (1) access of information and learning materials, (2) flexibility and convenience, (3) opportunity for interacting with peers, (4) opportunity for interacting with teachers, (5) the value of supplementary face-to-face resource sessions, and (6) overall satisfaction with online learning. The participants were asked to respond to this survey with a 4-point-likert scale that ranged from 'strongly disagree' to 'strongly agree' [10].

The COVID-19 Distance Learning Questionnaire (DLQ) was developed to estimate the effectiveness of remote learning in Ukraine. It both evaluates the negative and positive aspects of distance learning [11].

2.3.2. Measure of Satisfaction in Learning Experience (CEQ, CEQS)

Because the Performance indicators (PIs) only focus on the learning outcome, ignoring the learning and teaching process, the Australian researchers developed Course Experience Questionnaire (CEQ) to measure the teaching quality and perception of the learning quality of college students. It uses a 5-point Likert-scale. The initial 80 items were shortened into 57 items after ambiguous items were filtered. It measures five aspects of course experiences: (1) good teaching; (2) clear goals and standards; (3) appropriate workload; (4) appropriate assessment, and (5) emphasis on independence [12].

A shortened version of CEQ developed in [13] keeps 25 items and consists of six major dimensions. It filtered out the dimension of "emphasis on independence" and added two outcome constructs: generic skills (6 items) and satisfaction (1 item). The four antecedent constructs kept the same as the CEQ version in [12]: good teaching (6 items), clear goals and standards (5 items), appropriate workload (4 items), appropriate assessment (3 items). Through examination, the researchers found that there was a strong impact of good teaching and clear goals on students' generic skills and satisfaction, while appropriate workload and appropriate assessment did not have a strong impact on generic skills and satisfaction [14].

Course Experience Quality and Satisfaction Model (CEQS) [14] is used to evaluate student's general learning efficiency and satisfaction level of their learning experiences. It consisted of three major parts: demographic information, CEQ (25 items), and global student satisfaction measurements (4 items).

2.3.3. Measure of Motivation and Learning Strategies (MSLQ)

Motivated Strategies for Learning Questionnaire (MSLQ) is a Likert-scaled questionnaire developed to evaluate college students' motivational orientations and learning strategies. It consists of 31 items that access student's motivation and 50 items for accessing their learning strategies. More specifically, it includes the measurement of goal orientation, task value, control beliefs about learning, self-efficiency, and test anxiety. The scale is reliable and demonstrates valid results [15–17].

2.3.4. Measure of Emotions in Learning Experience (AEQ)

Achievement Emotions Questionnaire (AEQ) aims to evaluate student's achievement emotions. It uses a 5-point Likert scale and consists of three major categories: Class-related emotions scales (80 items), Learning-related emotions scales (75 items), and Test Emotions scales (77 items). Each category includes 8 emotions: enjoyment, hope, pride, relief, anger, anxiety, shame, hopelessness, and boredom [18].

2.4. Health Issues Related to COVID-19

Although the campus closure might be good for preventing the spread of COVID-19 virus, a long-term closure might cause both physical and mental health problems. In fact, the anxiety level was found to be higher during COVID-19 than before [19]. Obesity, which is usually caused by unhealthy diets and the lack of physical activities, was also a product of long-term closure. Even worse, the weight gain might make people more anxious and aggravate their mental health [20].

The social media exposure (SME) was a possible source of anxiety. A survey was conducted in China to discover the relationship between SME and the anxiety level [5]. People usually felt bored during the closure, so they might frequently visit social media. Based on the data collected from Jan to Feb 2020, about half of the people were at different levels of anxiety, during COVID-19, in Wuhan. Through the analysis and comparison between the SME and the results from a depression scale (WHO-5: Well-Being Index) and an anxiety scale (GAD-7: Generalized Anxiety Disorder Scale), the researchers found that the people with anxiety were more frequently using social media than people with no symptoms or slight symptoms, which indicated a direct relationship between the SME and high level of anxiety [5]. The anxiety might be caused by the mass amount of negative news and pessimistic discussion about COVID-19 that were glutting the social media [21].

Studies from other researchers also suggested that the people's anxiety level could relate to their locations [22,23] and the wellness of their relatives [22]. For example, people in China who lived in cities were found to be less anxious than people who lived in rural areas due to the better sanitization measures and medical resources in cities than in rural areas [22]. People who lived in countries with weak medical facilities were more likely to be involved with mental problems [23]. On the other hand, people who have relatives infected with Coronavirus had higher levels of anxiety than people with relatives who were safe and healthy [22].

The wellness of people could also vary by their education level and coping strategy [6]. For instance, highly educated people were less likely to be prone to health problems during COVID-19, and good coping strategies could effectively prevent people from getting infections.

In order to cope with these problems, governments developed intervention strategies to promote wellness, such as creating videos and webinars to educate quarantine information and skills [21], building an online platform for people to share their wellness approaches [19], and spreading of financial assistance [24].

In summary, the design of our survey was based on four existing scales from above. It turned out that the shortened version of CEQ, developed in [13], was most frequently used for measuring teaching quality and student's satisfaction. In the same way, the OLEQ, developed in [10], was specifically to measure the learning experience in online learning conditions. Two scales (GAD-7 and WHO-5) measuring mental health conditions during COVID-19 by [5] would be used by our study to measure college students' anxiety and depression.

3. Method

3.1. Research Questions

This study addressed following five research questions:

RQ1: What was college students' overall learning process during COVID-19?
RQ2: What was the impact of COVID-19 on college students' mental health?
RQ3: What was college students' perception of the learning community during COVID-19?
RQ4: What was college students' perception of student support during COVID-19?
RQ5: What were the benefits and barriers of taking a course remotely in COVID-19?

3.2. Participant

Upon xxx IRB approval, a total of 62 participants were recruited online from Amazon Mechanical Turk (Mturk), a virtual crowdsourcing marketplace in January 2021. The screening criteria was any college student currently studying in the U.S., and each participant obtained $1 from Mturk after their completion was verified.

Initially, we planned to recruit participants from a college campus. However, due to COVID-19, it was difficult to recruit enough participants on campus. We then decided to use Mturk to disseminate the survey to recruit participants.

3.3. Procedure

First, an online survey was developed in Google Form, an online survey platform.

Second, an online job—Human Intelligence Task (HIT) for completing the above survey was created at Amazon Mechanical Turk in the first week of January 2021. Participants were given up to 30 min to complete it.

Third, a $1 participation fee was awarded if the Mturk ID was matched between the one participant offered on Google Form and the one Mturk provided on the completion list. When participants filled out the survey repeatedly, the most recent response was taken, and all previous ones were discarded.

Fourth, the HIT of survey completion was reposted five days after the first round of dissemination. In the first round, 42 valid responses were received in three days, but the number of participants did not increase in the following days. By reposting the same HIT in Mturk, the survey job appeared on the top list. It brought an additional 32 participants. It was interesting to note that quite a few responses (12) in the second round were the same participants in the first round. Thus, a saturation in this participant pool was probably reached, and a total of 62 valid responses were obtained. Though we would have liked to receive more responses, we decided to stop the recruitment process three days after our second round of dissemination.

3.4. Survey Design

In this study, we investigated the learning experience of college students a year after the starting of school closure. The College Student Learning Experience Survey was developed based on Online Learning Experience Questionnaire [10], Well-Being Index (WHO-5) [5], Generalized Anxiety Disorder scale (GAD-7) [6], and the Course Experience Questionnaire (CEQ) [13].

The questionnaire consists of 42 items, including 6 items related to demographic information (age, gender, ethnicity, family income, learning mode, learning location), and 36 items of five major constructs corresponding to our five research questions (RQ). Table 1 showed the detailed mapping of RQ, survey constructs, survey questions and survey sources.

Table 1. Mapping of RQ, Survey Constructs, Survey Questions and Survey Sources.

RQ	Construct	Question	Source
	Demographic information	1. What is your current year in college? 2. What is your gender? 3. What is your family annual income? 4. What is your ethnicity? 5. What was your choice of learning mode? 6. If you were a remote/hybrid, where did you take your class?	SurveyMonkey®
RQ1	Overall Learning Process	Please indicate your agreement degree with the following statements. (5-likert scale) I was encouraged to take responsibility for my own learning I was able to work through the subject material at my own pace It was easy to navigate the subject learning material The face-to-face resource sessions were valuable when supplemented with online learning Electronic communication with the subject lecturer was useful	[10]
RQ2	Mental health	How often have you been bothered by the following feelings? (1 = not at all, 2 = several days, 3 = more than half of the days, 4 = nearly everyday) Feeling nervous, anxious, or on edge.Not being able to stop or control worrying.Being so restless that it′s hard to sit still. Becoming easily annoyed or irritable. Feeling afraid as if something awful might happen. Worrying too much about different things. Trouble relaxing. How often do you have the following positive feelings? (1 = no time, 2 = some of the time, 3 = less than half of the time, 4 = more than half of the time, 5 = most of the time, 6 = all the time) I have felt calm and relaxed. I have felt active and vigorous. I woke up feeling fresh and rested. I have felt cheerful in good spirits. My daily life has been filled with things that interest me.	[5,6]

Table 1. *Cont.*

RQ	Construct	Question	Source
RQ3	Perception of learning community	Please indicate your agreement degree with following statements about your study support. (5-likert scale) I felt part of a group of students and teachers committed to learning. I was able to explore academic interests with teachers and students. I learned to explore ideas confidently with other students. Students' ideas and suggestions were used during the classes. I felt I belonged to the school community.	[13]
RQ4	Perception of student support	Please indicate your agreement degree with following statements about your study support. (5-likert scale) The library services were readily accessible. I was able to access IT (such as Chromebook/iPad) resources when I needed them. I was satisfied with the course and career advice provided. Health, social worker, and psychological counselling services met my requirements. Relevant learning resources (eTextbook, database, software) were accessible when I needed them.	[13]
RQ5	Benefits/challenges/ barriers of remote learning	For my remote learning, I am satisfied with … (5-likert scale) Convenience in studying. Access of information and learning material. Opportunities to interact with teachers. Opportunities to interact with classmates. What are your learning hindrances with remote learning? (checkbox) Inadequate opportunity to study with other classmates. Inadequate opportunity to discuss with teachers. Inadequate opportunity to establish peer support. Not confident enough to handle difficult task with online learning mode. Difficult to apply concepts taught in the subject	[10]

3.5. Data Analysis

First, descriptive analysis (count and percentage) of demographic information were conducted. Second, reliability analysis was reported for all survey constructs. Third, descriptive analysis (mean and percentage) on survey response was conducted for each corresponding research question. Finally, to understand whether students' grade (freshman, sophomore, junior, senior), gender, ethnicity, family income, learning mode, and learning location have impacts on their learning experience, inferential analyses of ANOVA were conducted.

4. Results

In the following, the demographic results and reliability results of all survey constructs will be reported first. Then, survey results corresponding to five research questions, are presented. To understand the impacts of demographic variables on their learning experience, inferential analyses were conducted.

4.1. Demographic Results

Table 2 showed the result of demographic information with 62 respondents. First, the majority of our participants were seniors (53%) and juniors (23%). Second, more male (60%) than female (39%) participated in the study. Third, the family income of majority participants (63%) were towards the lower end (under $50,000), while 28% were middle-income ($50,001–$100,000) and 10% were high-income ($100,001–$200,000). Fourth, surprisingly, Asian (66%) and White (23%) made up the majority of our sample. Fifth, in terms of learning mode, almost half of the participants chose remote learning (45%), followed by in-person (36%), and hybrid learning (19%). Finally, in terms of learning location, most of the participants (52%) prefer studying from home, 37% prefer staying on campus, and the rest (11%) prefer staying off-campus with friends.

Table 2. Results of Demographic Information.

Measure	Item	Count	Percentage
College Year	Freshman	4	6%
	Sophomore	11	18%
	Junior	14	23%
	Senior	33	53%
Gender	Male	37	60%
	Female	24	39%
	Prefer not to say	1	1%
Annual Income	less than $25,000	21	34%
	$25,001–$50,000	18	29%
	$50,001–$75,000	9	15%
	$75,001–$100,000	8	13%
	$100,001–$150,000	5	8%
	$150,001–$200,000	1	1%
Ethnicity	African American	3	5%
	Asian	41	66%
	Hispanic	4	6%
	White	14	23%
Learning Mode Choice	In-person	22	36%
	hybrid	12	19%
	remote	28	45%
Place to Learn	On Campus	23	37%
	Off Campus	7	11%
	Home	32	52%

4.2. Reliability Results

First, the reliability tests of five survey constructs were conducted. All five constructs reached an acceptable reliability (Cronbach's Alpha > 0.70). Then the mean and standard deviation of each construct were reported in Table 3.

Table 3. Cronbach's Alpha, Mean, and Std Deviation of Five Survey Constructs.

Construct	Cronbach's Alpha	Mean	Std. Deviation
Learning Process	0.73	4.11	0.62
Mental Health	0.86	3.10	0.67
Learning Community	0.83	3.92	0.72
Student Support	0.78	3.95	0.72
Satisfaction	0.72	3.96	0.71

4.3. Survey Results

In the following, the aggregated results corresponding to above five research questions were presented in terms of college students' overall learning experience, mental health, perception of the learning community, perception of student support, and benefits and challenges/barriers.

On the Overall Learning Experience scale, the higher the response values are, the more positive students' overall learning process are. As shown on Figure 1, the average scores of all five questions were at a high level (around 3.98–4.19 on the 5-likert scale), which indicated an overall positive learning process. In particular, top three items were: the face-to-face resource sessions were valuable when supplemented with online learning (mean = 4.19); the student was able to work through the subject materials at their own paces (mean = 4.16); the student was encouraged to take responsibility for their own learning (mean = 4.15).

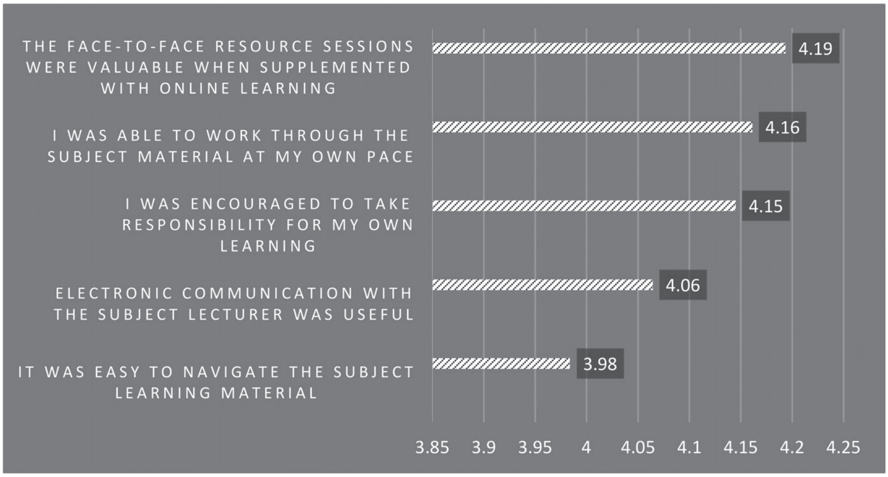

Figure 1. Result of Overall Learning Experience (1 = strongly disagree, 5 = strongly agree).

On the anxiety scale of GAD-7, the higher the response values are, the higher levels of mental problems are. As shown on Figure 2, the average scores of all seven questions were in low level (1.21–1.37 on 4-likert scale). A summered score (ranging 0–21) of 10 or greater represents a reasonable cut point for identifying cases of anxiety [5]. In our data, 55% of respondents demonstrated anxiety (Table 4).

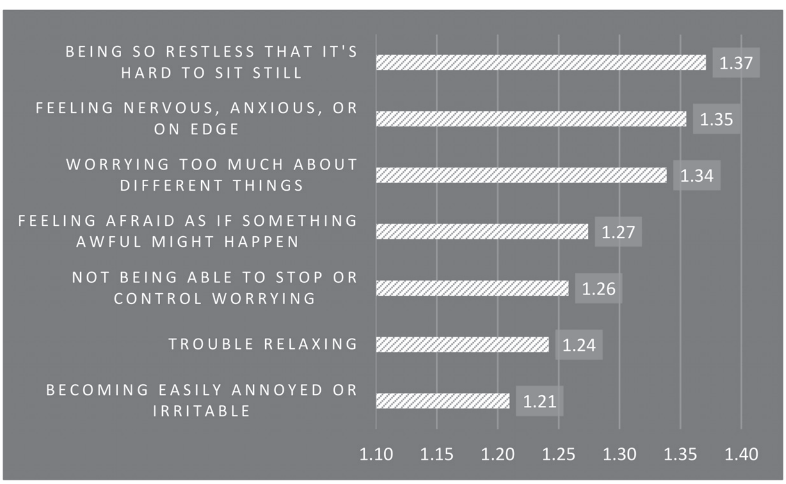

Figure 2. Result of Mental Health (GAD-7) (0 = Not at all, 1 = Several days, 2 = More than half the days, 3 = Nearly every day).

Table 4. Anxiety Score and Percentage.

Anxiety Score	Count	Percentage
0–9	28	45%
≥10 *	34	55%
Total	62	100%

* Note: Anxiety score ≥ 10 indicates anxiety (average = 8.05, std = 6.10).

On the depression scale of WHO-5, the higher the response values are, the better mental conditions are. As shown on Figure 3, the average scores of all five questions were in mid-to-high level (3.11–3.40 out of 6-likert scale), which indicated that the participants were inclined to a good mental health condition.

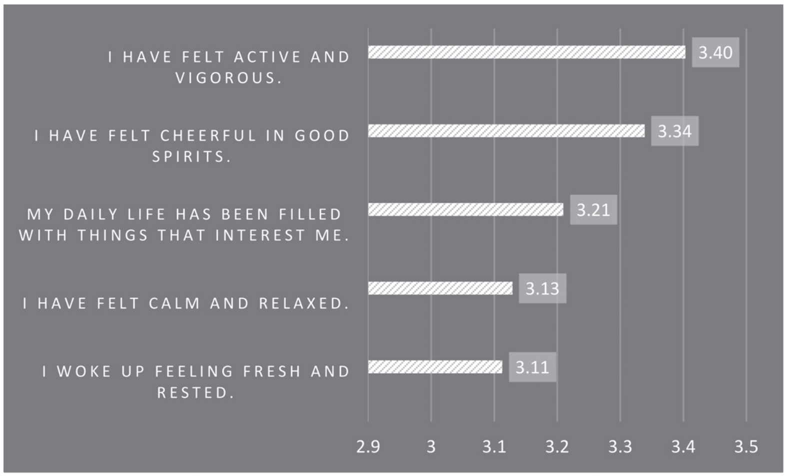

Figure 3. Result of Mental Health (WHO-5) (0 = No time, 1 = Some of the time, 2 = Less than half of the time, 3 = More than half of the time, 4 = Most of the time, 5 = All the time).

A summed score (ranging 0–25) below 13 indicates depression [5]. In our data, only 37% of respondents demonstrated depression, while the majority of respondents were free of depression (Table 5).

Table 5. Depression Score and Percentage.

Depression Score	Count	Percentage
≤13 *	23	37%
14–25	39	63%
Total	62	100%

* Note: Depression score ≤13, indicates depression (average = 15.19, std = 5.91).

Overall, no depression was present in our data. A large percentage (63%) of participants showed lower levels of depression than the cutoff value, and the average depression score indicated no depression. However, more than half (55%) of our participants demonstrated higher level of anxiety than the cutoff value, even though the average anxiety score indicated no anxiety.

On the Learning Community scale, the higher the response values, the better the feeling toward the learning community. As shown on Figure 4, the average scores of all above five questions were in high level (3.79–3.98 on 5-likert scale), which indicated that the participants were feeling well with their learning community.

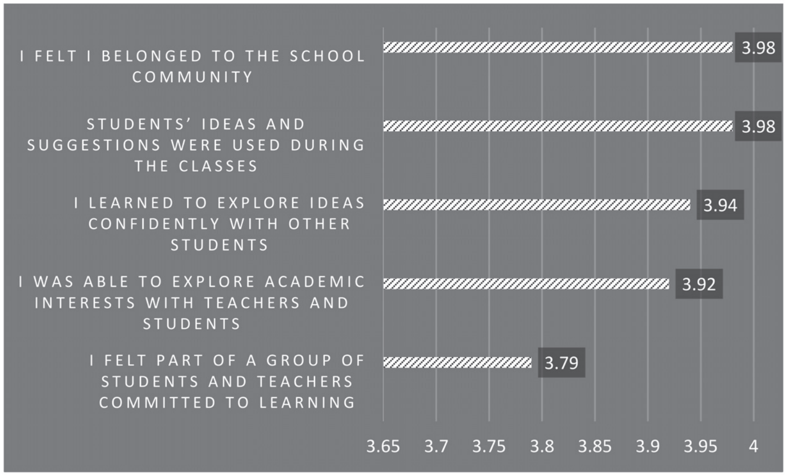

Figure 4. Result of Perceived Learning Community (1 = Strongly Disagree, 5 = Strongly Agree).

On the Student Support scale, the higher the response values are, the better student support are perceived. As shown on Figure 5, the average scores of all five questions were in high level (3.76–4.11 on 5-likert scale), which indicated that the respondents perceived sufficient student support.

Figure 5. Result of Student Support (1 = Strongly Disagree, 5 = Strongly Agree).

On the Satisfaction scale, the higher the response values are, the higher level of students' satisfaction are. As shown on Figure 6, the average scores of all above five questions were in high level (3.73-4.15 on 5-likert scale), which indicated that the participants were satisfied with their learning experience.

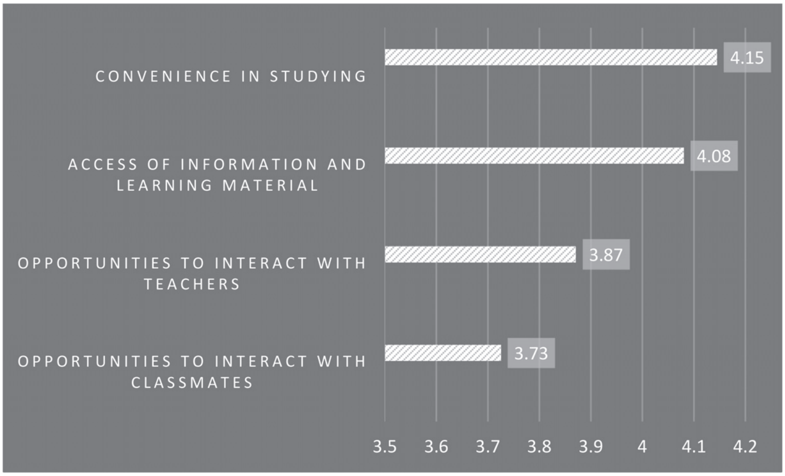

Figure 6. Result of Satisfaction (1 = Strongly Disagree, 5 = Strongly Agree).

This scale was a checkbox question. Figure 7 showed that online learning challenges students encountered included: inadequate opportunities to discuss with teachers (56%), lack of opportunities to study with their classmates (40%), inadequate opportunity for peer support (39%), difficulty to apply concepts taught in the subject (27%), and lack of confidence in handling difficult task with online learning mode (13%).

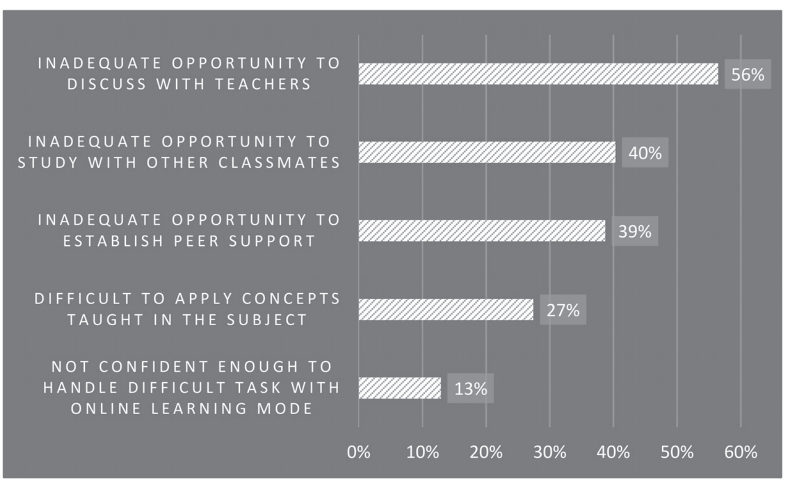

Figure 7. Result of Online Learning Hindrance (percentage).

4.4. Inferential Analysis Results

To understand whether students' grade (freshman, sophomore, junior, senior), gender, ethnicity, family income, learning mode, and learning location have impacts on their learning experience, inferential analyses of ANOVA have been conducted.

Results showed that no main effects of grade, gender, and ethnicity on all five survey constructs: learning process, mental health, learning community, student support, and satisfaction ($p > 0.05$). However, family income, learning mode, and learning location demonstrated significant effects.

First, the main effect of family income was significant on the perception of the learning community ($F(4,56) = 3.01$, $p < 0.05$). Students from high-income group (75 k–100 k) (mean = 3.30, std = 0.62) perceived significantly worse about the learning community than students from low-income groups (<25 k: mean = 4.10, std = 0.66; 25 k–50 k: mean = 4.11, std = 0.63).

Second, the main effect of learning mode was significant for anxiety ($F(2,59) = 9.81$, $p < 0.01$), but no significant differences for depression ($p > 0.05$). Anxiety was highest for the learning mode of in-person (mean = 12.55, std = 4.74), followed by remote (mean = 8.39, std = 5.89), and hybrid (mean = 4.17, std = 5.18). Posthoc Tukey of all three pairs comparisons were significant ($p < 0.05$).

Third, similar to the result of learning mode, the main effect of learning location was significant for anxiety ($F(2,59) = 3.44$, $p < 0.05$), but no significant differences for depression ($p > 0.05$). Posthoc Tukey of anxiety comparison showed that the on-campus group (mean = 11.52, std = 5.46) showed significantly higher levels of anxiety than the home group (mean = 7.31, std = 6.10) ($p < 0.05$). The off-campus group (mean = 8.86, std = 6.12) showed no differences between both on-campus and home groups.

In addition, the main effect of learning location was significant on the perception of student support ($F(2,59) = 3.02$, $p = 0.06$). Posthoc Tukey showed that the on-campus group (mean = 4.01, std = 0.44) perceived higher levels of student support than the off-campus group (mean = 3.37, std = 1.07) ($p < 0.05$).

5. Discussion

Our results provided rich information to the proposed research questions. Students' overall learning experience was found to be positive in this study. Students were in a good health condition in general. There was no presence of depression in our data, even though more than half of the students demonstrated anxiety. In addition, students felt that they belonged to their learning community. The students' support was found to be strong and adequate, and most of them were satisfied with their remote learning in COVID-19. Major benefits students perceived, related to remote learning, were the convenience to use online learning methods, and the easy accessibility to learning materials.

In the following, four major themes identified from our results will be discussed.

5.1. Socioeconomic Impact on Learning Community

Our inferential analysis showed that there were no main effects of grade, gender, ethnicity, and learning mode on five survey constructs. However, family annual income had a significant impact on a student's perception of the learning community. It is interesting that the students from low income families perceived more belonging to the learning community than those from high income families. This might be due to the likelihood that the students from low-income families received less restriction from their parents, so they were able to contact their friends in-person, while the students from high income families were more strictly prohibited to have face-to-face contact with their friends during COVID-19. Although the in-person interaction during COVID-19 did not necessarily benefit these students' physical health, it probably helped them to have better participation in their learning community in comparison to those high-income students who were constrained at home.

5.2. Optimal Learning Location and Learning Mode

Our results revealed that the learning location has an impact on students' learning experience. Specifically, the students who chose to study on-campus perceived better student support than those who were off-campus with friends. It is understandable that both academic resources (such as lab materials, abundant library in-print collection), technical resources (such as stable campus network, site accessible software, high-end computers), as well as other services (such as health, psychological counseling, career service events) are more accessible on-campus than off-campus. Surprisingly, the impact of learning location on mental health was opposite to our prediction. Initially, we assumed that students at home might feel isolated from their peers, thus exhibiting a higher level of anxiety than on-campus students. However, students in the on-campus group, in fact, showed higher levels of anxiety than the home group. A possible explanation is on-campus students, at the time, had to follow very strict social distancing and other related policies. There were many ambiguities in those evolving policies. Students constantly worried that they may be deported home if they violated those strict rules. Therefore on-campus students actually showed much a higher level of anxiety than home students. The off-campus group student stayed with their friends while taking courses online. It was considered the best choice at the time. However, the small sample size of that condition in our data did not allow us to draw any conclusive statements here. A future study with bigger sample size of this condition is warranted.

In addition, our results showed that the learning mode has an impact on students' mental health. In particular, hybrid students had the lowest anxiety level, and in-person students had the highest anxiety level. Remote students had a level of anxiety between in-person and remote students. The high level of anxiety from the in-person student group might be due to the likelihood that students were afraid of in-person infection of COVID-19. The first vaccine shots were given on 14 December 2021 in the U.S. When we collected data for this study in January 2021, only a very small portion of frontline workers and health care workers were vaccinated. The majority of college students were unvaccinated at that time. Although these in-person students got better support in learning, the peak of COVID-19 infection right after Christmas and New Year holidays in the U.S. might make them fear the possible virus spread out in-person. Remote learning was the safest learning mode in terms of possible COVID-19 infection. They did not have to worry about getting infected and social distancing. However, it lacks in-person interaction and social support. Therefore, the hybrid group was shown as the optimal learning mode in our study. On the one hand, the hybrid students got sufficient student support from the campus interactions. On the other hand, they did not have to worry much about keeping social distancing and infection too much, so they presented the lowest anxiety level.

5.3. Improved Mental Health

Studies similar to ours were conducted last year at the beginning of COVID-19. Compared to their findings [5,6,24], college students showed improved mental health in our study. In the spring 2020, when many universities in the U.S. closed their campuses due to the emergency of COVID-19, they were unprepared for the sudden shift to online teaching and learning. The campus network infrastructure was weak for heavy use, the grading policy had not yet been revised to adapt the new learning method, and psychological and material support to students were inadequate [7]. College students worried about the efficiency of remote learning [11]. Students reported negative impacts of remote learning on their mental health including high levels of stress, anxiety, and depression [5,6,24]. However, one year after the outbreak of COVID-19, the college students demonstrated positive overall learning experience, improved mental health, high levels of satisfaction, and student support in our study. The prevalence of depression dropped from 48.3% [5] to 37%. This positive shift is a good indication of students' successful adaption to remote learning as well as an overall improvement in university responses to COVID-19. Nevertheless, 55% of students still had prevalence of anxiety in our study. Thus, this evidenced that infectious diseases like COVID-19 may have an immense influence on youth mental health. While students coped with their depression pretty well, universities should continue to develop effective interventions for their anxiety. With the wide vaccine implementation on the way, we expect that students' anxiety will significantly drop in the future.

5.4. Overall Positve Learning Experience

As shown in the Results section (Figures 1 and 4–6), students in our study reported an overall positive learning experience, including high perception of learning community, sufficient student support, and high level of satisfaction with their learning experience.

This finding is consistent with other similar studies. In Gonzalez et al. [25], they reported a significant positive effect of the COVID-19 confinement on students' performance in Spain. They found that students adapted their learning strategies to a more continuous habit during COVID-19, and led to an improved learning efficiency, and better grades (improved learning performance). In another study at Pakistan [26], a positive relationship between technology acceptance and eLearning during COVID-19 was reported. An increased online learning adaptation was due to broader options to learn new things, which was provided by online technologies for both students and teachers.

5.5. Barriers for Online Learning

Despite that the students were satisfied with their communication with classmates and teachers, most students reported the inadequate opportunities to interact with both teachers and peers was still the major challenge and barrier to their online learning. Another challenge and barrier were the lack of confidence in dealing with difficult tasks in online learning, in which the weak network infrastructure and lack of equipment (such as iPad or laptop) were, in particular, out of the student's control.

The inadequate interaction problem in online learning is not new. In fact, a similar study [9] on online learning before COVID-19 showed similar findings. In that study, students who were unfamiliar with the online learning environment rejected using it as their study method. Four factors were identified for barriers to online learning: lack of face-to-face interaction, inadequate opportunity of real-time group discussion, low-efficiency, and causing anxiety [9]. Due to the innovative online learning technology and policy, the efficiency had been improved, and only 13% of students in our study felt uncomfortable to handle tasks with an online learning method. However, the inadequate interaction problem still remains. It is found, in our study, that 40% and 56% of the participants felt the lack of interaction between classmate and teacher, respectively. In fact, the inaccessible interaction of online learning mode is one of the major shortcomings that should be improved in the future.

6. Conclusions

In summary, our study found that students′ learning experience during COVID-19 was positive. They were in a fair mental health condition. Students reported good belonging to their learning community and sufficient student support. Most students were satisfied with remote learning, and no serious barriers were found except inadequate interactions between students and teachers, and between students.

In terms of college student's mental health, the hybrid model was shown to be the optimum learning option even one year after the outbreak of infectious COVID-19. It suggested that the colleges should consider encouraging hybrid learning, instead of other learning options, when on-site safety was not ensured. On-campus in-person learning is not always the best learning mode, as the majority of us thought.

6.1. Limitation

Due to the quarantine situation, we were unable to access students from campuses. Alternatively, we recruited our participants on an online survey platform. Even after several rounds of posting and reposting, the sample reached a saturation, in which the same participants responded to our solicitation. We were not able to grow our sample size as we liked. In addition, the variety of racial groups was limited with most participants being Asians (66%) and white (23%).

6.2. Future Research

In pursuit of more precise and reliable results, a larger sample size, and a broader racial group, is crucial in future research. Comparison between private and public colleges, small liberal art colleges, and comprehensive universities will expand our findings to a broader context, and different coping strategies might be identified for different settings. Finally, with wide implementation of COVID-19 vaccines and their effectiveness in coping with the disease, we expect great improvements in college students' mental health and learning experience in the near future.

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education sciences

Article

Schools, Universities and Large-Scale Assessment Responses to COVID-19: The Swedish Example

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Abstract: The aim of this paper is to describe, analyze, and discuss how Swedish schools and the national tests in schools, university teaching and examination, and the college admissions test, Swedish Scholastic Aptitude Test (SweSAT), have been affected by the COVID-19 situation. A further aim is to discuss the challenges in schools, universities and in the admissions test process in Sweden which are due to the COVID-19 situation. Contrary to many other countries, Swedish schools remained open, except for upper secondary school and universities where teaching went online. However, the spring administrations of the national tests and the high-stake college admission test, SweSAT, were cancelled, which had impact on admissions to universities in the fall. By using documentation from the news, school, and university authorities, as well as governmental reports of the events and a student survey, challenges are discussed. The novelty of this study includes a discussion of the events and their upcoming challenges. A discussion of what could be learned and what to expect in the close future is included, as well as conclusions which can be drawn from this situation.

Keywords: COVID-19; school response; university response; testing situations; testing challenges

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1. Introduction

In the spring of 2020, schools and large-scale assessments were forced to adjust quickly to a new reality due to COVID-19. In Sweden, COVID-19 had a direct impact on most parts of the education and assessment systems, including universities and schools, as well as national tests in the schools and the college admission test, Swedish Scholastic Aptitude Test (SweSAT). The national tests are compulsory and are used as a means of fair grading. The SweSAT is optional but still high stakes, as it is used for selection to higher education. Candidates with a valid SweSAT score can be admitted on the basis of either upper-secondary school grades (GPA) or the SweSAT score, and they are placed in the selection group (GPA or SweSAT) that ranks them highest in the selection process. About 2/5 and 3/5 of candidates are selected on the basis of SweSAT scores and GPA, respectively.

The overall aim of this paper is to describe, discuss and analyze how Swedish schools and the national tests in schools, university teaching and examination, and the SweSAT in Sweden, have been affected by the COVID-19 situation. Both national tests in schools and the SweSAT were cancelled during the spring of 2020, leaving those who planned to apply for college and university in the fall of 2020 in a state of grave uncertainty. A further aim is to discuss the challenges in schools, universities and in the college admissions test process in Sweden that arose because of the COVID-19 situation.

Previous research of how higher education has been affected due to COVID-19 is currently limited, but there are some studies. Researchers have recently described the impact of the COVID-19 situation on large-scale assessments in the US [1]. Researchers have studied the perceptions of teachers and students on online teaching–learning modes and the implementation process of online teaching–learning modes [2]. Other researchers have studied the capacities of Georgia and its population to continue the education process online, and it reviews the different available platforms. They also report on what can be learned from quick online transition for future transitions [3]. Although there are also some studies of plans for using online or distance education tools during a crisis, these are focused on local crises and not a global one, such as COVID-19. Finally, countries with limited technologies are less likely to be sufficiently prepared to implement online education in the whole country [4]. Our paper is different from these papers, as it describes and discusses assessment and testing in the Swedish context, and our paper has a clear focus on the challenges that arose due to the pandemic.

We suggest that the Swedish example is interesting to a larger audience, as Sweden chose a different path in the pandemic and neither implemented a major lockdown of society nor cancelled in-person instruction for compulsory school (Grade 1–9). To keep the compulsory schools open in Sweden was a unique decision compared to the US [1] and many other European countries. However, during the second wave, in the fall of 2020, most countries decided to keep their schools open, at least for schoolyears 1–6, as school closure and home confinement might have negative effects on the mental and physical health of children [5]. A recent study has also shown that the psychological impact of quarantine is substantial and can be long-lasting [6].

The full impact of COVID-19 is still unknown. We do not yet know how learning and assessments will be affected, when instruction on campus will return to normal, and when exams can again be given in large lecture halls. Different adjustments are still in place both in schools, universities, and with respect to national tests and the college admissions test. Here, we will describe, analyze, and discuss the state of events up until 15 February 2021.

Besides from describing the COVID-19 impact, we will discuss challenges in schools, universities and those connected to the national tests and the SweSAT. More specifically, we will answer the following research questions:

1. How were Swedish schools, universities, and large-scale assessments, in terms of national tests and the SweSAT, affected by the COVID-19 situation?
2. What were the challenges for the undergraduate students, graduate students, and university teachers due to the COVID-19 situation?
3. What were the challenges associated with the transition to online education and testing?

The rest of the paper is structured as follows. In the next section we present the method used, followed by a description, analysis, and discussion of the impact of COVID-19 in schools and national tests, as well as challenges and possible solutions related to this. Then, the effects and challenges due to COVID-19 on the SweSAT are discussed and analyzed, followed by a similar account of the effect of COVID-19 on undergraduate and graduate university education and assessment. Finally, a discussion of testing in schools, universities, as well as large-scale testing in the future is provided, followed by some conclusions.

2. Method

To answer the first research question, we used newspaper articles, governmental reports and journal articles. To find these various sources, we used different search engines (including Google Scholar, the ERIC database, and ScienceDirect) and we talked to those in charge of the SweSAT and national tests, as well as to a member of the discipline authority. To answer the second and third research questions, we talked to 10 teachers, 5 graduate students, and conducted a survey among 45 undergraduate students. We also used search engines to find journal articles and governmental reports about the situation in schools and universities, as well as exploring challenges with online education and testing.

3. Impact of COVID-19 on Swedish Schools and National Tests

3.1. The Swedish National Tests and the Swedish Grading System

The national tests in Sweden aim to support an equal and fair grading process [7,8]. The Swedish national tests are one out of many other tests that help teachers to provide fair grades to students, thus, they are not to be seen as final exams. From 2018, however, teachers have had to pay special attention to the results from the national tests when grading their students [9] and, thus, they are high stakes for the students, as they heavily influence their final grades. National tests are given to pupils in grade 3 (Mathematics, Swedish), grade 6 (English, Mathematics, Swedish), grade 9 (English, Mathematics, Swedish, one of biology, chemistry, and physics, and one of civics, geography, history or religion). In upper-secondary school national tests are mandatory for students in their highest course in English, Mathematics, and Swedish.

All national tests are composed of different subtests. A few subtests are oral, but most subtests are paper and pencil tests, although they are planned to be computerized in a few years. The examinees take all subtests individually, there are no collaborative subtests or components. The subtests are given on certain dates and contain items that require responses in the form of multiple choice, short answers, essays, or complete solutions. Each subtest is administered to the whole age cohort, which is about 100,000 students.

The Swedish grading system is criterion-referenced and teachers are responsible for grading their students at the end of a course or at the end of a school semester. The grading scale comprises six steps: A–F, where F is a fail and A–E are different levels of pass, with A as the highest grade. When calculating the grade point average (GPA), the grade letters are assigned the following numeric values: A = 20, B = 17.5, C = 15, D =12.5, E = 10, F = 0. The numeric values for each grade a student receives are summarized, and then an average is obtained by dividing the sum with the number of received grades in order to obtain a student's GPA. The grades in school-year 9, the last year in compulsory school, are used for admission to upper-secondary school. In the admission process to upper-secondary school, a majority of students enter their first choice [10]. The grades from upper-secondary school are used for both eligibility and selection in admissions to higher education. There is also a system with merit courses, where certain courses (e.g., modern languages and advanced mathematics) are worth extra points in the selection process. Hence, while the normal maximum GPA is 20.0, the maximum GPA for selection purposes is 22.5.

3.2. Impact of COVID-19 in Swedish Schools

On March 17, 2020, the Prime Minister of Sweden announced that upper-secondary schools were recommended to close and switch to distance education from the next day. Compulsory schools should remain open, but local authorities could decide to close a specific school if the spread of COVID-19 became too extensive. The reasons why Sweden, unlike almost all other countries, did not close compulsory schools were partly that children did not seem to drive the spread of infection, and also partly because children would retain their statutory right to education and parents could continue to work [11]. Recently published preprints of preliminary research results also support the hypothesis that younger children do not drive infection [12,13].

In Sweden, the vast majority of upper-secondary school students have a school computer, a prerequisite for the possibility of conducting distance education. Up to this time, however, the Education Act did not allow distance education and, therefore, schools and teachers were not prepared when schools closed. Still, when the Swedish Schools Inspectorate investigated how the transition to distance education had worked, after the first somewhat chaotic weeks, it seemed as it went quite well [14]. Most schools chose to follow a regular schedule in real time, and conduct teaching via various digital meeting platforms. To begin with, many students experienced that the workload increased, as the teachers required them to report what they had performed after each lesson. After a couple of weeks, the situation stabilized and teachers removed this type of reconciliation after each lesson [14]. In upper-secondary school, absence from school was slightly higher in the beginning, but overall absence actually turned out to be lower than normal [15].

Compulsory schools were, from one perspective, affected to a lesser extent, as teaching continued as usual. Still, absence rates, both among teachers and students, was greater than normal, partly due to the combination of regulations that you should stay at home if you have the slightest cold symptoms and the limited availability of COVID-19 testing [15].

The possibility of conducting distance education in compulsory school is more complicated, due to the fact that not all pupils have their own computers. In an investigation conducted in the autumn of 2018, only half of pupils in compulsory school have a school computer [16]. As most pupils in grades 7–9 have a school computer, the availability of computers is even lower among pupils in grades 1–6. Closing compulsory school had probably resulted in a situation where no teaching could have been conducted at all. Moreover, a general closure of compulsory school had probably meant that at least one of the younger children's parents would have had to stay at home to take care of the children.

Due to changed recommendations, pupils in compulsory school and students in upper-secondary school returned to school in the autumn of 2020. Yet, some restrictions remained, especially in upper-secondary schools. In order to reduce the number of students in corridors and school canteens, many schools had part-time distance education. In some schools, half of the students were on-site in even-numbered weeks and the other half were there in odd-numbered weeks.

Due to the increasing spread of COVID-19 in Sweden in the late fall, upper-secondary schools returned to full-time distance learning from the beginning of December. This time, however, students were permitted to come to school during practical course components and to take tests that could not be rescheduled.

3.2.1. Problems Connected to Assessment and Grading in Schools

One of the most common problems raised in the surveys connected to COVID-19 concerns assessment and grading [14,15], a problem that is more apparent in upper-secondary school, where students have studied from home to a large extent. In recent years, many schools have invested in some sort of digital assessment system to administer the school-based assessments, due to the requirement that, since 2018, the essays in national tests have to be written digitally. Due to COVID-19 and distance education, many teachers stated that it was very convenient to have access to these digital systems to administer assessments. However, many teachers expressed concerns about the obvious risk of cheating [14]. According to the surveys conducted by the Inspectorate and the National Agency of Education, teachers have been highly creative [14,15]. A common solution was to deliver the test through a locked digital assessment platform, and proctor the students via a mobile phone from which the students log in to a digital meeting room with video and a microphone to show what they are doing. Normally, one teacher proctored a whole class with 25 to 30 students, which is more than recommended [1]. Some teachers stated that, when they suspect cheating, they ask supplementary oral questions [14]. In addition, in some subjects such as mathematics, students have come to school and completed tests in small groups.

3.2.2. The Cancelation of the National Tests

In the spring of 2020, all national tests with test dates from the beginning of March were cancelled. The reason for canceling the national tests, although the schools were not closed, was that, since the national tests are rather high stakes, there was an obvious risk that students with mild symptoms would attend. Furthermore, as upper-secondary schools had distance education, it would have been necessary for students to come to schools at the test dates, which could have increased the spread of the disease.

The annual report on national school statistics from the National Agency of Education shows that the proportion of pupils who are eligible for upper-secondary school increased in the spring of 2020 [17]. Some have argued that the increase in grades is due to the fact that students had more teaching time when the national tests were canceled, while others have stated that the absence of national tests meant that there was nothing to relate to except the teachers own assessments. The raise in the grades is, however, quite small, and it is therefore difficult to conclude if the raise is only due to natural fluctuations or if teachers have taken the opportunity to reward students.

After schools opened up in the autumn of 2020, with more or less on-site teaching, national tests for upper-secondary schools were given in the fall of 2020. For compulsory schools, only the oral parts have testing dates in the autumn. A couple of days before the Christmas vacation in 2020, the National Agency of Education declared that the spring 2021 administration of all national tests was cancelled.

3.3. Challenges for School Assessments and the National Tests

When administering school assessments, Sweden has no tradition of using remote proctoring. Remote proctoring, or online proctoring, means to use either human proctors or automated processes to monitor the delivery of a digital assessment through microphone and web camera using the internet. Remote proctoring was introduced in large-scale assessment by Kryterion in 2008 [18]. If a human is used, the recommendation is to not monitor more than 16 students. If monitoring software is used, artificial intelligence (AI) is often used to monitor the test takers' behaviors. The AI algorithm searches to identify sounds, interruptions, suspicious movements, and whether an extra individual appears. Disruptive behaviors are flagged and the recorded movie could then be seen afterwards by a human. However, closure due to the pandemic revealed the need to be able to administer tests remotely, and to be able to proctor students. The digital assessment systems available for teachers to use can lock down the computer, but the system cannot know if students have someone else or another digital device in the room that can help them to solve items. The risk of cheating is therefore high.

In the case of the national tests, one challenge is the increasing risk of cheating due to remote administration. Since the national tests are rather high stakes, the incentive for cheating is high. A second challenge is that, when using remote administration, fairness issues are introduced. Even if most students, at least in upper-secondary school, have a school computer, they might not have a good internet connection or a room at home where they can close the door and be alone.

A third challenge is how to organize proctoring now and in the future. The Swedish school system is based on the premise that teaching and assessment takes place at schools. Thus, there has not been a need to develop systems with remote proctoring during assessments. It is also much easier to use human proctors in schools, since that is where students normally are. During the past few years, work has begun on computerizing the national tests so they can be administered digitally in a few years. A new digital assessment platform is under construction and, at the same time, digital test items are being developed. Human proctors are planned to be used and there is currently no plan to include any remote proctoring option in the assessment platform.

4. Impact of COVID-19 on the College Admissions Test SweSAT

4.1. The SweSAT

The SweSAT is a large-scale assessment which is normally administered twice a year—one time in the spring (usually early April) and one time in the fall (usually late October). The test is optional and the test taker can repeat the test as many times as she or he likes, and only the best result is used when applying for university. A SweSAT score is normally valid for five years. The test is typically administered to 40,000–70,000 test takers each administration, with more test takers in the spring than in the fall. It contains a verbal and a quantitative section, each containing four subtests. The verbal subtests are Swedish vocabulary, Swedish reading comprehension, Swedish sentence completion, and English reading comprehension. The quantitative subtests are diagrams, tables and maps, mathematical problem solving, data sufficiency, and quantitative comparisons. Each subsection contains 80 items, and the subsections are equated separately and placed on a scale from 0.0 to 2.0, with step increments of 0.1. This scale is constructed so that a score of, for example, 1.2, means the same regardless of which SweSAT administration it comes from. The verbal and quantitative scaled scores are averaged into one SweSAT score with a range from 0.00 to 2.00, with step increments of 0.05. For more information about the SweSAT and the Swedish admissions system, see [19].

4.2. Impact of Cancelling the Spring 2020 Administration of SweSAT due to COVID-19

The spring 2020 administration on April 4 of the SweSAT was cancelled on March 13 due to COVID-19. This decision brought about one immediate change, namely that the period of validity of SweSAT scores was increased from five to eight years. Because the pandemic caused large unemployment, the number of applicants to university increased by 13 percent in the fall of 2020, while the admitted candidates increased by 10 percent when compared with the fall of 2019; this means that, in general, competition was higher. Yet, the Swedish Council for Higher Education (hereafter referred to as the Council) concludes that cancelling the spring SweSAT administration seems to have had little impact on the chances of being admitted, when looking across all available programs and courses. However, as will be discussed later, the cancellation of the SweSAT appeared to have had an impact on the possibility of students getting into a university program of their choice.

4.3. The 2020 Fall Administration and 2021 Administrations of the SweSAT

The legislation surrounding SweSAT complicates decision making, as the Council is responsible for the test itself, 21 higher education institutions are responsible for the test day administration, and the Government (Department of Education; Stockholm, Sweden) is responsible for general regulations. Discussions between these three units about the fall administration of the SweSAT were lowkey during the spring and summer, but became intensified and highly political later on. The national university union magazine, *Universitetsläraren* [20], published a timeline of these events and this is displayed in Table 1, with some additions and edits for context and clarification, including a decision on 2021.

The different events in Table 1 led to an administering of the SweSAT in the fall of 2020 to a limited number of test takers in order to enable physical distance. From the event time line, it is noticeable that the Council did listen to the administrating institutions, as two limitations were put into place: (1) the test was only open for those who did not already have a valid SweSAT score, and (2) there was a cap on the number of test takers in each administrative region, which summed up to 27,600 seats nationally. As repeated test taking is common for the SweSAT (about 50 percent of the test takers in each administration has taken the test before), the first limitation alone had a large effect on the number of test takers. The 27,600 seats can be compared to the 40,000+ people who took the test in the fall of 2019. In the end, about 26,600 signed up for the test and close to 24,000 people ultimately took the test. The impact of the limitations on the composition and performance of the test takers was, when compared to the fall 2019 test-takers, a relatively large proportion of test takers under the age of 21 (69 percent compared to 64 percent) and over the age of 30 (11 percent compared to 7 percent), and a relatively poor performance, with an average score of 0.84 (compared to 0.89 in the fall of 2019), which corresponds to a difference of 0.13 standard deviations.

As stated in Table 1, there will be two spring administrations of the SweSAT in 2021. This was decided to provide test taking opportunities for more people while, at the same time, providing better possibilities for physical distancing. There will be two limitations: (1) an age limit of 19 years of age (or a certificate that the candidate is in the final year of upper-secondary school), and (2) a cap on the total number of test takers at 70,000; that is, 35,000 per administration. The sign-up period started on the 12 January 2021, with test administrations on March 13 and May 8. The fall administration of 2021 has not been publicly discussed yet, but anything other than a single test administration seems unlikely at this point. The Council has assigned the test developers, Umeå University and

Gothenburg University, to produce three test forms during 2021, so, with the extra test administration in the spring, there will only be one test administration in the fall.

From the events in Table 1 it is obvious that access to higher education is highly political, and one should keep this in mind if future administrations are threatened. A lesson learnt is the importance of preparing for possible future interruptions when SweSAT cannot be administered as planned; for example, to lift the responsibility of administrating the test from the administrative institutions to a higher decision level which can take full responsibility. One should also evaluate the currently imposed restrictions of test taking and examine the upcoming year's admissions in order to make sure that restrictions do not impose unfairness between certain groups. Depending on the outcome of such examinations, one should have a plan prepared for possible interruptions of future SweSAT administrations.

Table 1. Timeline of the events that led to administering SweSAT in the fall of 2020 and spring of 2021.

Date	Organization	Event
24/4	Council + institutions	Meeting regarding the conditions surrounding the fall administration
25/5	Council	Submits a memo to the Government regarding the possibility of limiting the number of test takers.
30/6	Council	Receives information that the Government moves forward with the issue of limitations and its corresponding need for changes in the Higher Education Ordinance
9/7	Government	Does not intend to make changes in the ordinance (i.e., the Council cannot limit the number of test takers).
20/7	Council	Are assigned, from the Government, to investigate the prerequisites for administering the SweSAT in the fall of 2020.
6/8	Council	Presents the prerequisites for administering the SweSAT in the fall of 2020.
7/8	Council	Decides to cancel the fall administration of the SweSAT.
19/8	3 political parties	Writes a debate article, demanding that the SweSAT shall be administered in the fall of 2020.
27/8	Government	Decides about changes to the Higher Education Ordinance regarding limitations to the number of test takers.
31/8	Institutions (Vice-Chancellors)	Write a debate article where they argue that the risk of an increased spread of COVID-19 during the SweSAT test administration day is far too great, even with a limited number of test takers.
1/9	Parliament's education committee	With an initiative from the three political parties, a meeting is held aimed at putting pressure on the Government to enable a test administration in the fall.
1/9	Liberal party	Backs on the initiative and a majority of the committee says no to a SweSAT administration in the fall
8/9	Government	Announces that a "national coordinator" will be appointed to help the Council make sure that the SweSAT can be administered in the fall. The responsibility for administering SweSAT is transferred from the admin to the Council.
9/9	Council	The Director General of the Council resigns.
17/9	National coordinator	Announces that the fall 2020 administration of the SweSAT will take place on October 25, with participant registration on a first come, first served basis
10/12	Council	Announces two spring administrations 2021 of the SweSAT.

Note. Institutions = the 21 universities and university colleges in charge of administering the SweSAT; 3 political parties = three political parties from the opposition: M (Moderate Party), L (Liberal Party) and KD (Christian Democrats).

4.4. Comparison of SweSAT and Its Use in College Admissions Compared with ACT and SAT in US

In the US, most students normally complete the college admissions test SAT and ACT at school-based test centers—distributed seven or eight times a year. Due to US school closures, the May and June SAT administrations and the April ACT administration were cancelled. Similar to SweSAT, many test takers repeat ACT and SAT: the first time in the spring of the junior year and the second time in the fall of the senior year. In 2020, ACT was administered to about 55,000 students at several smaller test centers that opened in June, and they have continued testing with reduced seating. In a normal year, about 300,000 test takers register to take the ACT and SAT on each of the national testing dates (March, April, May, and June). Due to school closures, about one million juniors may not have been able to take the test as planned in the spring 2020. However, as admission to university is centralized in Sweden, the SweSAT scores are valid for several years and have continued to be used during the pandemic. This is the opposite to a number of universities in the US, which have decided that valid ACT or SAT scores are not needed in the near future [21].

4.5. Challenges for the SweSAT

An important question for the future is how to administer large-scale, high-stakes tests like the SweSAT during a pandemic such as COVID-19. The main challenge for the SweSAT is that the current form of administration (paper-based, linear/fixed form) presupposes many people taking the test at the same time, which, in turn, leads to crowding. To prevent crowding, the test taker cohorts need to be spread out over time, and, to do this, there need to be more test forms. Producing more fixed test forms can be done to some extent, but, at some point, there will be too few test-takers per test form to be economically justifiable and to maintain a sufficient volume of item pretesting. Consequently, introducing some level of adaptivity in test delivery is probably necessary, and the only feasible way to do this is through computerization.

Another way of preventing crowding is remote test administration, where candidates take the test at home, for example. This could be possible in theory, but it is not practically feasible with a paper-based test, as it would be virtually impossible to implement sufficient security measures. Consequently, the solution seems to be delivery via computer. Computerization of the SweSAT was recently subject to investigations by the Council. The final report [22] came out in 2019 and concluded that, in the long term, there is a need to computerize the SweSAT. There are, however, currently no plans to start the computerization process, as there are several challenges connected to computerization, especially how to deliver the test to a large number of test takers at a certain date and time.

5. Impact of COVID-19 on Universities in Sweden

5.1. Application to University Programs

Most students apply to higher education in April and receive notification of acceptance during the end of July. Only a small number apply in the fall to start in January. In the fall of 2020, there was a large increase of applicants, which is probably due to higher unemployment rates and a more uncertain future in work areas such as restaurants, hotels, tourism, and entertainment. Table 2 illustrates the number of applicants to some of the most popular university programs, and the last admitted student's GPA and SweSAT score at the largest university in northern Sweden in 2018 and 2020. Note, the pattern is similar for other university programs. From Table 2, it is evident that the GPA is overall similar but the SweSAT score is much lower for all programs, except for the nursing program. The lack of the spring administration of SweSAT 2020 is probably the reason for the lower required SweSAT admissions score. The fact that the nursing program had a higher SweSAT score might be an effect of media coverage of nurses working during COVID-19, which made the program more attractive than before. Overall, there were more applicants in the fall 2020 than in the fall 2018 and 2019.

Table 2. Number of applicants (N), the last admitted student's grade point average (GPA), and the last admitted student's SweSAT score for different university programs in the falls of 2018 and 2020.

University Program	N		GPA (B1)		SweSAT	
	2018	2020	2018	2020	2018	2020
Medical	629	677	21.61	21.77	1.65	1.55
Law	450	467	20.13	20.21	1.30	1.20
Psychology	375	429	21.61	21.35	1.60	1.45
Nursing	238	309	17.90	17.90	0.70	0.80
Economy	268	299	17.50	17.50	1.10	0.90
Social work	370	253	17.81	17.49	0.85	0.75

5.2. On-Campus and Online Teaching

During the fall of 2020, all Swedish universities went back to some on-campus teaching, although the majority of teaching and examination was still performed online. To justify these openings, a huge COVID-19 testing was conducted at Umeå University, the largest university in northern Sweden. All (4062) employees and all (34,407) students with a valid Swedish social security number and electronic identification app (bankID) were invited to test for COVID-19 in the first week of instruction, and a follow up test one week later. A total of 9907 participants were tested, of which 6703 were tested on both occasions. Among those who were tested, about 2/3 were students and the rest were employees. Almost all participants had been in Sweden for the past two weeks, and about 40% outside of the region (n.b., Sweden is divided into 21 regions). Only six participants were found positive [23]. It was concluded that, at this time, there were very few who had the disease, and it was also concluded that opening up a university campus with social distancing restrictions tends not to be immediately dangerous. These are probably interesting results for the international community, as many campuses around the world hesitated to open up campus for students, and, instead, only used online instruction; for example, California State Universities, California Community Colleges, and a number of other colleges and universities.

In Sweden, the decision of how much instruction is given at campus and online during the pandemic differs between universities. Furthermore, the restriction rules differ between schools and universities. This is similar to the US, where these kinds of decisions for schools and colleges are made at the regional level, or by individual institutions, when it comes to higher education [1]. As the rules differ between schools and universities, it may cause problems or be otherwise challenging for some students.

5.3. Challenges for Undergraduate Students, Graduate Students and Teachers

All teaching and examinations were moved from campus to online due to recommendations from the national health authority on March 17, and most universities made the transition directly, so it was in effect on March 18. Different universities decided upon their own rules and guidelines, and this was the case when some universities decided to open their campuses again in the fall of 2020. Most teaching was moved to the Zoom platform, but examinations could either be live on Zoom or on a web-based platform, such as Canvas. There were several challenges in moving from campus to online teaching and testing for undergraduate students, graduate students and teachers, and these challenges are labelled A–F and later summarized in Table 3.

Challenge A concerns home work environment and living situation. If a student or teacher lives by themselves and has a good working place and no one around, they may get a lot of work done. Undergraduate students more often live by themselves than graduate students and teachers, and, thus, this might be less challenging for them. However, graduate students and younger teachers are often young adults, and it is not uncommon that they are parents with small children. Thus, although it is recommended from a health perspective to work from home, it may be very challenging for those who do not have access to a quiet workplace. This challenge also includes the physical home work place setup, such as screens, an office chair, and good lighting. This challenge is difficult for universities to handle. A possibility in the future would be to have small rooms that can be booked at university facilities for those students who do not have a good home work environment.

Challenge B concerns social environment. Undergraduate students usually belong to a class and, unless they are a freshman, they know their classmates and, thus, can keep in contact online. Group assignments can also help enforce the social environment. Graduate students in Sweden typically only follow a few classes with few students, and are used to working alone or in small research groups. To move everything online might, thus, be more socially isolating, especially as department colleagues work from home. This is particularly challenging when one needs to start building a work network and conferences are cancelled (e.g., FREMO in Norway), postponed (e.g., Compstat in Italy), or moved from in-person meetings to virtual meetings (e.g., AERA in the US). On the other hand, it might be cheaper to attend virtual conferences, thus, the project leader may allow the graduate student to attend more conferences than if they were to attend on site. As there are no student fees for higher education in Sweden, students have more choices of online courses from other universities. In the future, one should consider keeping some of the theoretical courses online in order to attract more students, and to give students more available courses, especially at graduate level.

Challenge C concerns the receiving and giving of teaching online versus in-person. An undergraduate student may feel a greater disconnect from their teachers, and the devices they have access to may influence their learning or how the material is perceived. Teachers may have a harder time to assess whether students understand their teaching in cases where students do not have their cameras on, because this leads to less teacher–student interaction. In the future, one should think of when cameras should be on or off and when smaller group assignments should be used to enhance social interactions. One could also consider alternative teaching forms, such as noted by [24], which could possibly be used with online teaching.

Challenge D concerns exams, especially in large undergraduate courses. Before COVID-19, most undergraduate exams and some graduate exams were taken in large lecture halls at certain dates and times. To use online exams is challenging, as students face a disadvantage relative to students who take exams in a traditional, proctored environment; this is because of the absence of a proctor who can provide clarifications on exam questions, the possibility of greater distractions in the home environment, and possible problems with internet connections and the students' computers [25]. For teachers, it may also be difficult to provide exams that are difficult to cheat on, or where answers are difficult to find with search engines. In the future, one should think of different ways of providing exams to students at different levels.

Challenge E concerns cheating, especially in undergraduate courses, as online testing facilitates cheating [26]. Different strategies can be used to prevent cheating, such as forcing the students to keep web cameras and audio on. A problem with keeping audio and video on is that unwanted noises and interruptions in privacy may be a larger problem for some students, if all students are online at the same time. Even if microphones and audio are on, there is a challenge of controlling the home environment. This includes which material the student may have access to, but, also, access to a quiet room with no interruptions of other individuals (Challenge A). Unless some kind of remote proctoring is used, it is difficult to ensure that students do not send cell phone photos of answers to their peers. Using human proctors is a possibility, but is challenging in large courses, as one may lack available staff.

Each university in Sweden typically has a discipline authority which handles potential cheating cases. The number of cheating matters in one university between 2015 to 2020 has been relatively constant (2015: 71, 2016: 100, 2017: 88, 2018: 60, 2019: 94: 2019 1/1–8/9: 53, 2020: 1/1–8/9: 52) as only about 0.2–0.3 percent of all students end up with a cheating matter in the discipline authority. Up until 2019, most of the matters were students with cell phones making sounds in jackets or bags during on-campus exams, which resulted in a warning. During 2020, all these kinds of matters were almost nonexistent, as no on-campus exams were given from mid-March. Instead, the matters concerned plagiarism, cheating, copying, or sharing solutions [27]. In the future, we need to work more proactively to reduce cheating and make students realize the problems with cheating.

Challenge F is to what extent it is possible to finish planned projects or compulsory course components. Some undergraduate students were affected in terms of practical parts of their education. Many graduate students and teachers with research projects have projects that require in-person meetings. In the COVID-19 situation, they have experienced delays with their projects, and some have been required to change or even cancel their projects. Although changing a research project may mean that the project takes a longer time, at this point, there are no general study time extensions for graduate students due to COVID-19 [28]; although, it is likely that several individual adaptions will be required within a close future.

Table 3. Challenges for undergraduate students, graduate students, and teachers.

	Undergraduate	Graduate	Teachers
A. Home work environment	Lives with another adult and/or children (less likely).	Lives with another adult and/or children (more likely).	Lives with another adult and/or children (more likely).
B. Social	Belongs to a class. Group assignments.	Attends small classes. Usually works alone.	Lack of in-person interaction.
C. Teaching	Receives online teaching.	Receives and provides online teaching.	Provides online teaching.
D. Examination	Written assignments. Online exams. Group work.	Written assignments. Online exams. Grade undergraduate exams.	Constructs and grades undergraduate and graduate exams.
E. Cheating	More common with online exams.	Uncommon.	Constructs exams to minimize cheating.
F. Work/Studies	Practical parts.	Time limited projects. May require in person.	Time limited projects. May require in person.

6. Challenges of Remote Testing in Schools, SweSAT and Universities

Regardless of whether a student is in school or at university, the challenges of remote testing are similar. The large-scale assessments in the US, such as the GRE General Test, Test of English as a Foreign Language (TOEFL), iBT Test, Graduate Management Admissions Test (GMAT), and Law School Admissions Test (LSAT), all cancelled in-person testing due to COVID-19, and, instead, used different remote proctoring solutions [1]. The use of remote proctoring software has not been used to any extent in Sweden during the pandemic. Common solutions are instead to use recorded test sessions (video and audio) and human proctoring.

Challenge A concerns the delivery of a digital examination. This includes the quality and the speed of the internet connection at students' homes. It could be viewed as unfair if some students only have a smaller amount of streaming, paid for by their parents or themselves, compared with those who have unlimited streaming services. This is probably more problematic in the US than in Sweden as, according to a US survey described in [1], only 35% of participants stated that their internet connection was great, 53% stated that it was ok, and 14% stated that it was terrible/unpredictable. In the large-scale assessment Trends in Mathematics and Science Study (TIMSS) 2015, 99% of the examined grade 8 students in Sweden had access to internet connection [29], but the quality of the connection (fiber vs. mobile) and how much streaming they have access to might be a reason for unfairness among different social groups, as would whether they live in a city or in the countryside [30]. One study [31] concluded that test takers who take a computerized test instead of a paper and pencil test are not disadvantaged. Others [18] found, when controlling for school and student background, that students who took a test in a paper and pencil format scored higher than students who took the test online. Thus, if the students are able to choose how to take a test, this might create unfairness. A person in a risk group may prefer to take a test online even if it may be disadvantageous compared with a paper and pencil test. Furthermore, students with disabilities may find it more difficult with digital exams. There is also a question of how much extended time one should provide (e.g., 50% or 100% extended time). In addition, to deliver a high-stake test like SweSAT at two particular dates each year means that nothing is allowed to go wrong during those days. There must be a backup system and plans for how to handle, for example, a loss of internet connection.

Challenge B is the large variation of devices that students use to take the test. The differences concern platforms, on-screen tools, screen-sizes, and screen quality. Depending on devices used, the test may be more or less difficult for the test taker. In compulsory school, this can be controlled by giving each student a school device. As this cannot be controlled in higher educational levels or the SweSAT, one needs to be careful which platforms to use, and how the test is set up, so that the test is fair regardless of the device used.

Challenge C is similar to Challenge A for university students and teachers, and concerns students' home environment in terms of access to quiet places, study desk size, and a private room. According to the TIMSS 2015 survey data of Swedish eighth graders, 95% had a study desk and 93% had their own room [29]. Schools or universities cannot control a student's home environment, but they could have small rooms that can be booked for exams in the future.

Challenge D concerns privacy and integrity during online testing—for example, when using cameras and microphones to scan the room and record a student testing session. A disadvantage with remote proctoring is a problem with personal integrity [32,33]. Although some countries, such as the US, use this, the Swedish Authority for Privacy Protection has concluded that the EU general data protection regulation (GDPR) cannot be fulfilled if one is using remote proctoring software [34]. We conducted a survey among 45 undergraduate students, in November 2020, about online teaching and digital testing of a university course taking elementary statistics. The answers revealed that about 37% believed that their studies had been affected negatively, and 49% thought it was negative to have a digital examination in comparison to an in-person classroom examination.

Challenge E concerns the higher risk of cheating associated with online testing, and this overlaps with Challenge E for undergraduate and graduate students. For example, the issue of identification is problematic if one is using an electronic ID app on one's cell phone (e.g., bankID), as one does not want students to have cell phones during a test. There might also be interactions between students, both live and digitally, which are difficult to control for. An advantage of remote proctoring is that it helps in detecting cheaters [32,33]. However, one problem with remote proctoring in large-scale assessments, such as SweSAT, is the large number of proctors that would be needed on a single test occasion.

7. Discussion

The full effects of COVID-19 on schools and large-scale assessments are yet to be seen, but the experiences gained from the pandemic should be considered when forming the future of large-scale assessments and examinations in upper-secondary schools and higher education. The first research question concerned how Swedish schools, universities and large-scale assessments, in terms of national tests and the SweSAT, were affected by the COVID-19 situation. The impact on compulsory schools was limited, as they remained open the whole time, contrary to many other countries, including the US [1]. During the second wave, most countries did as Sweden did and kept their schools for lower grades open, with the motivation that young children do not drive the infection [13,14], and school closure and home confinement might have negative effects on the mental and physical health of children [5]; there was also the question of the psychological impact of quarantine, which is substantial and can be long-lasting [6]. This is an important lesson, because, if schools are closed, fewer adults can go to work and, thus, the impact on society is greater. Many young children would also be disadvantaged, since not all families have the means to conduct distance education, and lower-grade students typically do not have a digital school device.

Upper-secondary school and universities were heavily affected, as most teaching moved online from one day to another. A strength was the fact that Sweden is a high technology country, which made it quite easy to adapt to online teaching, as opposed to countries with limited technologies [4]. A facilitating fact is also that most Swedish students have access to a computer and internet connection [29,30]. Sweden also has a history of remote higher education due to local politics, to facilitate for people who lose their jobs to educate themselves to get another job without moving. Thus, most Swedish universities already had some courses that were completely taught online before the pandemic, and this probably facilitated the transition. A weakness was, however, that on-campus students were not prepared for the situation and, in the future, it is important to examine the impact of this transition for different groups of students, so no group is disadvantaged.

National tests were cancelled, and that could have affected students' final grades, as they are used to support a fair and equal grading between schools. As noted in [35], there is already a difference between schools, and it is possible that the cancelation of the national tests made the difference even larger. A weakness is that the organization was not prepared, and, if we want to maintain a fair grading system, we also need well-functioning tools under extraordinary circumstances. A strength is that the national tests will soon be computerized, and that could probably prevent them from being canceled during a pandemic in the future.

In Sweden, the selection quota groups for university admissions have still not changed; even though the spring administration 2020 of SweSAT was cancelled, the fall 2020 administration of the SweSAT was limited, and teaching is still digital for many students in upper-secondary schools. The cancellation of the SweSAT spring administration had an impact, as the admissions showed that it was easier to get into some high-profile university programs if one had a valid SweSAT score. Leaving the quota groups unchanged is different from how it was performed in the US, where more than 50 percent of the 3330 four-year colleges and universities will not require applicants to submit test scores from their college admissions tests, ACT or SAT, for the 2021–2022 admissions cycle, including a majority of the liberal arts colleges. Several institutions have also made it optional for a limited period of time [1]. In the future, a preparation for disruption of a single testing date per semester (national tests, SweSAT) might be needed, as other threats may disrupt a testing occasion (such as security threats, which may require different forms). COVID-19 may be the catalyst for moving some tasks permanently in a digital direction.

The second research question concerned the challenges for undergraduate students, graduate students and teachers in universities due to the COVID-19 situation. From the conducted survey and interviews with graduate students and teachers, it was obvious that the groups had similar overall challenges; although the extent of the different challenges differed between the groups, and they ranged from home and social environment to actual teaching, working and examinations. Whether working from home was beneficial depended on the physical work environment, as well as whether the person had others at home or not. To be alone is difficult if it is not chosen, and [6] stressed that being in quarantine can have long lasting effects. The move from in-person teaching to online teaching went relatively smoothly, and is probably partly due to a high availability of digital devices and internet access in Sweden; although the quality can differ [30] and potentially create unfairness. To provide appropriate and fair online exams without possibilities to cheat is still a major challenge, and different systems might need to be developed and implemented in the future to accommodate specific needs. As certain parts of society have opened up, practical parts in the studies are allowed to be done in schools and on campus, which facilitates these learning situations. What remains to be solved is how to plan research projects and change graduate projects that demand in-person meetings. This is a challenge that should be considered when planning projects in the future, as a similar situation could potentially occur.

The third research question concerned the challenges of switching from in-person teaching and testing to online teaching and testing. Several challenges were addressed, but perhaps the most difficult one to solve is how to ensure fair testing while making sure that personal integrity is not violated. If one decides on remote testing, a possibility for creating a fairer testing environment is to create test centers or rooms in universities and schools where tests can be conducted for those who lack resources, and where remote proctoring can be used. This would create a more equal situation between different groups. If one would pursue online teaching and testing, one may also encourage schools to provide digital devices to each student, even in lower grades (e.g., one Swedish northern community gave computers to all pupils in grade 4, and another community gave all pupils computers from grade 1, instead of grade 6), and to see the advantages of computerized tests over paper and pencil tests in, for example, learning geography [36]. A downside is that the cost of providing devices to a large number of students has to be taken from other parts of the students' education. The main advantage, however, is that all students would have the same tools and, thus, it would facilitate a fairer education.

8. Conclusions

The overall conclusion from this study is that the pandemic has forced a number of major changes, and several challenges that need to be addressed have come to the surface. COVID-19 has changed large-scale assessments in terms of the administration of the SweSAT, national tests, and how exams are taken at the universities, and it will probably influence these areas in several years to come. Some changes have been positive, but others are still to be discussed, as not all of them are desirable from an educator perspective or from a personal integrity perspective. COVID-19 has forced educators and testing institutions to reconsider how, when, and where assessments are taken. Teachers and students have learnt how to work remotely, which will probably be useful even when life goes back to normal.

There are some limitations with our research. First, the pandemic is still ongoing and, although some universities and upper-secondary schools have opened up to some extent, a large mass of students is still receiving their instructions and exams online. What the really good examples are is still to be decided. Second, whether the students learn more or less due to online learning needs to be examined, but it is too early to examine this. During 2022, the national tests will probably be taken, and one can then compare the students' results from those taken before the pandemic.

In the future, it would also be interesting to conduct a large survey of how students on different levels and teachers have perceived working from home, and what could be improved if we have a similar situation in the future. It would also be interesting to study the effect of teaching format (online class versus in-person class) on students' knowledge.

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Teaching Online during the COVID-19 Pandemic: A Phenomenological Study of Physical Therapist Faculty in Brazil, Cyprus, and The United States

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Abstract: The COVID-19 pandemic led to a global transition from in-person to online instruction leaving many higher education faculty with little time or training for this responsibility. Physical therapist education programs were especially impacted since a large part of the development of skills rely on face-to-face onsite practice. This phenomenological study explored the perceptions of physical therapist educators in three countries—Brazil, Cyprus, and the United States, who transitioned to an entirely virtual medium of teaching during the pandemic. Sixteen faculty participated in 1:1 semi-structured interviews. Trustworthiness of qualitative inquiry was ascertained using triangulation, thick descriptions, and peer reviews. Four major themes emerged from analysis of participants' interview data: adapting pedagogy in real-time, expected excellence, limitations of the medium, and informing future teaching practice. All participants described teaching during the pandemic as one of the most challenging experiences of their professional careers. Despite available resources, faculty noted challenges in making authentic connections with students, adapting to technological interruptions, assessment of student understanding of content, and managing work-life balance. Despite the challenges, faculty worked collaboratively with peers to innovate new approaches of creating social, cognitive, and teaching presence. Unique opportunities arose from the pandemic to enhance future teaching practice.

Keywords: physical therapist educators; online teaching and learning; pandemic

1. Introduction

On 30 January 2020, The World Health Organization Director-General declared the outbreak of novel coronavirus 2019 (COVID-19) "a public health emergency of international concern" [1]. In response to the outbreak, countries adopted safety measures, including social and physical distancing, travel restrictions, and stay-at-home orders [2,3]. Limitations of large gatherings resulted in educational institution closures worldwide, necessitating rapid transition from face-to-face academic instruction to online delivery. The pandemic has impacted an estimated 280 million learners across 22 countries, affecting over 80% of the global student population [4]. As the pandemic spread globally, school closures began in March in the United States [5] and Cyprus [6,7], and April in Brazil [8]. To avoid disruption of education, institutions of higher education rapidly transitioned to virtual learning formats leaving educators with little choice or time to prepare.

The transition to remote learning posed additional challenges to health professions programs, including physical therapy (PT). Since PT is a profession that leverages hands-on skills [9], learner development of patient assessment and treatment skills requires a notable amount of training in a face-to-face setting [10–13]. An additional component of physical therapist education, like many health sciences curricula, includes an apprenticeship in the clinical environment. The concept of guided practice in the healthcare environment under the role of a mentor is one of the hallmarks of PT education. Classroom knowledge does not begin to make sense to the PT student until they apply their knowledge and skills in the clinical environment and the student engages with the community of practice [14]. However, because of the pandemic, PT students were forced to leave their classrooms and clinical sites due to limitations on non-essential personnel in healthcare facilities.

Before the pandemic, the delivery of PT education in the US was evolving to include online, blended, and hybrid learning experiences to minimize barriers to education. Deliberate curricular design, which leverages both online (synchronous and asynchronous) and face-to-face learning strategies to maximize learning in both environments, continues to gain traction in the health professions education, including PT [11–13,15]. However, despite the growing research, implementation of fully hybrid or blended PT programs that employ online instruction, followed by intensive onsite coaching in laboratory classes to solidify and assess motor skills, are still scarce within the US, and non-existent in Brazil and Cyprus. Unlike the deliberate development of a blended or hybrid curriculum in PT programs pre-pandemic, teaching during the pandemic required a quick pivot, in some cases within a matter of days, with little time for extensive faculty training in technology or online pedagogy. While the impact on students during the pandemic cannot be overstated [3,16–23], physical therapist faculty across the globe were challenged to convert traditional in-person curricula, heavy in psychomotor skill development, to entirely virtual models to keep students safe, socially distanced, and on track for graduation.

The pandemic provides a unique opportunity to explore the viability of virtual PT education and the associated burden incurred by physical therapist educators. To date, this experience has not been investigated. Therefore, the purpose of this phenomenological study was to explore the perceptions of physical therapist educators in Brazil, Cyprus, and the United States, new to online teaching, who transitioned their in-person curricula to entirely virtual models during the COVID-19 pandemic. We selected three countries, separated by thousands of miles, to investigate the barriers and facilitators to remote PT education in these countries but also to explore the shared experience of this phenomenon and how lessons learned from remote instruction might inform PT educators' future teaching practice.

Theoretical Frameworks

As described, the faculty in this study were new to online teaching. The COVID-19 pandemic forced institutions of higher education to consider, not whether quality education could be delivered virtually, but how to implement online teaching and learning in a short period of time. Even prior to the pandemic, natural disasters necessitated e-learning in many parts of the world. Dhawan [24] highlights that online learning was the future but that the pandemic accelerated the process. However, there is a difference between online learning that is implemented with time to orient educators to the pedagogy of online learning and the crisis e-learning, which was implemented by the faculty in this study. In describing the rapid shift to online learning during the pandemic, or crisis e-learning, Dhawan coins the term "*Panicgogy*" [24]. Despite being unfamiliar with online learning pedagogy, faculty may have put existing frameworks into practice. As such, two theoretical models situate this study. The first is the online community of inquiry (CoI), which uses the themes of social, cognitive, and teaching presence to maximize online learning [25]. Social presence establishes relationships between faculty and students and between students through effective and open communication. Cognitive presence explores, constructs, and confirms understanding through collaborative group work within a CoI. Teaching presence involves the design, facilitation, and direct instruction within the CoI to work towards learning objectives [26]. We sought to investigate which elements of a CoI faculty leveraged when they transitioned their curricula to a virtual platform.

The second theory, the cognitive apprenticeship model (CAM), addresses the challenge of providing effective and meaningful feedback through open communication and cohesion in an online classroom [27]. Cognitive apprenticeship involves the learner completing tasks in the authentic environment with the focus shifted on expert reasoning, which precedes and occurs during task completion [28–30]. The purpose of cognitive apprenticeship is to bridge the gap between knowledge taught in the classroom and the application of knowledge in the real world [28,30]. Cognitive apprenticeship is vital to facilitate PT students transferring classroom concepts to a dynamic and complex clinical environment. With the transition to online learning, physical therapist students were missing the opportunity for apprenticeship in the clinical environment. We sought to explore how PT faculty fostered cognitive apprenticeship in the virtual environment.

2. Materials and Methods

2.1. Study Design

Phenomenology is a careful examination of human experiences focused on how people make sense of their engagement in the world and life experiences. This qualitative inquiry method also focuses on making meaning of participants' experiences with a shared phenomenon [31,32], which in this case is a transition to online teaching. We used a comparative phenomenological design to investigate how physical therapist faculty from three countries perceived the transition to online learning during the pandemic, discover their perceived barriers and facilitators to delivering physical therapist education online, and explore how the transition to online learning may inform teaching practices moving forward once no longer mandatory.

2.2. Participants and Context

Three higher education institutions participated in this study: Institution A in the United States, Institution B in Brazil, and Institution C in Cyprus. Physical therapist education in all three institutions occurred primarily in-person before the pandemic. Institution A is a graduate school in the Northeast region of the United States, dedicated to the health sciences with entry-level and post-professional programs in PT, occupational therapy, physician assistant studies, speech-language pathology, nursing, and genetic counseling. At the time of this study, the PT program included 211 graduate students, supported by 22 core faculty members. A typical PT class in Institution A comprises 70 students. PT students in Institution A complete two years of didactic coursework followed by a year-long clinical internship.

The physiotherapist degree requirements in Institution B involve completing a five-year undergraduate program, including one year of clinical internship. Institution B, located in Northeastern Brazil, includes both undergraduate and graduate programs. The 21 undergraduate programs include those dedicated to the health sciences (medicine, physiotherapy, nursing, dentistry, biomedicine, psychology, and nutrition). At the time of the study, Institution B included 360 physiotherapy students supported by 34 faculty members. Class sizes average between 30–40 students.

In Cyprus, a physiotherapy degree requires a four-year bachelor's degree that includes health and field-specific coursework. Institution C, located in North Cyprus, offers both undergraduate and graduate programs. Undergraduate programs are taught by 11 faculty including those in the health sciences department. The Institute of Graduate Studies and Research at Institution C offers both Master's in Science and Doctor of Philosophy degrees. At the time of this study, Institution C included 328 students in the physiotherapy department supported by nine faculty. The average class comprises 80 students. Students complete theory-based courses during the first three years of study, followed by a year-long clinical internship.

2.3. Sampling

Researchers used purposeful sampling to recruit faculty from three major continents—North America, South America, and Europe, that were geographically distanced to make our results globally representative. Additionally, we identified institutions of higher education from the US, Brazil, and Cyprus where the physical therapy curricula were taught primarily in-person prior to the pandemic. The transition to virtual learning began between March and April in these countries and all three academic institutions had comparable infrastructure and resources. Faculty members who were full-time or part-time employees in the PT department, who had delivered at least one course online during the pandemic with a minimum of 24 h of synchronous online teaching over a twelve-week semester were asked to participate in virtual 1:1 interviews with researchers. The need to speak English was not an inclusion criterion as researchers in Institutions B and C conducted interviews with faculty in their first language of Portuguese or Turkish.

2.4. Ethical Approval

Institutional review board approval was obtained from each of the three participating institutions. All participants reviewed an information sheet and the interview protocol before participating in a 1:1 virtual interview. Participants were informed that researchers would deidentify all study data and report only aggregate data. The researchers specified criteria for stopping data collection to safeguard participant time, including when data saturation had occurred (no new codes or themes emerged from the data during concurrent thematic analysis).

2.5. Instrumentation

Researchers from all three institutions participated in designing the interview protocol. Interview questions were based on the protocol used by Oreshkina in a phenomenological study exploring teacher experience in three countries (South Africa, Russia, and the United States) [33]. The final semi-structured interview protocol included three consent questions, six open-ended questions, and seven demographic questions (Appendix A). The brevity of the interview protocol helped to keep the focus on the participants' experience of the phenomenon under study (transitioning to online teaching during the pandemic) [34]. As the interviews were conducted by different researchers with participants in three countries, researchers also specified common follow-up questions and prompts. Once finalized, the interview protocol was translated to Portuguese and Turkish by researchers for use at Institutions B and C.

2.6. Data Collection and Analysis

To minimize coercion between the researchers and fellow faculty members, program staff at each institution distributed recruitment materials via email to faculty. Due to a larger local sample (n = 8) who consented into the study at Institution A, two faculty from that institution conducted 1:1 interviews with those participants. One faculty from Institution B and one faculty from Institution C interviewed faculty from their institutions. Virtual interviews, each lasting a maximum of 45 min, were conducted during October and November 2020 using Zoom (Institution A), Google Meet (Institution B), or Microsoft Teams (Institution C). Interviews were audio-recorded and transcribed. The four researchers shared their field notes and transcripts to allow for concurrent data analysis. Data analysis concurrent with data collection allowed for correcting blind spots throughout the study period and to ensure that sample and variable saturation was approached by the time the last interview was conducted [35].

Each researcher who conducted the interview reviewed the interview transcript for accuracy. Transcripts from Institutions B and C were translated into English before thematic analysis commenced. Transcripts and field notes were subjected to the six-step process for thematic analysis by two researchers using NVivo Software, QSR International Pty Ltd. The six steps include: (1) familiarizing themselves with the data, (2) generating initial codes, (3) searching for themes, (4) reviewing themes, (5) defining and naming themes, and (6) producing the report [36]. During step 1, each researcher read the data multiple times for initial ideas. During Step 2, the researcher completed first cycle coding [35]. The researchers relied on a descriptive coding process and summarized data chunks into words or short phrases (see Table 1 for examples of codes). The researchers used an inductive coding approach due to the lack of research into the area of virtual physical therapy education during the pandemic. During step 3, the researchers met to review and compare the codes generated and agree on the final codes and operational definitions. The researchers reached 85% agreement on codes which is within the acceptable range of agreement [35]. The researchers jointly completed second cycle coding at this stage. During second cycle coding, the codes were grouped together into smaller categories (themes) and assigned names (see Table 1). All four researchers who completed the interviews completed step six. Step six included identifying compelling quotes from participants across contexts.

Table 1. Themes and supporting codes.

Theme	Codes	Description of Code	Code Supported by Data from Institution A, B, or C
Adapting Pedagogy in Real-Time	Steep learning curve	Orienting to new technology and pedagogy in an abbreviated period	Institution A, B, and C
	Multiple moving parts	Teaching online involved instruction, monitoring technology, and the student experience resulting in divided attention (for both faculty and students)	Institution A and C
	Overwhelmed	Adapting curricula and pedagogy while stressed about the pandemic	Institution A, B and C
	Innovation	Both faculty and students had to be creative to teach and learn psychomotor and patient care skills online	Institution A, B, and C
	Resources	Faculty relied on instructional designers/pedagogical support centers, information technology support, and external support	Institution A, B, and C
	Collaboration	Teamwork and support from fellow faculty seen as the greatest resource	Institution A, B, and C
Expected Excellence	High standards	Faculty used to being experts were now novices in teaching online	Institution A
	Expectations	Faculty were managing expectations from leadership and students	Institution A and B
	Psychosocial stressors	Workload, lack of rest, concern for student wellbeing	Institution A and B
	Caring	Invested in the educational experience/product. Motivated to keep students on track to graduate	Institution A, B, and C
Limitations of the Medium	Teaching psychomotor skills online	Hands-on nature of PT education in the virtual space resulted in missing subtleties and a lack of control	Institution A, B, and C
	Missing connection	Faculty felt disconnected from fellow faculty, from students, and felt that students missed opportunities for peer learning	Institution A, B, and C
	Lack of teaching feedback	Missing the in-the-moment feedback from students to inform the teaching process	Institution A
	Assessing understanding	Faculty questioned whether students were understanding content delivered, "Did they get it?"	Institution A, B, and C

Table 1. *Cont.*

Theme	Codes	Description of Code	Code Supported by Data from Institution A, B, or C
	Low student engagement	Students not engaging with material, faculty concern about knowledge retention	Institution A, B, and C
Informing Future Teaching Practice	Flexibility of online teaching and learning	Students benefited from learning at their own pace and taking time to process	Institution A and C
	Unique opportunities	Introducing students to telehealth, use of the 1:1 coaching model for feedback	Institution A and B
	Establishing different types of connection	Online learning broke down barriers and the power differential between students and faculty	Institution A, B, and C
	Gratitude	Faculty were grateful to be have been able to retain their jobs	Institution B
	Grit	Faculty gained insight into their resilience when faced with adversity	Institution A and B

2.7. Trustworthiness

Several methods, including member checking, triangulation, thick descriptions, peer reviews, and external audits, are available to work toward validity in qualitative inquiry [37]. In this study, researchers leveraged two forms of triangulation: data triangulation and researcher triangulation, as well as peer review and thick descriptions to increase trustworthiness. Data triangulation included analyzing interview transcripts and field notes from four researchers. Researcher triangulation leveraged data analysis performed by two of the researchers with experience in qualitative research. Secondly, researchers from all three countries reviewed the codes and themes for accuracy. Researchers also ensured that the results represented the data set by selecting quotes from participants across the three institutions. Finally, as the researchers adopted a constructivist paradigm during thematic data analysis, thick, rich descriptions were used to work towards credibility in this analysis [38,39].

3. Results

Sixteen faculty members participated in 1:1 interviews with researchers: eight in the US, five in Brazil, and three in Cyprus. All faculty members were licensed physical therapists in their country who had, on average, eight years of experience as educators (range = 1.5–18 years). Only one participant reported experience teaching online before the COVID-19 pandemic, and ten faculty (62.5%) reported having experience as students in the online learning environment. Researchers identified the following themes following thematic analysis of interview data: adapting pedagogy in real-time, expected excellence, limitations of the medium, and informing future teaching practice.

There were a few instances where a phenomenon was only experienced by faculty at one of the institutions. Participants in Institution A described the high standards set in their context and the discomfort associated with feeling like novices in the online teaching arena (see Table 1). The phenomenon was not noted at the other two institutions. Similarly, every participant from Institution B reported being grateful that they were able to retain their jobs while many in the country faced unemployment, an experience unique to the context of Institution B. However, ultimately, there were more similarities than differences during the phenomenon under study (as evidenced by Table 1). Each theme is discussed further next.

3.1. Theme 1: Adapting Pedagogy in Real-Time

With little time to adapt, participants described a steep learning curve associated with converting classes, designed to be delivered in-person, to a fully online format. In some instances, faculty had as little as ten days' notice (in Institutions A and C) before country-wide social distancing measures were put in place and teaching transitioned to fully remote. One participant in Institution A described the transition as a whirlwind, another as: "*trying to fly the plane while writing the manual at the same time.*" Needing to master multiple pieces of new technology was described by some as anxiety-provoking, and faculty relied on a variety of technology with preference for medium varying by country.

While participants were aware of the challenges facing all educators teaching virtually, they highlighted the uniqueness of PT curricula, which involve teaching a significant amount of psychomotor skills. Converting content that was typically delivered in-person required innovation and creativity from faculty and students. Additionally, students in all three countries were residing in different time zones, sometimes socially distancing alone, in varying home situations. To overcome the challenges of teaching psychomotor skills online, participants in Institution A described using video resources to demonstrate a skill followed by having students practice the skills on family members or roommates. Students would then film themselves to receive 1:1 feedback from faculty. Students who were social distancing alone also demonstrated creativity with finding solutions to practice and demonstrate their skills:

> *Some of the more memorable ones were watching students using stuffed animals to be their patients, or in one instance, using their pet dog to do elbow and wrist range of motion, and it was incredibly creative and sweet and probably much better than not having a model at all. (Participant, Institution A)*

Participants used a host of technological resources and games to foster student engagement. One participant in Institution A described mocking up their home to allow students the opportunity to practice an in-home evaluation with a patient. Performing patient telehealth visits with students required authorization from the physiotherapy council in some countries. However, once approved, participants described the student and patient interaction as incredibly rewarding. Here a participant describes a patient's reaction to the students' efforts to provide treatment virtually:

> *She was talking about her functional limitations during her daily activities when she stopped to thank our group for the effort we were all making to see and talk to the patients and try to provide them with some sort of treatment. My students cried, and that made me realize that as hard as this pandemic can be, we can do something to help others. (Participant, Institution B)*

Transitioning to virtual instruction was also resource-intensive. Whether participants referred to instructional designers in the U.S. or pedagogical support centers in Brazil, the support of those with expertise in designing teaching and learning experiences was vital. Participants attended workshops and sought technological support and external resources. In the U.S., participants relied on faculty familiar with teaching online in hybrid PT programs. However, in all three countries, the most valuable resource was ultimately the collaboration and teamwork among the faculty at each institution. One participant from Institution B described, "*Teaching through this pandemic has been the hardest thing that I had to go through in my life, professionally, but it can be done efficiently if we work together as a group, learning with each other.*" Another participant in Institution A concurred, "*I found faculty's experience actually was probably the best part of the collaboration, the most useful collaborative resource. People who had the experience and were able to give us tips. What worked, what didn't work.*"

3.2. Theme 2: Expected Excellence

Participants in all three contexts stressed the exorbitant amount of time required to adapt their pedagogy in real-time and orient the rest of the teaching team. While participants felt supported by their institutions, some noted leaderships' lack of understanding about the amount of effort it would take to convert PT curricula to an online format in a short amount of time. Preparation time increased significantly. In the U.S, participants described that laboratory instructors, usually charged with guiding student mastery of psychomotor skills in-person, were now serving as facilitators in the online environment. Both laboratory instructors and students were unfamiliar with the technological tools being employed. Students needed additional guidance on how to access materials and submit assignments on new platforms. A participant from Institution C described, "*It was a difficult process for us to get used to the system, for students to get used to the system, and to change the ways of education methods to remote instruction.*"

Faculty participants in all three countries described being conscious of multiple moving parts when delivering education in the virtual environment. As they shared their computer screen, taught their content, fielded questions from students, and attempted to monitor student engagement and use breakout room functions proficiently, participants were also assisting students with technological challenges. Teaching, already so nuanced, took on a new layer of complexity. A participant from Institution A recalled:

> *It was certainly stressful because, at any moment, Zoom could go off, a student could be disconnected, they would be stressed because they felt they missed important material. So you're trying to get back into Zoom, fielding texts because they're out of Zoom, but you're still trying to teach the content at the same time. There were just so many moving parts happening at the same that it was really stressful and fatiguing.*

Participants described being invested in the student educational experience and wanting to keep students on track to graduate. Faculty also cared about the educational product that they were creating. Some participants questioned whether they had tried to accomplish too much in a short period but were used to setting high standards for themselves. At times, participants working 14- and 16-h days questioned whether they were working from home or living at work. Some participants described the experience as demoralizing. They felt that they were investing a significant amount of time into creating an educational product that could be perceived as inferior. Participants, accustomed to serving as high-functioning classroom authorities, now felt pressure to advance their novice skills as online educators to expert levels in a short period. When participants observed role models who appeared to be functioning at a high level, they wondered about the costs. They described the experience as overwhelming, challenging, and exhausting:

> *Faced with this gigantic task and I have no clue how I'm going to do it and knowing that it's not an area that I'm comfortable in, the technology part of it . . . exhaustion was probably the biggest emotion. I was too tired to cry. (Participant, Institution A)*

While there was pressure to maintain high institutional and personal standards, the real driver was that participants cared about the student experience and expectations and were thinking about the ultimate stakeholder in this situation: the students' future patients:

> *You know, it's such a hard thing because I feel like no matter what mode we are in during this sort of pandemic, I think the psychological costs are high because you realize that things are different. We care a great deal about our students, them as humans but also knowing that they get what they need and deserve for the time they're putting into this and ultimately caring for others. (Participant, Institution A)*

3.3. Theme 3: Limitations of the Medium

The majority of participants, regardless of country, remarked on the challenge of low student engagement in the online environment. However, participants were acutely aware that students were stressed about the pandemic's uncertainty and unknown timelines. Students were understandably anxious to return to campus for in-person learning. Participants were also aware of the added pressures that students were facing. Participants in Brazil worried that students would not be able to afford to complete their programs with parents facing unemployment due to the pandemic. Even students who were able to remain enrolled were frequently dealing with a lack of access to technology or poor internet connections. Every participant reported being concerned about the effects of low student engagement and worried about students understanding and retaining the course materials. One participant from Institution C remarked, "*While teaching online, I constantly questioned whether they understood the lesson. I think my questioning was about ten times more than the class situation.*"

Participants described using no- and low-stakes assessment techniques much more frequently to overcome the barrier of low student engagement and held regular virtual open office hours. However, in this, they perceived an added limitation of the medium. Whereas students tended to gather around professors before and after class to talk in-person, seek clarification, and ask questions of an organic nature, participants noted that students only attended virtual office hours if they had a specific problem. They described that the organic discussions, common in the classroom or during informal meetings in offices and hallways, failed to materialize. Ultimately, this element of missing connection was perceived as the most significant limitation to teaching and learning in the virtual classroom.

All participants described that they missed the in-person connection with students. They noted a social awkwardness to the virtual platform where everyone except the speaker was muted. Additionally, privacy and student video-sharing issues added to the complexity of establishing a connection in the online environment. Participants felt that students should not feel compelled to share their videos and were conscious that some students did not feel comfortable sharing their home environment. One participant remarked:

> *Sure, the students tend to be more shy in virtual classes, and I think it's because they are in their home environment. So, they don't talk much and even turn off their cameras so that they don't have to show their background, their home, and how they live. (Participant, Institution B)*

However, participants emphasized that teaching requires real-time feedback or reactions from students to assess understanding and inform the teaching process. They described it as challenging to teach to multiple muted, black screens. Participants described asking questions, telling jokes, and hearing "crickets":

> *I think the feel of the classroom, the general vibe of how your students are doing, and what you're able to ascertain just by being in the same room with them . . . gives you the opportunity to adjust how you're teaching or maybe what you're going to go to next, how you're going to set up a lesson, and that seems very hard to do in the virtual environment. There's much less of that feeling you get from your students. (Participant, Institution A)*

Participants also noted that students had limited opportunities to connect with classmates thus missing opportunities for peer learning. To attempt to minimize this limitation, participants leveraged small group activities and virtual breakout rooms with facilitators when possible. However, virtual breakout rooms meant that faculty could not gauge the temperature of the room during small group activities and remarked that virtual teaching had an unfamiliar rhythm and pacing to which they had to acclimate. Finally, participants also missed their connection with their fellow faculty. While participants relied on innovation and creativity to teach psychomotor and patient care skills virtually, they remarked that PT curricula were ultimately not meant to be taught entirely online. Participants remarked that they were challenged to fit their content to the medium instead of the other way around. One participant from Institution A mentioned: "*For some reason, being on zoom encouraged us to want to lecture, and I think that was not what the students needed. It tired them out tremendously.*" Participants felt that they were limited in their ability to introduce different patient care scenarios so that students would have to reason in the moment and make decisions about how to proceed with patient care and put psychomotor skills to use. Another participant from Institution A remarked, "*It was very limited what we could ask them to do, so we really couldn't introduce those higher-level skills.*"

3.4. Theme 4: Informing Future Teaching Practice

Participants remarked on the flexibility that online teaching and learning afforded both students and educators when asked what lessons they might carry forward once they returned to in-person teaching. They described the benefit of students having time to learn and process foundational concepts before coming to class to apply and practice content: "*They actually had time to process some of the cognitive information and sort of let it sit for a little bit and then perhaps their practice was more meaningful and at a higher level*" (Participant Institution A). Another participant concluded:

> *I never thought that this method would be suitable for physiotherapy education. I was thinking that online education may be appropriate for some courses in other departments, but not for physiotherapy. But for now, with the support of resources that our university provided us, I believe that this method can be used for some lectures in our profession as well. Now we are doing "hybrid" education ... We have very positive feedback from students. (Participant, Institution C)*

There were unique opportunities for learning with the use of video technology and online coaching models. Participants gained an appreciation for the importance of allowing students to learn about and practice telehealth skills. While there was still the emphasis on missed connection when using virtual platforms, participants noted that they were able to make different types of authentic connections with students. Teaching and learning in their respective home environments, participants described having opportunities to interact with students' families, and students got to see their faculty's family members. Despite the physical separation, participants described feeling closer to students. In some ways, the virtual learning platform helped to decrease the power differential between students and their professors, as articulated here:

> *In the middle of the class, one of my kids, the youngest one, came inside my office asking for food, and the oldest came right after yelling at him because he was disturbing me. I hugged them both and calmed them down, excused [myself] for one second while I gave him some food and took them both to the living room. When I came back to class, the students were all smiling and said that they were touched by my kindness and calm [demeanor] with my kids. This was especially nice because my relationship with these students was very cold from the beginning, and all of a sudden, it changed after this. We became much closer, and they started to show up more for the classes. (Participant, Institution B)*

Another participant mentioned:

> *Being engaged all day made students share all their daily life activities and special occasions on the [online] platform. I had a student who wanted to celebrate her birthday after the lecture ended, which was a memorable experience for me ... She said that she is away from friends and wanted everybody to write some [messages] for her. (Participant, Institution C)*

The final aspect of lessons learned from virtual instruction during the pandemic included gratitude for job security and an insight into their resilience and grit. Participants in Brazil described being relieved that they were able to retain their jobs while many in the country were facing unemployment. However, despite feelings of gratitude, all participants described teaching during the pandemic as the greatest challenge of their professional career and some had considered retiring from teaching. However, realizing the need for a well-prepared future generation of physical therapists and their roles as educators, they were motivated to persevere:

> *I learned that we have to be resilient. This process has been very difficult on everybody's lives, and we have to deal with these difficulties in order to keep going. I thought of giving up and retiring from teaching, but I saw everyone in the same situation and thought to myself that I could not give up. My reason for teaching is the pleasure that I have of seeing so many new good professional PTs, so I decided that no matter what happened, I had to continue. (Participant, Institution B)*

4. Discussion

In March 2020, the COVID-19 pandemic necessitated global safety measures of social and physical distancing and stay-at-home orders [2]. There was a sudden pause in the work and life routine as we knew it. This was by far the most significant shift of the workforce to a remote work environment, affecting businesses and industries across the world. Faculty in physical therapist education programs found themselves needing to rapidly adopt new pedagogical models. Despite the faculty workload and new technology skills required for this transition to online learning, research in higher education during the pandemic has focused primarily on the student experience [17,19,20,22,23] and the effectiveness of virtual formats for student learning [16,18,21]. Faculty experience has been less thoroughly investigated [40–42]. This study describes the experiences of an international group of physical therapist faculty whose work-life shifted significantly during this global crisis. To our knowledge, this is the first study exploring the perceptions of physical therapist educators about the online transition. Notably, we observed more similarities than differences in the experiences of barriers and facilitators among this international group of faculty participants.

Preserving high-impact educational practices such as experiential learning [43] was particularly challenging with a transition to fully remote learning. Many educational activities, including service-learning projects, clinical education experiences, and internships, needed to be postponed. In all three countries, physical therapist faculty described several challenges with this sudden, unanticipated transition including steep learning curves and significantly increased workloads associated with meeting student needs. Changes from onsite to remote teaching could not occur without substantial changes to delivery methods, content, and learning assessments, thereby mandating more time and effort be allocated to preparing for teaching [12,44]. These substantial changes at such an accelerated pace came at a psychological cost to faculty who set high standards for themselves and were heavily invested in producing a quality educational product for their students. Faculty described virtual teaching as “living at work,” often putting in 14–16-h days to design new learning activities and assessments and provide additional time dedicated to student support.

The community of inquiry theory identifies the importance of social, cognitive, and teaching presence for successful online learning [25,26]. Faculty described challenges to all three of these critical components of online learning. Social presence is the ability of participants to project themselves socially and emotionally as ‘real’ people through the medium being used, engaging in open communication and developing interpersonal relationships [25]. Faculty described struggles with creating social presence as students joined class sessions from home, sometimes uncomfortable sharing their screens and thus their home environments. While faculty appreciated and respected students’ need for privacy, they reported challenges connecting with students who chose to keep their cameras off. Mood and tone, traditional indicators of presence and engagement, were lacking within the virtual environment where only the speaker was unmuted. These findings were consistent with a previous study of faculty in the Philippines teaching online during the pandemic who reported ambivalence with online education due to feelings of depersonalized education [40].

With students joining class from their homes which were often in different time zones, supporting relationship-building was imperative. Although faculty leveraged virtual breakout rooms for small group discussions to promote personalized education, this strategy required additional laboratory instructor training in pedagogy and technology. Faculty employed humor, ice breakers, and low stakes assessments to increase engagement and build group cohesion, thereby establishing a safe learning environment. Students’ self-recorded skills practice using family members to play patient roles helped break down barriers and engage family, roommates, and pets in ways that increased faculty understanding of student contexts and home life. In turn, faculty teaching from their homes exhibited increased vulnerability and diminished power differentials as their homes and families were also on display. Despite physical distance, the pandemic, in some ways, brought students and faculty closer together.

Teaching presence refers to the organizational structure, the design, facilitation, and direction of cognitive and social processes to realize personally meaningful and educationally worthwhile learning outcomes [45]. Teaching presence depends on the instructor's ability to communicate goals and learning activities, motivate and engage the student and provide timely feedback [45]. Like previous research on online teaching presence [46], this study revealed a rapidly evolving organizational structure, learning activities, and teaching and assessment strategies. Faculty leveraged new virtual platforms and devised new active methods of teaching and assessment, including low stakes assessments on quiz applications, case scenarios, and group discussions.

As faculty were embracing new instructional platforms, they were also seeking resources at their workplaces. Unlike faculty dealing with limited access to technology [3] and reliable internet services [40], faculty in this study did not report challenges with infrastructure, although they had concerns about student internet connectivity. Without the technological tools that made remote instruction possible, higher education would have been significantly disrupted in the face of the pandemic [44]. However, rapid adoption of new technology came at a cost of stress, time, and feelings of inadequacy. Faculty were accustomed to being perceived as high functioning classroom educators. Indicators of course quality such as student satisfaction are heavily influenced by the extent to which educators are prepared to teach in the online learning environment [47]. Faculty across the three countries embraced resources and learning opportunities from the teaching and learning centers, librarians, and information technology services in their institutions. Faculty created high expectations for themselves to deliver an educational product equivalent to their classroom instruction, and some questioned if they expected too much of themselves in an unprecedented time. Despite the exhaustion, anxiety, and challenges, upon reflection, faculty were proud of their grit and resilience. Faculty reported overcoming many barriers to educating via a virtual platform and cited collaboration with fellow faculty as their primary resource for success.

Cognitive presence is the extent to which learners can construct and confirm meaning through sustained reflection and discourse in a community of inquiry [45]. Cognitive presence relates to the ability to obtain meaning through discussion and interaction with the community. Faculty built a cognitive teaching presence by developing new learning activities that could help students develop their knowledge and skills in a virtual medium [45]. Development of videos to demonstrate psychomotor and communication skills replaced in-person demonstrations. Increased virtual office hours were implemented to allow further co-construction of knowledge and replace organic conversations less likely to occur in the virtual medium. More frequent ungraded homework and pausing and questioning throughout the class were thoughtfully added to build depth and breadth of content delivered asynchronously. We noted that despite not having formal training in the community of inquiry framework, faculty from all three countries leveraged social, cognitive, and teaching presence.

The cognitive apprenticeship model (CAM) focuses on completing tasks in an authentic environment with modeling of expert reasoning and meaningful feedback as tasks are completed. The CAM focuses on using modeling, scaffolding, and coaching to help students integrate cognitive and metacognitive practices, along with articulation and reflection to promote problem-solving [27]. Modeling includes student learning through observation of experts. In the online environment, this may be achieved through videos that mimic real-life situations and role-modeling based on observing peers. Scaffolding entails supporting students in task execution through instructional, sequential modules, course rubrics, online discussions, and private communication. Coaching serves as a method to monitor student progress and activities, with support provided as needed. The instructor leverages videos, screencasts, and emails to interact and provide feedback [27]. Faculty in this study described using virtual patient experiences and virtual simulation to help students develop critical thinking skills and make connections to practice. Faculty used their home environments to create a meaningful context and facilitate conversation rather than lecture. Educators in some countries reported needing approval for telehealth from PT governing bodies. However, once approved, faculty leveraged telehealth and virtual patient interactions and panels. Students interacting with patients in their homes and understanding patient context provided meaning and application of classroom learning when clinical experiences were limited due to the pandemic.

The pandemic provided a unique opportunity to practice alternate models of delivering physical therapist education. The physical therapist educators in this study acknowledged new ways of teaching online that they plan to bring forward to their onsite teaching, such as flipped classrooms, low stakes assessments, video practice of psychomotor skills, virtual simulation, and telehealth to access more diverse patient populations. However, although participants felt there are foundational and didactic aspects of PT curricula that may be suited to the online environment, ultimately, they described that the hands-on and communication skills unique to PT curricula are best practiced in an in-person environment.

Limitations

The authors recognize the limitations of the study. Sampling from institutions in three countries potentially limits the transferability of the results to the countries studied; however, we attempted to increase trustworthiness by using multiple cases in each context. Although 3–8 faculty members from each academic program also limits transferability, we found reemerging themes in the interviews and approached data saturation. While there was a greater representation of U.S faculty than faculty from Cyprus and Brazil, re-emerging themes were identified in data from those institutions also despite smaller samples. Two researchers from the study team completed independent coding and then reached intercoder agreement on codes and themes. While both researchers were from one institution in the U.S., researchers from Brazil and Cyprus agreed that the codes and themes developed represented the data gathered from their institutions. Future research may benefit from external auditor(s) given the researchers' roles in the academic programs. An additional limitation is that interviews from Cyprus and Brazil were translated into English by the researchers. Although a formal forward and backward translation process was not utilized for the translation of transcripts to English, both translators from Cyprus and Brazil were fluent in both languages, and care was taken to ensure that meaning was preserved in the translated transcripts.

5. Conclusions

Physical therapist faculty from three international PT programs describe teaching during the COVID-19 pandemic as one of the most challenging experiences of their professional careers. Despite this, faculty innovated and developed meaningful learning experiences for their students creating social, cognitive, and teaching presence. The virtual medium created challenges to student engagement and assessment of student understanding of content, and faculty found themselves working longer and harder to make authentic connections with students to ensure that understanding was achieved. Collaboration with faculty peers sharing this experience was perceived as the greatest facilitator of success. Ultimately, faculty persevered during a trying time due to the joy of contributing to the development of new health professionals. As institutions of higher education reopen for in-person learning [48], faculty have learned alternative approaches to delivering content that will enhance teaching practice in the future regardless of the context. Future research will explore the physical therapist student experience with online learning.

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Appendix A

1. Tell me what it is like to be a physical therapy educator in (Cyprus, United States) using remote instruction to teach physical therapist students online during the COVID-19 pandemic?
2. What resources were available to you to facilitate the transition to remote instruction?
3. What stories can you share about the experience that were particularly memorable?
4. Tell me some stories about how you navigated this challenge. Follow up questions:
    a. You said it was a challenge to . . . Can you say more about this challenge?
    b. You said that you had difficulty with . . . Can you elaborate?
5. What type of assessment methods did you use to evaluate students during the period of remote instruction?
6. Are there lessons learned from remote instruction that will inform your teaching practice moving forward when you return to the classroom?
7. Do you have anything else to share about teaching online during the COVID-19 pandemic?

We are almost done with this interview. I am going to ask a few additional questions about you and your institution.

8. How many years have you been an educator?
9. Did you have experience with online learning or instruction prior to the COVID19 pandemic?
    a. Follow up question: Can you tell me more about your experience with online learning/instruction?
10. On average, how many physical therapist students are in your class?
11. What year of study are the students in (that you teach)?
12. Describe a typical semester including what a typical day looked like prior to the COVID-19 pandemic
13. What faculty supports are typically available on campus to help with teaching (prior to COVID19)?
14. In what ways did your Institution support you during the transition to remote instruction?

Probing questions during the interview

- Could you say something more about . . . ?
- Can you give a more detailed description of . . . ?
- Can you think of times when . . . ?
- Do you remember a time when you noticed . . . .

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education sciences

Article

Online Education and the COVID-19 Outbreak: A Case Study of Online Teaching during Lockdown

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Abstract: The COVID-19 pandemic has become a critical challenge for the higher education sector. Exploring the capacity of this sector to adapt in the state of uncertainty has become more significant than ever. In this paper, we critically reflect on our experience of teaching urban design research methods online during the early COVID-19 lockdown in the UK. This is an exploratory case study with a qualitative approach with an aim to inform resilient practices of teaching in the face of public health emergencies. Drawing on the experience of teaching the Research Methods and Techniques subject during lockdown, we discuss the rapid transition from face-to-face to online teaching and point to the challenges and opportunities in relation to the learning and teaching activities, assessment and feedback, and digital platforms. This paper concludes by outlining some key considerations to inform the development of more adaptive and resilient approaches to online teaching in the context of unprecedented global health crises such as the COVID-19 pandemic. We argue that it is critical to move beyond fixed pedagogical frameworks to harness the productive capacities of adaptive teaching.

Keywords: online teaching; urban design; higher education; pandemic; COVID-19; public health; technology; EdTech; research methods

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1. Introduction

The COVID-19 pandemic has become a critical challenge across many sectors, including higher education. Exploring the capacity of the higher education sector to adapt in the state of uncertainty and manage the emerging situations associated with the pressing challenge of the coronavirus outbreak and subsequent lockdowns has become more critical than ever. There is an emerging body of knowledge exploring the impacts of the COVID-19 pandemic on higher education [1–8]. Many universities across different countries have experienced an unprecedented transition from face-to-face to various forms of online education and remote learning amid the COVID-19 outbreak and subsequent lockdowns as discussed in case studies in China [9], India [10], Bulgaria [11], Pakistan [12], and Germany [13], among others. Reflecting on the early experiences of managing the conditions of uncertainty and emergency can pave the way for developing more nuanced approaches to learning, teaching, and assessment (LTA), and for enhancing the resilience of the higher education sector in the face of public health crises.

In this paper, we focus on a case study of teaching urban design research methods right in the middle of the early COVID-19 outbreak in the UK (March 2020) by drawing on the experience of teaching the Research Methods and Techniques (RMT) subject during lockdown. RMT is an intensive subject in the MA Urban Design (MA UD) programme at Cardiff University. The MA UD students take this subject before dissertation. While the RMT subject used to be delivered mostly face-to-face, it has been inevitably and rapidly adapted for online mode of delivery during the early lockdown period. This rapid transition from face-to-face to online teaching delivery is further discussed in this paper with the aim to outline some key considerations for online education in the face of unprecedented public health emergencies. We argue that it is critical to move towards diversifying online teaching practices and developing adaptive approaches to sustain effective forms of online education and remote learning, particularly in response to unprecedented global challenges such as the COVID-19 pandemic.

This is an exploratory case study with a qualitative approach. The research questions that we seek to address are: How did the rapid transition from face-to-face to online teaching play out in the RMT subject delivery during the early COVID-19 lockdown in the UK? What were the key adaptations in this process? What were the challenges and opportunities associated with online mode of teaching delivery? How can learning from these rapid changes and adaptations during the early COVID-19 lockdown inform post-COVID-19 educational practices as well as measures to be taken in higher education against potential public health crises in the future? Following a concise review of relevant literature on online education and teaching during the COVID-19 pandemic, we discuss methods and case study analysis with a particular focus on the ways in which teaching urban design research methods played out during the early COVID-19 outbreak and the subsequent lockdown in the UK. The paper concludes by outlining some key considerations including primary challenges and opportunities to inform the development of more resilient and adaptive teaching frameworks in response to public health emergencies.

2. Online Education and Teaching during the COVID-19 Pandemic

2.1. Higher Education and Online Mode of Delivery

There is an evolving body of knowledge exploring the capacities and challenges of online education [14–18]. The constant and rapid evolution of information and communication technology has undoubtedly had profound impacts on the academic discourse and everyday practices of research, scholarship, and teaching. The use of up-to-date online technologies and the process of continuously evaluating them have also become integral to students' changing demands, particularly within their online educational contexts [19]. A substantial change has been "the speed and power of communications technology and the expanded capacity to send, receive, and use information" [20] (p. 57) along with the increased capacity to bridge time and space for educational purposes and goals [21]. As Prensky [22] (p. 1) puts it, "our students have changed radically. Today's students are no longer the people our educational system was designed to teach". Prensky views today's students as "digital natives" and their less digitally competent educators as "digital immigrants". It is important to note that digital natives have not only acquired a set of skills in using up-to-date technologies but also have developed new learning skills and styles using them. The induced learning styles may include "fluency in multiple media"; "learning based on collectively seeking, sieving, and synthesizing experiences"; "active learning based on experience"; "expression through non-linear, associational webs of representations rather than linear stories"; and "co-design of learning experiences personalized to individual needs and preferences" [23] (p. 10).

With the proliferation of online teaching in higher education, there is an increased need to discuss the challenges associated with this mode of delivery for both instructors and students alongside the related capacities. It has been argued that students taking online courses are less likely to participate in collaborative learning activities, discussions with others, and student–faculty interactions, compared to their counterparts in face-to-face settings [14]. For Norton et al. [24], developing core professional qualities, including communication, interpersonal and practical skills among students, and sustaining student retention rates, along with training and support to effectively use online technologies and address technical issues and cyber security risks, are seen as major challenges for online education. Shuey [25] discusses challenges faced by instructors in higher education when adapting certain activities (e.g., continuous assessment and performance assessment) to the online setting without losing content knowledge or interactions between peers and/or instructors.

Despite the recent surge of interest in the introduction of research-based principles and instructional models for effective online teaching and learning [18,26], the remaining challenge to address "is not whether online courses will replace classrooms, but whether technology will drive the redesign of teaching and learning" [24] (p. 1). Public discourse on online education often makes a clear distinction between online and on-campus study, both of which are subject to change as a result of online technology. What matters is how emerging technology can be utilised to support teaching and learning activities regardless of the medium of delivery. Johnson et al. [27] (p. 9) highlight that "simply capitalising on new technology is not enough; the new models must use these tools and services to engage students on a deeper level." This accords with Hattie's [28] argument that effective teaching and learning strategies in higher education involve giving primacy to pedagogy over technology. To explore the potential benefits of learning with technology, it is also helpful to understand what technology this form of learning encompasses. As discussed by Norton et al. [24] (p. 21), such technologies vary between recorded lectures uploaded online and interactive digital subjects with adaptive learning platforms, in-built assessment, virtual simulations, and the like.

Online learning can act as a complementary approach to face-to-face training. This focuses attention on today's blended learning approaches, which typically include online lectures, discussions, forums, and interactive software with the capacity to connect students for synchronous learning activities. In other words, blended learning approaches and designs are among the most favoured course delivery models in higher education [29], typified by the "integration of thoroughly selected and complementary face-to-face and online approaches and technologies" most effective for meeting the learning outcomes of a course [30] (p. 148). A multifaceted approach is then required to enable effective blended teaching and learning [31]. The question here is to explore whether students favour blended learning design or other fully face-to-face or online options as their preference for course delivery models.

Technology inevitably will have impacts on students' choices between higher education providers. It is likely that competition will be most apparent between online universities and on-campus universities where the desire to blend technology and in-class teaching will be peaked [24]. This continues to have significant impacts on reimagining the future of universities and the academic community despite the widely held critique of higher education's digital transformation in the wake of rapid technological innovation and labour market transformation [32–34]. According to the findings from the ECAR Study of Undergraduate Students and Information Technology 2019, about 70% of students favour mostly or completely face-to-face learning environments [35]. This suggests that students continue to have a stronger preference for some forms of blended learning environments; they see in-class lectures as an opportunity to engage with teaching staff, peers, and course content, and they see technology as useful means to enable such engagement. The increased flexibility, integration of sophisticated multimedia, and ease of access have been among the most acknowledged advantages [29] (p. 12). While online tools and their effective application have been reported as increasingly useful to students' learning experiences, accessibility to stable internet connection is almost limited due to the low rate of Wi-Fi reliability in dormitories/campus housing and outdoor areas. The preferences (e.g., learning environments, technology experiences, and use in the classroom) might be considerably influenced by the changing landscape of the student demographics [35]. The 2019 EDUCAUSE Horizon Report cites the significant challenges that are more likely to impede technology adoption as "improving digital fluency", "increasing demand for digital learning experience and instructional design expertise", "the evolving roles of faculty with ed tech strategies", "advancing digital equity", and "rethinking the practice of teaching"—out of which, the first two are the most solvable [29] (pp. 13–19). Therefore, one can argue that rather than considering this report as the end of the discussion about the use of technology in students' learning experiences, it is important to pose the question of how the meaning and use of these findings might change in the face of COVID-19 and emergency remote LTA.

2.2. COVID-19 and Online Teaching

The emergence and unprecedented spread of the COVID-19 as a global pandemic has been posing substantial challenges to the practices of everyday life. There has been a surge of interest to explore the dynamics of online education across different contexts amid the COVID-19 pandemic [36–40]. Many higher education institutions, particularly in the context of the global North, have inevitably made some urgent adjustments to LTA designs while coping with profound social suffering and significant economic hardship. To remain competitive within the emerging market conditions and to be adaptive to uncertainties and changing situations, academics as frontline providers of higher education did not cease all their programme deliveries although some LTA activities such as national and international field site visits and certain forms of assessment were suspended or adapted. The immediate impact of the outbreak left many higher educators with limited choices to address the condition of urgency by a headlong transition to digital interfaces [41]. It has also been reported that for many academics, the forced immersion into technology-enabled forms of LTA has become a disorienting and unusual experience shaped under the weight of panic and duress [42].

The rapid transition of higher education to online provision and the enforced digitalisation of pedagogical approaches in relation to LTA have engendered significant challenges for both the academic community and students. Gamage et al. [43] indicate the increased importance of the ways in which technological advancements enabling online delivery works otherwise to challenge academic integrity management and assessment security during the COVID-19 pandemic. A recent study derived from UK academics of various disciplines and positions identified an abundance of "afflictions", which overshadowed the potential "affordances" in the context of emergency online migration and online pedagogies [42]. These afflictions will continue to have undeniable impacts on "student recruitment", "countries' GDP made by international students", "local economies", "sustainability of universities within a global student marketplace," and "academic labour-market" [42]. While the majority of the survey respondents critically articulated the dark side of the rapid online migration, there were some—much fewer yet no less visible—who positively debated about its capacities and turned the tragedy of COVID-19 into an opportunity to deliberate its impacts on higher education. For these optimistic academics, the forced transition in the light of the coronavirus crisis could inform different forms of change that were long overdue. Besides, the technology advocates echoed how the enforced online migration has contributed to the professionalisation of academics as pedagogues, moving beyond "the tokenism of pedagogic credentialism" (i.e., outlining higher education "as a socially immersive and participatory learning experience") and further incentivising better practices [42] (pp. 631, 636). Such debates serve as the basis for diagnosing and exploring the impacts of emergency adoption and experimentation of online and other forms of technology-enabled LTA on the role of the academic community and the long-term future of higher education. This resonates with what other higher education commentators have previously argued as digital transformation [32–34]. Answers to many questions in this context are far from clear, yet the extent to which the higher education sector has the capacity to adapt in the context of emergency immersion into online/distance LTA and digital pedagogies remains a critical discourse and is a subject to further elucidation.

3. Methods

This is an exploratory research [44] (p. 64) with a qualitative approach focusing on a single case study [45]. We used the case study research design to "describe and diagnose" processes by observing their developments and contextual influences [46] (p. 98). The significance of case study has also been addressed in the context of education research as it can be adopted as an effective method to provide teachers with a range of experiences that can enable them to become prepared and knowledgeable to manage different situations [47]. We selected the online teaching design model—what Power [48] (p. 509) called "blended online learning environment design model"—for the delivery of the RMT subject at Cardiff University as a critical response to the process of rapid transition from a face-to-face to a remote online mode of delivery during the early COVID-19 outbreak and subsequent restrictions in the UK. Access to the case study has been among the key selection criteria. We also used diagrammatic thinking as an abstraction with the capacity to unravel relationships between different elements/activities in the context of higher education. This paper was mostly written in May—July 2020 during the public health emergency related to the COVID-19 pandemic in the UK. In addition to scholarly publications, we also relied on emerging discussions in the digital media and news articles at the time.

The following limitations have also been identified in this study. Due to the suspension of face-to-face academic activities and rapid shift to remote online delivery during the early COVID-19 outbreak and subsequent lockdown in the UK, it was not possible to develop and collect comprehensive surveys from students and/or academic staff members at the time. In addition, subject evaluations were suspended for Spring semester subjects such as RMT. It is also beyond the scope of this paper to evaluate the process of learning, the associated institutional frameworks, or the related policy setting. Exploring the experiences of students is a limitation of this paper and remains a task for future research. The tight schedule of this study and the related subject delivery during the rapid period of transition to online teaching has also been among the key limitations.

4. Context

4.1. The Early Lockdown in the UK and Transition to Online Education

UK government announced a national lockdown in March 2020 [49] and fully suspended face-to-face teaching in higher education to contain the coronavirus. Consequently, universities across the nation including Cardiff university closed their campuses and took the steps necessary to rapidly move to remote and blended online methods of LTA during this period of disruption. Regardless of the difficulties imparted by government enforced movement constraints and social distancing measures, universities must have continued to ensure that necessary academic standards and high-quality student experience were maintained in accordance with the "safety net policy" and learning outcomes associated with each degree programme. In this paper, to reflect on the experience of teaching urban design research methods in the RMT subject, we carry out a comparative analysis of the pre- and post-adaptation of the subject design pertaining to digital transition to online platforms. We elaborate on the ways in which the RMT subject was adapted and redesigned when the COVID-19 outbreak led to the immediate closure of Cardiff University campuses and emergency migration of the teaching activities into online domains.

4.2. Urban Design Education and Research Methods

Urban design is an evolving field with critical links to a range of other disciplines including architecture, urban planning, geography, urban studies, social sciences, environmental psychology, and urban economics, among others. Addressing any research question in this field relies on a strong use of case studies, looking hard at cities [50] and adopting multiple methods and scales of analysis [51]. While engaging with specific research methods has been integral to some key contributions to the development of the knowledge base in the field of urban design [52–57], research methods have often remained underexplored, particularly in the context of urban design education. Learning urban design research methods can enable students to focus their inquiry by critically observing, analysing, exploring, and understanding cities.

There have been attempts to outline the capacity of certain methods in urban design education, such as urban mapping, digital parametric methods [58], and extensive geospatial databases such as GIS [59]. There has been less scholarly focus on developing pedagogical frameworks based on a more extensive range of urban design methods. This paper focuses on teaching the RMT subject amid the COVID-19 outbreak and the subsequent lockdown in the UK. The primary aim of this subject is to introduce a range of research methods concerning critical questions in the field of urban design. It also seeks to enable students to deepen their methodological understanding and critical thinking in relation to those forms of urbanism that have remained underexplored [60–62] and to the ways in which urban places work at the intersections between spatiality and sociality [63], between the measurable and the non-measurable [64], and between urban morphology and streetlife intensity [65,66].

4.3. Research Methods and Techniques Subject in MA Urban Design

Figure 1 illustrates the position of the RMT subject within the broader context of the MA Urban Design (MA UD) programme at Cardiff University. The RMT subject typically starts in the last weeks of the Spring semester and ends before the Urban Design thesis—called Research-based Design Project (RbDP)—starting in summer. The MA UD programme is organised in three semesters from Autumn to Summer, and the main subjects include Urban Design Foundation, Urban Design Thinkers, Autumn Studio, Urban Development Debates, Spring Studio, Research Methods and Techniques, and Research-based Design Project. The programme also includes field study visit. Figure 1 illustrates the RMT subject in relation to other subjects in the MA UD. The RMT subject has been designed to support the MA UD students to prepare for their end-of-year dissertation subject.

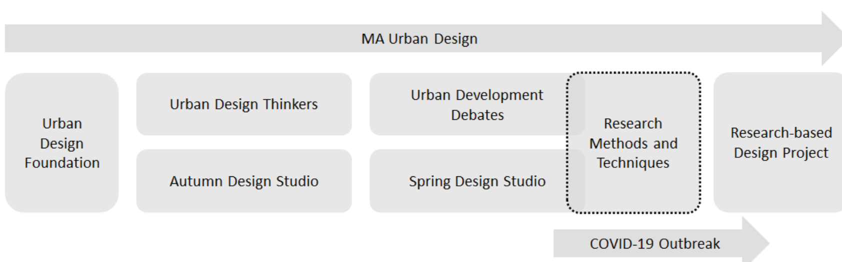

Figure 1. The Research Methods and Techniques (RMT) subject in relation to other subjects in the MA Urban Design programme.

The RMT subject introduces students to various key methods and techniques for urban analysis and design through a mix of weekly lectures, reading seminars, and work-in-progress tutorials. The aim is to enable students to deepen their critical understanding and methodological approach in relation to a range of key topic areas and questions in urban design. The subject develops skills to draft a research proposal related to urban design and provides an understanding of alternative approaches to research in urban design. It also helps develop an ability to identify suitable methods to address the outlined research questions and provide an informed explanation for selecting a particular methodology to address the related research questions. Enabling a constructive alignment [67] between the subject material, teaching and learning activities, assessments, and intended learning outcomes has been a primary focus in developing the RMT subject.

5. Case Study Analysis

The RMT was among the subjects in the MA Urban Design programme that was hit the most in the time of the early outbreak in the UK. To become more amenable to online LTA, as illustrated in Figure 2, the entire subject was inevitably adapted and redesigned for online delivery under unprecedented pressures with limited substantial resources and increased demand for online teaching and learning. In what follows, we discuss the challenges and capacities of online teaching based on the experience of delivering the RMT subject during the lockdown with the aim to outline some key considerations for sustaining effective remote LTA in the face of uncertain, changing, and challenging situations such as the COVID-19 pandemic. The case study analysis section is structured in relation to the three themes of teaching and learning activities, assessment and feedback, and digital platforms with a focus on the conditions before and during the lockdown. The RMT subject delivery before and during the lockdown in the UK is comparatively summarised in Table 1 as well.

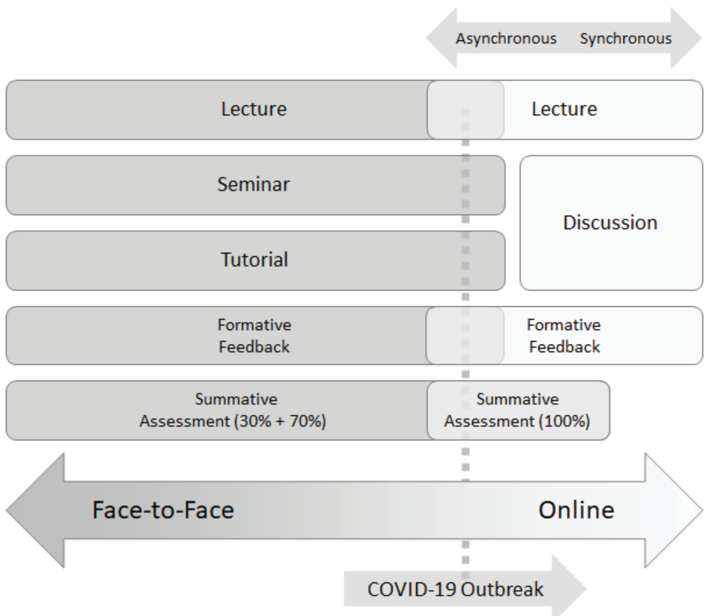

Figure 2. The emergency transition of the RMT subject from face-to-face to online learning, teaching and assessment (LTA) during the early COVID-19 outbreak in the UK.

Table 1. The RMT subject delivery mode before and during the early lockdown in the UK.

		Before the Lockdown	During the Lockdown
Learning and teaching activities	Lecture	Primarily face-to-face with subject leader and guest lecturers and on campus with the support of asynchronous online material	Online and primarily synchronous with subject leader and guest lecturers with the support of asynchronous online material
	Seminar	Primarily face-to-face with subject leader and on campus with the support of asynchronous online material	Combined with tutorials and primarily changed to live online discussion sessions with subject leader and tutors
	Tutorial	Primarily face-to-face with tutors and on campus with the support of asynchronous online material	Combined with seminars and primarily changed to live online discussion sessions with subject leader and tutors

Table 1. *Cont.*

			Before the Lockdown	During the Lockdown
Assessment and feedback	Formative feedback	Sessional oral feedback	Primarily face-to-face during lectures by subject leader; during seminars and tutorials by subject leader, tutors, and peers with the support of asynchronous online material	Online during live synchronous lectures and discussion sessions by subject leader and tutors with the support of asynchronous online material
		Interim presentations	Primarily face-to-face with the format of individual presentations by students followed by feedback from internal/external crits	Online parallel sessions with the format of individual presentations by students followed by feedback from internal/external crits
	Summative Assessment		30% (lecture/seminar contribution) + 70% (research proposal)	100% (research proposal)
Digital platform	Synchronous			Microsoft Teams
	Asynchronous		Learning Central	Learning Central

5.1. Learning and Teaching Activities

Core lectures and guest lectures were the primary means for the face-to-face delivery of the academic content of the RMT subject. They presented the critical knowledge that students needed to develop their research proposals. A range of guest lectures were designed in a way that supervisors of the RbDP subject could deliver short presentations on their research themes and respond to students' questions. All face-to-face lecture material was uploaded online on a weekly basis. As an important component, face-to-face reading seminars allowed students to individually discuss their reflections from the readings while interacting with their tutors and other students. These weekly RMT seminar readings were about empirical investigations that used or adopted those methodological approaches, methods, and techniques discussed earlier in that week's lectures. They also gave students the opportunity to understand other multiple ways of observing and analysing cities without reducing them to a single way of observing or analysing. Similar to seminars, face-to-face work-in-progress tutorials included a combination of group and individual activities. Encouraging discussion and enabling a critical understanding of the subject material and its relevance were among the effective teaching principles [68]. The weekly interactive tutorials provided the opportunity for students to critically discuss their ideas on how to develop their individual research proposals with their peers and tutors.

After the inevitable migration to online teaching and learning during the COVID-19 outbreak in the UK and the subsequent national lockdown, all the on-campus face-to-face lectures were replaced by a mix of synchronous and asynchronous online lectures (Figure 2). A part of the asynchronous online lectures included short lectures delivered by RbDP supervisors in the second week of the subject after the introductory lecture in the first week. All supervisors were expected to deliver a short presentation on their research themes in the RMT subject. These presentations were mostly recorded as PowerPoint presentations saved as narrated video files and made accessible via the Learning Central (LC) online platform—the Cardiff University's primary virtual learning and teaching environment. The advantage of making short presentations of supervisors available online was that it could allow students to engage with various research topics as well as each supervisor's broad research expertise in addressing different questions in relation to urban design thinking. The online material delivery rather than cessation of all such learning and teaching activities could also facilitate a better fit and informed alignment between supervisors' expertise and students' interests.

More asynchronous lecture material about research ethics, library resources, literature search, annotated bibliography, and referencing were made available using the LC online platform. The rest of the online lectures were synchronous, using Microsoft Teams as the primary online platform. As shown in Figure 2, reading seminars and work-in-progress tutorials were entirely replaced by online discussion sessions using the Microsoft Teams General interface. The Microsoft Teams has been quite effective in facilitating both synchronous online lectures and discussion sessions and enabling an engaging environment for a large cohort of students joining from multiple geographical locations and time-zones. It also facilitated both individual and group discussions, using different channels, conversations, scheduling, file sharing, and storage features.

5.2. Assessment and Feedback

Assessment in this subject includes both forms of summative and formative. Formative assessment allows tutors to gauge students' learning during the learning process mainly through synchronous interim presentations. Interim presentations include those sessions designed particularly for students to individually present their pre-submission work-in-progress assignment and obtain timely and focused feedback and advice from their instructors (i.e., a number of supervisors who are involved in supervision in the RbDP subject). This will help students learn and improve their work for the final submission. The importance of timely and clear formative feedback has been acknowledged in relevant studies [69]. Other work-in-progress tutorials and reading seminars offer students the opportunity to obtain formative feedback from their peers and instructors. Summative assessment in this subject includes two main components: lecture/seminar contribution and a written research proposal attracting 30% and 70% of the total mark, respectively.

During the lockdown, to include the component of interim presentations in the blended online delivery mode, different channels were created in the Microsoft Teams, each of which included about 16 students presenting their works individually to an internal/external crit and receiving immediate synchronous feedback and advice. Nevertheless, a specific form of summative assessment, including the 30% lecture/seminar contribution, was suspended as the individual contribution could no longer be fairly assessed online during the lockdown. Thus, the assessment changed into a 100% research proposal submission with a higher word count.

5.3. Digital Platforms

As previously noted, LC has been the primary online learning and teaching platform in different degree programmes across Cardiff University. Subject description, schedule outline, seminar and tutorial structure, interim presentation schedule, learning material, reading list, assessment brief, group allocation, list of the subject team as well as the supervisors involved in the next subject, supervisors' research themes, and presentation materials were all available on LC. Students were also provided with supporting documents such as research proposal templates and guides (e.g., library search guide, preliminary draft research proposal template, individual writing and reflection guide, and reading summary template).

We have primarily used a mix of Learning Central and Microsoft Teams as the key online platforms to deliver the subject material during the lockdown period. LC has been used as the main platform to facilitate asynchronous learning and teaching while Microsoft Teams has been utilised to enable a range of synchronous learning and teaching activities. We have noticed some of the critical capacities and limitations of both platforms in teaching urban design research methods online. The core subject materials, such as lecture slides, reading lists, and assessment briefs, have been made available on LC so that individual learners would be able to download and access them anywhere and anytime. The LC platform, though, has been found challenging and not particularly user friendly when it came to synchronous teaching and learning. In contrast, the Microsoft Teams platform has become quite useful and more user friendly in enabling an engaging learning environment for lectures and seminar discussions. Both platforms fell short in the extent to which they could effectively simulate the whiteboard as a collaborative platform for sharing ideas and diagrams. Collaborative drawing is particularly difficult in both platforms, partly because it relies on the degree to which the teaching team and individual learners have access to related hardware, including digital pens and drawing boards. We also noticed the following limitations using Microsoft Teams as the primary online platform for coordinating synchronous learning and teaching: all the team members were added manually, which was quite time-consuming given the large size of the cohort; there were limited number of participants visible on screen at once; anonymous file sharing and archiving seemed impossible since all members could access any shared files by either students or tutors.

6. Discussion

Moving towards online teaching during urban public health emergencies such as the COVID-19 outbreak has become necessary rather than optional as the demand for the development and implementation of adaptive learning spaces and the integration of virtual reality and innovative digital learning pathways is growing. At stake is to avoid normalising hasty transitions to online teaching in the face of such global challenges. While the condition of emergency may justify immediate action, it is the role of academia to remain reflective of its practice. The COVID-19 outbreak might be an opportunity for universities to learn from the rapid changes and adaptations during this unprecedented time, and as such rethink the extent to which many courses rely on face-to-face teaching on campus. Nonetheless, the COVID-19 pandemic cannot be simply considered as an excuse to prioritise online teaching and dismiss traditional face-to-face learning. Forms of blended teaching and learning are already underway to at once harness the capacities of both online and face-to-face teaching and hopefully manage the limitations of both when it comes to learning. Focusing on the learning experience is critical in the process of integrating traditional and online forms of teaching and learning and implementing blended learning [70]. In what follows, we open the discussion in relation to the capacities and challenges of online mode of teaching.

One of the significant challenges associated with blended online teaching delivery is about the extent to which online platforms can enable and sustain small-group learning and student-to-student communication. This is mainly at stake in the context of urban design pedagogy, which often aims to enhance teamwork skills among different learners through small group teaching and peer learning. This is linked to the idea put forward by Exley and Dennick [71] that communication is integral to effective small group teaching in higher education. While online teaching enabled student-to-teacher communication, it fell short in sustaining student-to-student communication, which is even more important in urban design subjects relying on effective teamwork and collaboration among students within small groups. Teaching urban design research methods during the lockdown period has shown that blended online modes of teaching delivery have less effectively enabled discussions among students. This partly supports Dumford and Miller's [14] argument that students taking online courses are less willing to participate in collaborative learning, interactions with diverse peers, compared to those in the traditional classroom. This also means that students are less likely to develop core professional qualities including communication, interpersonal and practical skills [24]. Facilitating synchronous communication through discussions among individual learners has also become more challenging using online platforms such as LC and Microsoft Teams. The challenges of establishing eye contact with students, forming sub-groups, and encouraging active engagement have made online synchronous small group teaching and learning activities less productive. Synchronous discussions sessions have been more effective as individual learners had the opportunity to raise questions using oral and/or textual means of communication. Nevertheless, it is worth noting that similar to Bryson and Andres's [72] observation, managing multiple cues from students including those who engage in voice-based discussions whilst observing and responding to the questions in the chat box in the synchronous discussions sessions can be particularly challenging for the teaching staff.

While the transition to online teaching may offer more flexibility in terms of the university-based timetabling and location, it poses critical concerns regarding the challenge of home-based timetabling. Arranging appropriate places for on-campus face-to-face teaching has been a burgeoning challenge for many academics and professional staff involved in timetabling. Desirable physical spaces for teaching certain subjects face-to-face may not often be available on campus when needed. One of the key capacities of online teaching lies in the ways in which academic staff can allocate more time to focus on actual teaching and learning activities and subject materials instead of spending a considerable amount of time to organise suitable physical spaces on campus corresponding a desirable schedule, which often ends up in working with what is available, rather than what is desirable. Nonetheless, scheduling synchronous interactive teaching and learning has become problematic due to the challenge of managing different geographical locations and time zones of international students [42,73] along with the challenge of developing a functional arrangement for home-based teaching and learning. Many students, particularly those self-isolating as protection against COVID-19, may not have access to the appropriate space to effectively concentrate and engage with online synchronous learning activities. Many academic staff members with home-schooling and caring responsibilities have to manage double burden of paid work with unpaid care work. As such, they struggle with the challenge of arranging a suitable physical space and time with minimum disruption for online synchronous teaching activities. This has been particularly experienced by female academics with younger dependents, often engaged disproportionately in household and pastoral activities, in the face of emergency online LTA transition [42,74].

Practices of online teaching and learning cannot be simply generalised as differences can play a crucial role in the ways in which they play out in reality. Attracting a mix of international and local students from different backgrounds has become integral to how many universities can most effectively work, mainly in the context of the global North. In the UK, for instance, a considerable proportion of the annual tuition fee income in many higher education institutions is made up by Chinese international students [75]. Having said that, hasty transformations to online teaching and learning are likely to remain blind to such differences. While there is no systematically complied data on the extent to which international students consider studying abroad in the current climate of uncertainty, it would be naive to assume that online learning works similarly for different students. While local and international students cannot be considered as homogenous groups, a common characteristic of international students is about their endeavours to leave primary networks of support in pursuit of higher education in different contexts [76] (p. 201). For many international students, going through the challenge of moving to another country for education and finding an appropriate place to stay during their study may seem unnecessary when they can effectively benefit from a mix of synchronous and asynchronous online learning. This might be substantially different for many local students who have physical access to on-campus learning environments.

Using online platforms can arguably facilitate more equitable opportunities, particularly for those students who are likely to be less involved with teaching and learning activities. This lends itself well to the argument that "virtual identity will be unfettered by physical attributes such as gender, race, or disabilities" [23] (p. 10). It is critical to note that providing equal access to appropriate hardware such as laptops or tablets and infrastructure such as broadband and stable internet connection needs to be addressed first before we can discuss the issue of equity in relation to online platforms. As such, individual learners with different learning capabilities are empowered to participate more effectively in discussions and interact with their tutors asking questions and communicating their comments. These include different forms of communication, such as textual conversations, along with oral comments and questions. Some reticent students appeared to be more comfortable using text-based communication rather than oral communication. The use of technology can potentially enable a more inclusive access to lecture and discussion session materials. Students can get back to the discussed material from lectures or discussion sessions by checking the chat history and reading the minutes. This can provide opportunities for deeper and more critical reflection particularly for those students in different time zones.

Effective adaptation to online modes of pedagogy is subject to accessibility of new, relevant, and regularly updated technological tools and services on laptops and other mobile devices. More importantly, the challenge for many universities and educational institutions is to provide their academic staff and students with necessary guides to develop their technological literacy skills. Nevertheless, as discussed in the 2019 EDUCAUSE Horizon Report, merely facilitating the basic technological literacies among students and instructors is no longer sufficient to respond to and support the complex needs of people in a digitally mediated society [29] (p. 14). Hence, focusing on the distinction between technological fluency and technological literacy alongside further leveraging the technological fluency is crucial in the age of pandemic crisis to support personal and professional development and acquiring skills in the education such as creativity, critical thinking, independent problem solving, effective collaboration and self-directed learning. The demand for adaptive learning and teaching environments, digital learning innovations, and pedagogically sound teaching and learning designs will increase in the face of the COVID-19, and those universities investing in integrating more learning designers and instructional design experts will be better placed in their strategic attempts to design or redesign programmes. Having said that, it is worth noting that decisions about technology should not take priority over the content and the learning outcomes [72].

Online pedagogical approaches and the use of technology can facilitate parallel modes of online teaching. Examples of this have been evidenced in the RMT experience where the subject leader and tutors could simultaneously address multiple questions and comments, written and verbal, raised by students. Using a mix of audio, visual, and textual means of parallel communication, along with screensharing, has enabled the teaching team to address different questions and engage with individual learners simultaneously. Using live text-based communication for raising questions or responding to questions has been found particularly popular online as it allowed individual learners to receive an immediate response by one of the teaching team members. This is linked to the ways such synchronous communications help e-learners feel like members of a community rather than isolated individuals communicating with their computers [77]. The Microsoft Teams platform has enabled effective management of parallel presentations across different groups using channels functionality and live screensharing. Screensharing is a key feature of using technology in synchronous teaching and learning. In addition to the possibility of delivering live talks and presentations, screensharing has provided the critical benefit of immediate synchronous feedback from both tutors and students. Using the tool, it is possible to also share visual content as part of the lecture and seminar activities and leave the chat and messaging features open for live student-to-student and student-to-teacher communication as well as synchronous Q&A sessions. Such increased engagement in both lecture and seminar sessions can result in deeper learning through the representation of multiple viewpoints. This supports the idea that "technology can now provide immediate, nuanced feedback on student progress, drill down in areas of misunderstanding, tailor curriculum to personal needs, and create new ways for students to interact with their peers and teachers – all factors known to drive learning effectiveness" [24] (p. 20).

Establishing eye contact is integral to face-to-face teaching and learning. Yet, it is a burgeoning challenge for online platforms to at least enable a degree of such contact via digital technology. The importance of such a contact for a successful online learning has been previously outlined, which is mainly due to the fact that learning is a social act [36]. We argue that the rights to see and to be seen are taken for granted in the face-to-face teaching environments. However, in online teaching and learning, the discussion of such rights can pose challenges as cameras can be easily switched off, and participants, including tutors and students, can choose to become visible or remain invisible during synchronous teaching and learning. The use of technology also matters here to enable or constrain the capacity of seeing all those attendees with open cameras simultaneously. For instance, such a capacity is constrained in Microsoft Teams as only a limited number of attendees can become visible on the screen during an online session. There have been ongoing conversations about how to address this limitation in Microsoft Teams, yet the point is not necessarily limited to the capacities of specific online platforms. While it might not be possible to simulate the nuances of face-to-face interactions in online settings, the task is to critically reflect on the extent to which the rights to see and to be seen in online learning environments can be negotiated to enable active engagement.

7. Conclusions

Drawing on the experience of teaching the Research Methods and Techniques subject during the early lockdown in the UK, we discussed the rapid transition from face-to-face to online teaching and pointed to the associated challenges and opportunities in relation to the learning and teaching activities, assessment and feedback, and digital platforms. We also outlined some key considerations to inform the development of more adaptive and resilient approaches to online teaching in the context of unprecedented global health crises such as the COVID-19 pandemic. Much less acknowledged, yet no less crucial are challenges such as the development of core professional qualities, including communication, interpersonal and practical skills, along with the integration of thoroughly selected online technology to most effectively redesign teaching activities and deeply engage students. We argue that it is critical to move beyond fixed pedagogical frameworks to harness the productive capacities of adaptive teaching. As discussed, pedagogy should be given primacy over technology in the wake of the COVID-19 pandemic and emergency online teaching and learning. In this sense, the pandemic can also be considered as an opportunity to deliberate over its impacts and associated changes in a way that contribute to the pedagogical reinventions as well as the evolution of online education.

The question of equity is paramount, yet it cannot be simply reduced to dichotomous thinking outlining online teaching in contrast to face-to-face teaching. Online and face-to-face teaching can both become problematic when it comes to the provision of more equitable opportunities for different learners. Addressing diversity and the inequality of access to infrastructure, such as suitable hardware and required software as well as a stable internet connection, is critical for enabling a more inclusive online teaching and learning in the first place. Regardless of the specific capacities and limitations of online platforms, it might not be possible for all individual learners to equally and effectively benefit from synchronous teaching and learning due to limited access to adequate infrastructure, software and hardware. Normalising the condition of emergency cannot justify the ways in which hasty practices of online teaching dismiss differences, including the pre-existing inequalities concerning digital technology and its literacy. Face-to-face teaching is not necessarily a more just alternative as it can also dismiss differences and normalise or even intensify the pre-existing inequalities. While a blend of synchronous and asynchronous online teaching may provide more equitable opportunities for whom access to face-to-face teaching is limited, face-to-face teaching can also provide more equitable opportunities for those with limited access to the required infrastructure. The discussion, though, is not simply about selecting one and dismissing the other. The task is to focus on the intersections and productive capacities of online and traditional campus-based forms of learning and how they can most effectively co-function to facilitate learning outcomes and provide more equitable opportunities for different learners.

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Article

Teaching Mathematics at Distance: A Challenge for Universities

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Abstract: The focus of this research is how Sicilian state university mathematics professors faced the challenge of teaching via distance education during the first wave of the COVID-19 pandemic. Since the pandemic entered our lives suddenly, the professors found themselves having to lecture using an e-learning platform that they had never used before, and for which they could not receive training due to the health emergency. In addition to the emotional aspects related to the particular situation of the pandemic, there are two aspects to consider when teaching mathematics at a distance. The first is related to the fact that at university level, lecturers generally teach mathematics in a formal way, using many symbols and formulas that they are used to writing. The second aspect is that the way mathematics is taught is also related to the students to whom the teaching is addressed. In fact, not only online, but also in face-to-face modality, the teaching of mathematics to students on the mathematics degree course involves a different approach to lessons (as well as to the choice of topics to explain) than teaching mathematics in another degree course. In order to investigate how the Sicilian State university mathematics professors taught mathematics at distance, a questionnaire was prepared and administered one month after the beginning of the lockdown in Italy. Both quantitative and qualitative analyses were made, which allowed us to observe the way that university professors have adapted to the new teaching modality: they started to appropriate new artifacts (writing tablets, mathematical software, e-learning platform) to replicate their face-to-face teaching modality, mostly maintaining their blackboard teacher status. Their answers also reveal their beliefs related to teaching mathematics at university level, noting what has been an advantageous or disadvantageous for them in distance teaching.

Keywords: COVID-19 pandemic; university mathematics professors; teaching mathematics at a distance; blackboard teacher; teacher beliefs

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1. Introduction

Once upon a time, there was a world that believed in technology and connections between people, but one day a viral pandemic stopped everything and compelled the entire world to sit down and think. It was the COVID-19 disease, caused by a new virus that started to infect people in China at the end of 2019 and spread worldwide in 2020. From Wuhan (China), the virus, called SARS-CoV-2, spread across nearby countries in Asia first, and then moved across the world. On 20 February, the first infected person was certified in the north of Italy. Within a few days, the Italian government had decided to close schools and universities all over the country, since the virus was spreading further, and the whole of Italy was "closed" in quarantine: stores, restaurants, and factories as well as schools and universities were closed to the public. On 11 March, 12,462 people had been infected by SARS-CoV-2, and 827 people had died in Italy. This number was fated to grow to over one million people. Schools and universities were still closed in May 2020.

In the first week of March 2020, the Italian Ministry of Education, University, and Research called on schools and universities not to abandon students who were quarantined at home and to start distance teaching.

Figure 1 summarizes the number of infected people in Italy by the end of the first Italian quarantine (June 2020).

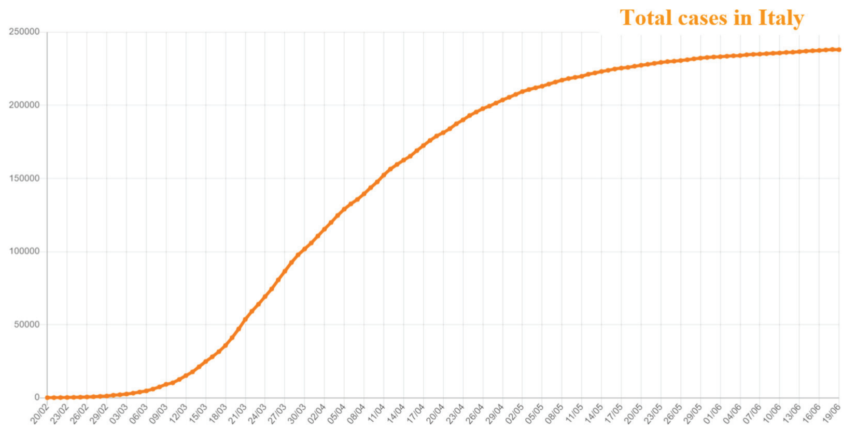

Figure 1. Trend of COVID-19 cases in Italy until June 2020 (taken from https://lab24.ilScheme24.ore.com/coronavirus/ accessed on 30/06/2020).

As shown in Figure 1, there were more than 230,000 infected people out of 60 million inhabitants in Italy in the middle of June 2020 (0.395% of the population). There were not as many cases when distance teaching began, but we thought that the worst was yet to come.

The situation induced by the COVID-19 emergency required us to make an extra effort not only as individuals, but also as educators. We believe that the worldwide emergency requires us to reflect on its consequences for mathematics education and research, in a connected and technological world that suddenly found itself connected only through technology. We used a great deal of technology before the pandemic and believed it was a good mediator of mathematics education between teachers and learners, but we were forced to use only the mediator, and we have to reflect on the importance of the main characters in education: the teachers and learners.

Many studies in mathematics education demonstrate the importance of artifacts, and technological artifacts in particular, becoming instruments to mediate mathematical topics [1–3], but in this situation we were alone with these artifacts and the mediators were far away. Schools in Italy were accustomed to using technological devices (even when teaching face-to-face) and teaching aid platforms. In fact, thanks to law 107/2015 (https://www.gazzettaufficiale.it/eli/id/2015/07/15/15G00122/sg), the Digital Animator was introduced to Italian schools in 2015, which supports headteachers in the design and implementation of digital innovation projects (internal training, involvement of the school community, and the creation of innovative solutions with the use of technology). Nothing similar is planned for Sicilian universities. Moreover, university mathematics courses are traditionally taught by chalk and blackboard, at least in Sicily, where there are universities with ancient traditions (the oldest is in Catania, founded in 1434). The shift to distance learning was therefore a serious challenge for their professors.

The focus of our research is how Sicilian university mathematics professors faced the challenge of teaching via distance education during the COVID-19 pandemic, using a new technology (a distance learning platform) promoted by their universities. In addition to the emotional effects of the pandemic, there are two aspects of teaching mathematics at a distance to consider. The first, without judging the suitability of this approach, is related to the fact that lecturers at university level generally teach mathematics in a formal way, using many symbols and formulas that they are used to writing for their students to see. The second aspect is that the way mathematics is taught is also related to the students to whom the teaching is addressed. Not only online, but also in face-to-face modality, teaching mathematics to students on the mathematics degree course involves a different approach to lessons (as well as to the choice of topics) than teaching mathematics on another degree course [4].

Our study population comprises all the university professors in the three Sicilian State universities that teach mathematics, on both mathematics and non-mathematics degree courses (e.g., engineering, computer science, etc.). We will specify this in the methodology, but we anticipate that, at least as far as Sicilian universities are concerned, the mathematics or physics degree courses have less students than the other degree courses in which mathematics is taught.

The research questions that guide our study are as follows:

- As they moved to distance teaching, what artifacts did university professors adopt in their didactic transposition of mathematics?
- What effect does the number of students and the university degree course have on how a professor explains mathematics?
- Does distance teaching have disadvantages for teaching mathematics, and if so what?
- Do university mathematics professors gain any advantages in terms of professional skills from a potential crisis? Do opportunities arise from difficulty?

The paper consists of five sections in addition to the introduction. In the next section (Section 2), we present the theoretical background, including features of e-learning environments, the use of artifact in teaching/learning mathematics, the process of objectification, the role of corporeity in the teaching/learning of mathematics, the concept of teacher beliefs, and a teacher's need for virtue when faced with unforeseen situations, such as the COVID-19 pandemic. The methodology that guided the research is presented in Section 3, with a description of the participants involved in the study and an illustration of how the data was collected and analyzed. The results section (Section 4) is dedicated to the exposition of both quantitative and qualitative analyses. The final section (Section 5) is dedicated to discussion and proposes lines for future research.

2. Theoretical Background

With the advent of the pandemic, universities have had to arrange various forms of e-learning in order to complete their teaching activities for the 2019/2020 academic year. E-learning delivers content through electronic information and communications technologies (ICTs). There are several definitions of e-learning. Here we assume the following: ICT is used to support distance teaching/learning processes, based on both e-content delivery and active and/or collaborative learning approaches [5].

To propose and manage e-learning means working within a complex system, involving not only the content to be delivered, but also theoretical models, technological and methodological choices to be made, the use and coordination of human resources, and the integration processes of the organization adopting e-learning as an additional way to acquire new knowledge and skills [5]. There are different kinds of e-learning activities. There are e-learning activities in which materials are provided for self-education (e.g., [6]) and also e-learning activities in virtual spaces able to host collaborative learning communities, organized in real learning groups, or in communities of practice [7], where each member increases their knowledge and skills by building them with the rest of the group, based on the cognitive problems typical of a given profession (e.g., [8,9]).

Issues arise in e-learning in mathematics, regarding the design of effective learning objects, when provided at distance. Borba et al. [10] discuss the use of digital learning objects in mathematics education, in blended teaching, but also in MOOCs and virtual learning environment. "It seems clear that digital technology involves "deconstructing" the notion of the classroom" ([10], p. 605), and this is more and more true when the classroom does not physically exist anymore.

The management of e-learning activities also involves various figures who are involved with its different aspects: administrative, technological, and didactic. An e-learning system involves the overall management/responsibility of the system, analysis of training needs, path design, teaching management/responsibility for the path, tutoring (network/coaching/mentoring/counselling), knowledge/competence of the content, evaluation of the learning and training process, in-depth knowledge of the e-learning platform, IT administration of the platform, knowledge/competence of the organization's ICT systems, information retrieval, knowledge management, the design and implementation of e-content (graphic story-boarding and multimedia development, didactic communication, etc.), an administrative/operational office, monitoring design and management, quality analysis, and so on [5]. In short, it is a complex system that involves more than simply choosing an e-learning platform in order to achieve the final goal, that is, to create good e-learning paths.

To use technological artifacts (as for other artifacts) in an effective way from an educational point of view means to achieve an *instrumental genesis*, in the sense introduced by Rabarderl [11]. The process can be long and difficult, because it requires two phases, which Rabardel and Samurcay [12] call *instrumentalization* and *instrumentation*. The first phase is concerned with the approach to the artifact, and, for example, with the progressive awareness of its potential and its limits. The second phase, which is deeper, is devoted to rising and developing the artifact's schemes of use, with the appropriation of social utilization schemes for the artifact and/or the arising and development of private schemes. The sudden closure of universities and the switch to distance teaching required efforts to appropriate new artifacts (platforms, devices, etc.) in the senses of both instrumentalization and instrumentation.

We have to consider that "this type of school closure has never happened on this scale before. It will require all stakeholders to rethink how education happens during this emergency scenario and, then beyond. [...] Designing the learning experience for students must be differentiated when possible. It is not just as simple as putting your course online. Teachers need to think and choose how they can incorporate a blended learning approach and which tools will best serve their students and pedagogical practice. They need to consider what is accessible and fit for purpose, as well as ways in which to bring connectivity, relationality, and humanity into a distance learning model" ([13], p. 1).

In the particular case of mathematics, we must remember the importance of the embodiment component. Andrà [14] compares the blackboard teacher and the body teacher. The former manages communication through the written word and symbolic language, in which the blackboard is always at the center of attention, because the teacher is writing on it or indicates or underlines a written part on it; for the latter, communication is characterized by an intensive use of iconic and metaphorical gestures, which mainly involve an imaginative and figurative component.

There are several ways to represent mathematical objects: formal mathematical language, iconic representations, etc. The learning process that leads students to recognize the same mathematical object seen from different points of view is called *objectification* [15]. Teaching a discipline like mathematics, made of abstract objects that you cannot touch, often requires the use of metaphors to achieve the objectification of mathematical topics, which students can understand in terms of something already known. According to theorists of the embodied mind [16], people use physical objects or situations to understand complex topics in depth. They specifically use conceptual metaphors: this is not simply a metaphor in the poetic sense of the word, but rather a cognitive mechanism that projects the inferential structure of a source domain into a target domain. It is a map, in the mathematical sense of the word, between the two domains (source and target), preserving all the properties of the two elements corresponding in the map. When using metaphors, it is important that teachers make use of their body and gestures to help students envision in their mind the new mathematical objects in terms of objects they are familiar with and are able to visualize and manipulate. See [16] for more details. The use of different representations, such as metaphors, in conjunction with formal mathematical language, is useful, because several studies have demonstrated that students have difficulty with the process of objectification [17].

There is a risk of losing the dimension of the body teacher, in favor of the blackboard teacher in the transition from traditional classroom teaching, involving presence, to distance learning, or e-learning. The professors involved in our research were very tied to the blackboard and mostly represented mathematical objects using formal mathematical language. They thus found themselves suddenly deprived of their "safe place".

The ways in which professors are comfortable teaching, their "safe teaching place", are related to their mathematical and pedagogical knowledge and to their beliefs. More than 30 years ago, in Shulman's famous paper "Those who understand" [18], educators pointed out the crucial role of integrating mathematical and pedagogical knowledge. Here we deal only with the Mathematics Teacher's Specialized Knowledge (MTSK) model, introduced by Carrillo et al. [19], inspired by the research of Ball et al. [20] on mathematical knowledge for teaching (MKT). Carrillo and the other authors of the MTSK model discussed the "precise images by which the teacher's practice can be interpreted in the light of those aspects which most influence it, based on the knowledge underlying this practice" ([19], p. 5).

The two domains of the MTSK model are the Mathematical Knowledge and Pedagogical Content Knowledge, divided into various sub-domains as shown in Figure 2. Teacher beliefs are at the center, due to the close relationship between beliefs and the two knowledge domains. By "beliefs" we mean the more or less coherent set of personal truths, mental images, conceptions, meanings, and preferences of teachers introduced by Thompson in 1992 [21], which strongly influence what happens in class and, therefore, student learning. In the MTSK model, beliefs are distinguished (although the boundary is fragile, as shown in Figure 2) as beliefs about math and beliefs about the teaching and learning of math. Beliefs as a mediator between knowledge and practice are discussed in [22], and much work has been published about primary and high school teachers, but the role of beliefs at university level has not yet been fully investigated, as claimed by Mora and Rodriguez [23]. Fukawa-Connely et al. [24] studied teacher beliefs and practices at the tertiary level, and found an interesting contradiction between professors' beliefs about mathematical teaching and their classroom practice: 85% of studied professors (in abstract algebra) used lectures as standard pedagogical practice, 82% answered that lecturing was the best way to teach. However, 56% agreed (plus 26% more who slightly agreed) with the statement "I think students learn better when they do mathematical work (in addition to taking notes and attending to the lecture) in class", showing a mismatch between beliefs about student learning and actual teaching practice. Even when teachers recognize that a constructivist approach is more effective for student learning, they continue to use a transmission-oriented methodology.

If this mismatch is important in a normal situation, then it becomes more serious in an emergency such as that induced by COVID-19, with the sudden immersion in distance teaching.

The new pandemic dimension requires, in the emergency, the even greater involvement by teachers, who must complete their work in new way even without further training. They are called on to activate the creative capacity that Berthoz [25] attributes to our brain, which he calls "vicariance". It is the vicariant component of the human brain that allows people to use multiple and unexpected strategies to achieve a goal, to replace one sense with another (such as when we move in the dark after an accident). Vicariance, says Berthoz, is a simplex principle that refers to the adaptive character of the individual in situations, environments, and interactions with others.

In the following sections, we will see how university professors implemented vicariance for the transposition of knowledge to their students during distance teaching, which is less structured in an e-learning environment, even when they were usually blackboard teachers, during the COVID-19 pandemic.

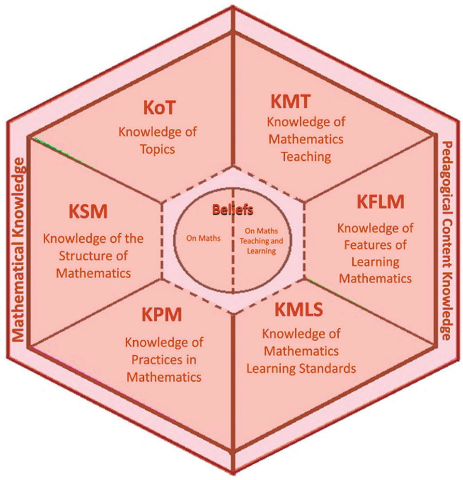

Figure 2. The Mathematics Teacher's Specialized Knowledge model.

3. Methodology

3.1. Participants

The research involved 27 university mathematics professors. They were voluntary respondents to an anonymous questionnaire, addressed to professors who taught mathematics at the three Sicilian state universities (Catania, Messina, and Palermo) in the second semester of the 2019/2020 academic year. The participants represented one-third of the entire population of state university mathematics professors (82) teaching in Sicily, regardless of their semesters of activity [26].

Eighteen of the professors who answered the questionnaire taught only one course, seven taught two courses, and two taught three, for a total of 38 courses. The focus of the questionnaire, as we will specify in more detail in the next section, was to identify strengths or weaknesses highlighted by the shift to distance learning in each course taught. Since those who teach two or three courses teach different subjects to different students, we considered the 38 courses independent of the fact that some were taught by the same person. The data below thus refers to 38 responses.

3.2. Data Collection and Method of Analysis

An anonymous questionnaire to collect data was prepared by the Mathematics Education Research Group (MERG) of the Department of Mathematics and Computer Science at the University of Catania, Italy (which includes Ferrarello, Mammana, Pennisi, and Taranto). It was based on in-depth interviews conducted with experienced professors teaching three different university mathematics courses during the first few weeks of the pandemic (March 2020). This initial step provided data for structuring the different sections and specific contents of the questionnaire.

Three strands of mathematics courses can be identified in Sicilian universities:

(1) Courses as part of mathematics (and possibly physics) degree courses, in which mathematics is quite appreciated by students, generally offered in small classes.
(2) Mathematics courses (analysis, geometry, physical mathematics) in engineering degree courses, in which mathematics is on average appreciated by students, generally offered in large classes (even more than 100 students).

(3) Basic mathematics courses offered for science degree courses (e.g., biology, geology, natural sciences, agriculture, computer science, architecture, economics, etc.), where mathematics is (often) little appreciated by students, generally offered to classes with many students.

The questionnaire was made up of four sections: the first gathered general information; the second investigated teaching habits and emotions related to courses held before the COVID-19 pandemic. The third section investigated new teaching habits and emotions related to the courses held during the COVID-19 pandemic. The fourth and last section included questions about the technologies used for distance learning. Each section contained open-ended, semi-open, closed, and Likert scale questions. We validated the questionnaire by sharing it with a group of six experts in mathematics education and educational psychology. After including their suggestions for modifications to the questionnaire, we conducted a pilot study, administering it to three additional university math professors, who only suggested a few small final changes.

The questionnaire, produced using Google Forms, which is an open source application for online surveys, was administered to the final participants about one month after the start of the lockdown in Italy. The MERG contacted the Directors of the Mathematics Departments of the three Sicilian State universities by email, with the request to distribute the questionnaire to all professors teaching math courses that semester. The data collection lasted one month. The data that we will illustrate in the next section therefore captures a precise moment: April 2020.

The analyses were carried out by MERG, in collaboration with psychologist colleagues (Cassibba, Musso), using Version 24 of the Statistical Package for the Social Sciences (SPSS). The analyses are both quantitative and qualitative. In the quantitative analyses, we generally reported the frequencies of the responses or their cross-tabulation, associated, when appropriate, with nonparametric statistics (i.e., chi-square test, Kruskal-Wallis test, McNemar test, and Median test) given that the data was categorical or ordered categorically. Because of the largely exploratory approach of our study, and to ensure the high sensitivity of statistical tests in the initial phase of our research project, we set the critical p value for significance at 0.10. This a priori choice was also connected to the high sensitivity of the chi-square test to sample size, while the distribution of the variables seemed less problematic considering the use of nonparametric statistics. The responses to the open-ended and semi-open questions were subjected to thematic analysis. The analysis followed the principle of data reduction and the generation of themes, which allowed an in-depth reading of the meaning-making processes related to the closed-ended questions. Specifically, the analysis process was structured in (a) open coding for the generation of the themes; (b) comparison with existing knowledge for the reorganization and grouping of the themes that emerged; and (c) selective coding, to extract illustrative examples of central experiences. The classifications and identification of the themes were carried out by the study authors, reaching a good degree of agreement ($k = 0.83$); in cases of disagreement, a discussion was initiated, which led, in all cases, to a final shared decision. We used qualitative data in this manuscript to better interpret quantitative results, without their in-depth descriptive analysis.

4. Data and Analysis

The sample of respondents had the following characteristics: 61% were men; 39% were women (Figure 3). Eleven percent were up to 40 years old, 34% were between 41 and 55 years old, and 55% were over 55 years old (Figure 4). This reflects the general state university mathematics professor population in Sicily well in terms of gender and age, with proportional differences under 5% [26].

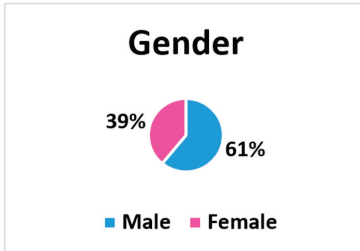

Figure 3. Gender of the sample.

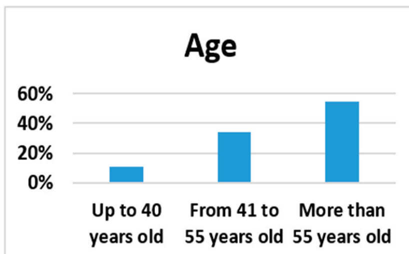

Figure 4. Age of the sample.

Fifty-five percent of respondents taught at the University of Catania, 34% at the University of Messina, and 11% at the University of Palermo (Figure 5). Sixty-eight percent of respondents taught on a Bachelor's degree course and 32% on a Master's degree course. Sixty-six percent taught in Mathematics or Physics, 18% in Engineering, and 16% in "Other" (Figure 6)—the three categories of degree courses specified in the previous section.

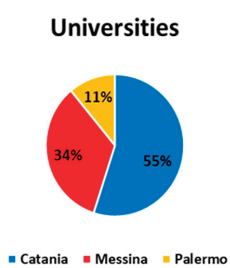

Figure 5. Universities at which the sample teaches.

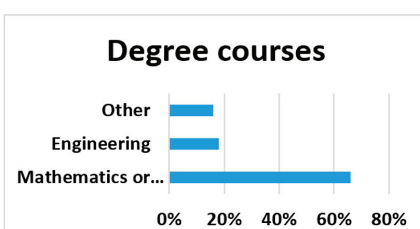

Figure 6. Degree courses of the sample.

Compared to the distribution of mathematics professors across the three state universities in [26], those in the University of Palermo were underrepresented (37% of the population), while those at the University of Catania (41% in the population) and the University of Messina (22% in the population) were overrepresented. These three universities and their professors have very similar characteristics, however, given that the rules for their functioning (e.g., recruitment procedures, number of courses provided, credits per course) are clearly established at both national and regional levels.

Fifty-eight percent of professors had taught their course for less than five years and only 34% had done so for more than 10 years. Before filling in the questionnaire, 37% had taught four to eight distance learning lessons and 63% had taught more than nine distance learning lessons. All respondents gave their lectures at a distance via the Microsoft Teams e-learning platform, as this was chosen by the three universities involved in the study. The didactic offices on Microsoft Teams created as many virtual classrooms (Teams) as courses provided by the university. Table 1 shows the number of students who were members of a Team and the percentage of students regularly attending distance learning, for each degree course. We can see that the majority of degree courses in mathematics or physics (56%) had between 11 and 40 students and 60% of these students attended distance classes assiduously (attendance between 75% and 100%). Most engineering degree courses (57%) had more than 100 students, most of whom (43%) attended distance learning (attendance between 75% and 100%). The other degree courses, including mathematics courses, varied between 41 and 100 students (50%), or over 100 (33%), and 50% of these students had an attendance rate of between 0% and 50%.

Table 1. Cross-tabulation between the number of students who were members of the Teams and the percentage of students who attend distance learning, compared to the degree courses (n = 38).

			% of Distance Learning Students			Total
			From 0 to 50	From 51 to 75	From 76 to 100	
Mathematics or physics	# students members of Teams	From 1 to 10	0.0%	4.0%	28.0%	32.0%
		From 11 to 40	4.0%	24.0%	28.0%	56.0%
		From 41 to 100	8.0%	0.0%	4.0%	12.0%
		More than 100	0.0%	0.0%	0.0%	0.0%
	Total		12.0%	28.0%	60.0%	100.0%
Engineering	# students members of Teams	From 1 to 10	0.0%	0.0%	0.0%	0.0%
		From 11 to 40	0.0%	0.0%	14.3%	14.3%
		From 41 to 100	0.0%	14.3%	14.3%	28.6%
		More than 100	28.6%	14.3%	14.3%	57.1%
	Total		28.6%	28.6%	42.9%	100.0%
Other	# students members of Teams	From 1 to 10	0.0%	0.0%	0.0%	0.0%
		From 11 to 40	16.7%	0.0%	0.0%	16.7%
		From 41 to 100	0.0%	16.7%	33.3%	50.0%
		More than 100	33.3%	0.0%	0.0%	33.3%
	Total		50.0%	16.7%	33.3%	100.0%
Total	# students members of Teams	From 1 to 10	0.0%	2.6%	18.4%	21.1%
		From 11 to 40	5.3%	15.8%	21.1%	42.1%
		From 41 to 100	5.3%	5.3%	10.5%	21.1%
		More than 100	10.5%	2.6%	2.6%	15.8%
	Total		21.1%	26.3%	52.6%	100.0%

Using a multiple-choice question, we asked the professors how they used to prepare their lessons before the COVID-19 pandemic. The same question was asked in the section "During COVID-19". Table 2 shows that, with the transition to distance learning, the percentage of professors who prepared everything in detail has increased. The chi-square test, $\chi^2(4) = 22.86$, $p < 0.001$, allows us to confirm that the passage to distance teaching has pushed the professors in a non-random way to better prepare their lessons.

Table 2. Lesson preparation ($n = 38$).

	Before COVID-19 Pandemic	During COVID-19 Pandemic
	Percent	Percent
Everything in detail	39.5	68.4
Basic step ladder	47.4	26.3
No preparation	13.2	5.3
Total	100.0	100.0

Before the COVID-19 pandemic, as Table 3 shows, no professor had ever lectured online. They all lectured at the front of the class using blackboard and chalk. Thirteen percent also used slides (.ppt or .pdf files), and 11% also used mathematical software.

Table 3. How did you previously teach a lesson? (multiple answer options)—($n = 38$).

	Percent
Not online; in front of the class with blackboard and chalk	81.6
Not online; in front of the class with blackboard and chalk; slide	7.9
Not online; in front of the class with blackboard and chalk; slide; mathematical software	5.3
Not online; in front of the class with blackboard and chalk; mathematical software	2.6
Not online; in front of the class with blackboard and chalk; mathematical software; laboratory activities in groups	2.6
Total	100.0

The symbolic and formal writings of mathematics had to be digitized during the COVID-19 pandemic, so we asked the professors how they adapted to this. Table 4 shows that the writing tablet was considered a worthy substitute for the blackboard, and in fact 61% of the professors continued to manually write the symbolic and formal writings of mathematics with a tablet. Thirty = seven percent used mathematical software, 42% showed slides—resources prepared before the lesson (.ppt files or sheets that were handwritten beforehand and then scanned to be shown on screen as .pdf files). In fact, someone wrote:

> *I do not have a writing tablet, blackboard, or anything else, so the only way is to write by hand before the lesson, scan the many sheets and insert them on the PC to share during the lesson: hard work.*

Table 4. What do you use to digitize the formal and symbolic writings of mathematics? (multiple answer options)—($n = 38$).

	Percent
Writing tablet	26.3
Writing tablet; slides	18.4
Mathematical software	18.4
Slides	18.4
Mathematical software; writing tablet	13.2
Mathematical software; slides	2.6
Mathematical software; writing tablet; slides	2.6
Total	100.0

The McNemar test showed that there was a significant increase in the use of slides, from 13% to 42%, $p = 0.01$, and there is also a significant increase in the use of mathematical software, from 11% to 37%, $p = 0.03$.

We investigated how often professors used their handwriting during their distance learning, using a writing tablet and sheets of paper that they then converted into .pdfs for projection. The answers were: *never* (23%), *sometimes* (21%), *often* (16%), and *always* (40%). Table 5 shows that those who chose to use their own writing did so to improve teaching effectiveness and content exposure (58%) or to recreate the traditional atmosphere of class (19%). Some of the answers given by professors, for example, were:

It is easier to show the progress of an exercise.

I believe that the professor's personal writing makes the text "less cold" and more effective from a didactic point of view.

Table 5. Explain how much you use your writing (writing tablet, sheets shown to students, etc.)—(n = 38).

	Percent
To improve teaching effectiveness and content exposure	58.1
To recreate the traditional atmosphere of class	19.4
I prefer to use other modalities	12.9
I cannot use it	9.7
Total	100.0

We were interested in understanding what actions the professors took, and how often they were teaching using a personal computer in distance learning. In particular, we asked if they activated the camera, shared their screen, and asked students to share their screens, and asked them to explain their habits. Sixty percent *always* activated the camera (Table 6). The open-ended responses that explained this answer are related to choices for relational and communication reasons. For example:

To have more contact with students.

Students follow better.

I like the idea of eye contact.

It is important that students see me, both to create a "classroom" relationship and because I often show objects or "help" myself with gestures.

Those who did not use a camera for distance learning explained that they preferred other educational tools or did not do so for privacy reasons. For example:

I do not think it is necessary and I prefer students to focus on the content of the presentation.

[. . .] since my class consists of 180 students, I prefer not to show myself on video to avoid any unpleasant episodes.

Although it was a small percentage of teachers who did not turn the camera on, we wondered if this choice was related to the number of students following their distance teaching, or whether it was related to the degree course. The Kruskal–Wallis Test, in both cases, did not support this hypothesis, $p > 0.50$.

Eighty-seven percent of professors shared their screens frequently (Table 6, *often* + *always*). The open-ended responses showed that professors took this action because they needed to show resources that they had prepared for the lesson (63%) or because they needed to build the lesson in front of the students (37%). For example:

Sharing is necessary to show what I have prepared, but also to show further examples, to do exercises, to focus on key steps . . . using a writing tablet.

I think it is necessary to share the screen in a presentation, especially for mathematical formulas. I couldn't do without it.

During a three-hour lesson in front of the class, I fill four blackboards at least ten times, because I always have to write, now with no other way I show the many papers I write before each lesson, so I always talk and share.

I use Mathematica software. Students see either my notebook where I explain the topic, or my notebook where I solve a problem.

Table 6. Frequency with which a certain action takes place on the PC during the distance lesson ($n = 38$).

	Activating the Camera	Sharing the Screen
	Percent	**Percent**
Never	21.1	5.3
Sometimes	18.4	7.9
Often	0.0	10.5
Always	60.5	76.3
Total	100.0	100.0

Using natural language in an informal way, mathematical language and iconic representations (diagrams, function graphs, charts, etc.) did not undergo significant variations during the mathematical lectures taught at a distance. In fact, as Table 7 shows, 87% of professors continued to use these three signs (natural language in an informal way, mathematical language, and iconic representations) in the same way as before the COVID-19 pandemic. This means that the modality of distance learning had not affected the way in which the terminology proper to the discipline and its iconic representations were used in teaching practices. This is independent of the number of students attending that particular course (Median test, $\chi^2(2) = 0.53$, $p > 0.50$). Almost all the professors (95%) used gestures less than before or in the same way as before. In particular, the median test, $\chi^2(2) = 8.67$, $p = 0.013$, shows that professors who had more students (percentage of attendants between 75% and 100%) reported using gestures in the same way as before, while those who have few students (percentage of attendants between 0% and 50%) reported having used fewer gestures.

Table 7. Frequency of formats during distance learning compared to the usual presentation of topics? ($n = 38$).

	Natural Language in an Informal Way	Mathematical Language	Iconic Representations	Gestures
	Percent	**Percent**	**Percent**	**Percent**
Less than before	5.3	0.0	10.5	63.2
Same as before	86.8	86.8	86.8	31.6
More than before	7.9	13.2	2.6	5.3
Total	100.0	100.0	100.0	100.0

School teachers on some social networks in Italy often noted that during the quarantine: "distance teaching requires twice as long to prepare a lesson and you can explain half the things you have prepared". We asked the university mathematics professors how much they agreed with this, especially the second part. Table 8 shows that 82% (*definitely disagree* + *quite disagree*) disagreed with this statement, and the distribution of the answer options is significantly different, $\chi^2(3) = 27.05$, $p < 0.001$).

The open answers explaining the degree of agreement reveal that 18% found the distance modality ineffective. Twenty-three percent used similar modalities to their previous ones, and 59% used new teaching modalities to try to maintain the same standard as when teaching in person. The fact that the same modalities used in person were adopted even at a distance, and that new "compensatory" tools were used (such as prepared notes, slides, etc.), allows us to conclude that teaching on Teams had not reduced the number of topics explained by professors. Open answers from the professors included:

> *With distance learning, having already prepared the material/presentation to share during the lesson (which then becomes teaching material available to students), it is possible to explain more quickly and therefore explain more topics than in traditional lessons.*
>
> *The use of the blackboard meant more time to explain the topics. Students don't have to take notes. I provide them at the end of each lesson.*
>
> *Actually, with distance learning you do more with the same amount of time.*
>
> *I spend lot of time handwriting what I would write on the blackboard while I explain, and because I can't see the eyes of the students I'm not inclined to repeat concepts or demonstrations, and so I do everything I set out to do.*

Something more emerges from the open answers: the professors managed to transpose even more knowledge than they were able to transpose in person. Some said that this was probably due to not having to write on the blackboard and wait for the students to transcribe the notes, others said that by sending the (previously prepared) notes to the students, they could afford to go faster. Some also said that more was done because there was a lack of interaction with the students.

Table 8. How much you agree with these statements: "with distance learning you can only explain half the things you have prepared"? (n = 38).

	Percent
Definitely disagree	60.5
Quite disagree	21.1
Quite agree	7.9
Definitely agree	10.5
Total	100.0

We investigated long-distance professor–student relationships through the two following questions. First of all, we used a Likert scale to ask whether the professors could perceive whether the students were keeping up with them in the lesson, and then used an open question to ask what strategies they adopted for perceiving this. Twenty-four percent said *definitely not*, 40% *more no than yes*, 26% *more yes than no*, and 10% *definitely yes*. In most cases, therefore, professors were not able to perceive whether students were keeping up with them in the lesson, and this is also demonstrated by the chi-square test analysis: $\chi^2(3) = 6.42$, $p < 0.10$. A Kruskal–Wallis test showed that this inability depends on neither the number of students attending the course, $\chi^2(2) = 0.699$, $p = 0.70$, nor on the degree course, $\chi^2(2) = 0.960$, $p = 0.62$. The double entry table (Table 9) correlates the strategies adopted by professors with the previous answer. We can see that those who claimed they were able to perceive that the students were keeping up with the lesson did so by asking the students directly whether they were following the explanation (30%), by asking the students questions about the content they had explained (27%), or by deducing it from the interventions made by students (24%).

One comparison was related to concerns about the use of distance learning that had been raised before the COVID-19 pandemic, with respect to concerns about distance learning during the COVID-19 pandemic. Table 10 shows that before starting distance learning due to the pandemic, 74% (*pretty concerned* + *very concerned*) were concerned about the thought of having to give their lessons online. This percentage dropped to 40% during the pandemic wave. This suggests that the professors' concerns were lessened when practicing distance learning.

Table 9. Cross-tabulation between degree of agreement and strategies adopted to perceive whether students are keeping up with the lesson (n = 38).

			Categories of Answers for Professors' Strategies				Total
			Asking the Students If They Are Following the Explanation	Understanding via Student Interventions	Asking Questions about the Lesson Contents	Not Verifiable	
Likert scale items	Definitely not	% of Total	3.1%	0.0%	0.0%	12.1%	15.2%
	More no than yes	% of Total	12.1%	12.1%	12.1%	6.1%	42.4%
	More yes than no	% of Total	12.1%	12.1%	6.1%	0.0%	30.3%
	Definitely yes	% of Total	3.0%	0.0%	9.1%	0.0%	12.1%
Total		% of Total	30.3%	24.2%	27.3%	18.2%	100.0%

Table 10. Likert-scale response percentages about concerns regarding distance learning before and during COVID-19 pandemic (n = 38).

Likert-Item Items	Concern before COVID-19	Concern during COVID-19
Not at all concerned	7.9%	36.8%
Little concerned	18.4%	23.7%
Pretty concerned	42.1%	31.6%
Very concerned	31.6%	7.9%
Total	100.0%	100.0%

As noted in the methodology section, our sample respondents adopted Microsoft Teams as the e-learning platform for distance learning. We emphasize here that none of the professors in the universities at Catania, Messina, or Palermo had received training in the use of this platform. This is certainly due to the fact that the academic community found itself suddenly (within five days) required to provide distance learning in order to continue guaranteeing the right to university education, despite the health emergency and the pandemic situation. Although professors discovered the Teams functions on their own, some expressed their willingness to continue using it. In fact, professors plan to continue using Teams and/or the other platforms at the end of the COVID-19 pandemic (Table 11). Twenty-six percent said they do not want to use any platform, and 5% were unable to respond. Teams was confirmed as the choice of 58% of respondents. Whereas 39% had been using other platforms, there is now increased willingness to use a digital platform, Teams, in the future.

Table 11. Which of these e-learning platforms do you plan to continue using after the end of COVID-19 pandemic? (multiple response options)—(n = 38).

	Percent
Teams	28.9
No platform	26.3
Teams and Studium	18.4
Studium	10.5
Teams and Moodle	10.5
I do not know	5.3
Total	100.0

We wanted to investigate whether the age of the respondents affected this choice. It emerged that 77% of those up to the age of 55 said they wanted to continue using Teams or similar, while 57% of those over 55 said they did not want to continue using it. The older a professor, the less willing they are to continue using distance learning platforms. This assumption is confirmed by the fact that the distribution of the answer is significant, $\chi^2(1) = 4.35$, $p < 0.10$.

Using open questions, we asked the professors to comment on how much they felt they had gained and lost through distance learning. Table 12 shows the cross-tabulation of the thematic categories of answers that emerged for both issues. The chi-square analysis related to this contingency table was not significant, $\chi^2(12) = 15.72$, $p = 0.21$, meaning that the association between the two thematic variables were no different from chance. However, considering each variable individually (see the total column in the Table 12), the frequencies of the identified categories were significantly different for the loss in distance modality, $\chi^2(4) = 22.26$, $p < 0.001$, with the "Human exchange" category more frequent compared to the other categories. No differences were revealed for the gain in distance modality variable.

Table 12. Cross-tabulation between thematic categories of "Gain in distance modality" and "Loss in distance modality" (n = 38).

			Thematic Categories for "Loss in Distance Modality"				**Total**
			Human Exchange	**Interaction for Learning Purposes**	**Both (the Previous Ones)**	**No Loss**	
Thematic categories for "Gain in distance modality"	No profit	% of Total	13.2%	5.3%	7.9%	0.0%	26.4%
	Better learning/involvement of students	% of Total	13.2%	7.9%	0.0%	2.6%	23.7%
	Improvement of didactical/technological skills	% of Total	10.5%	0.0%	7.9%	0.0%	18.4%
	Less organizational/physical stress	% of Total	5.3%	2.6%	7.9%	0.0%	15.8%
	Improved lesson planning	% of Total	2.6%	10.5%	2.6%	0.0%	15.7%
Total		% of Total	44.8%	26.3%	26.3%	2.6%	100.0%

We note that compared to earnings, 21% of professors believed they benefited from an improvement in terms of their didactical and technological skills:

I discovered other ways of teaching, through the use of technology.

I learned how to use the iPad board and the Microsoft Teams platform.

Twenty-three percent believed that the distance modality had a positive impact on learning/involvement of students.

The ability to produce a PDF file that reproduces exactly what I wrote on the board. In this way students will find faithful notes and avoid transcribing inaccuracies that often cause confusion on important issues such as definitions or various observations.

A greater sense of responsibility on the part of the students, who have understood that to follow well they must "study" punctually and in advance.

The blackboards are published, the lesson is recorded, I have the ability to use software and also to show a video, which in traditional lessons I did not do because it was too laborious.

Fifteen percent said that having to do the lesson at a distance improved the planning of the lesson, and another 15% said they suffered less stress on a physical and organizational level.

The in-depth planning of the lessons.

The lesson is smoother, and the material I have prepared will still help me in the years to come.

Comforts.

Time.

The majority (26%) said they had not benefited from any earnings.

The majority (43%) complained about a loss of human exchange. Twenty-seven percent complained of losing interactions with students for learning purposes, and another 27% claimed to have lost both.

A part of human contact, useful to transmit the passion for discipline.

Eye contact with students.

Human contact with students.

The ability to see positive or negative reactions to what is proposed not explicitly manifested through interventions.

When I saw the empty eyes of so many students I understood that they hadn't understood me and so I repeated it all with other words until I saw their eyes full: I lost the joy of having been able to fill those eyes.

We emphasize that student cameras were generally off and that the Teams platform does not allow the presenter to see more than one student when they share the screen, or more than nine when they do not. The presenter thus cannot see the students' eyes.

5. Discussion and Conclusions

The e-learning system is a complex system that involves several kinds of capabilities (and people). It is not easy to change in a few days from the way one has taught for years to a new way, without any training, while worried about the health, economy, and social perspective of your country. We asked how, in this situation, professors were able to move to distance teaching. The problems of adapting ways of teaching to the new e-learning environment are particularly relevant when teaching mathematics, because of the frequent use of symbols and formulas, as well as gestures and body. Let us review how the university professors adapted themselves to the new teaching modality, attempting to teach "in the same way" in this new environment. We discovered that professors moved from lecturing with chalk and blackboard (100% used them) to lecturing with writing tablets (61%), which they had never used before, and slides or mathematical software (79%), which they had used to some extent (only 15.8% used slides or software before the pandemic). Most of the professors involved in our research started a process of instrumental genesis, through the appropriation of new artifacts (writing tablets, mathematical software, e-learning platform) in an *instrumentalization* phase: they managed to use them, found their potential and limits, but only to recreate the same teaching they were used to without the artifacts. So far, they had not reached an *instrumentation* phase, with the proper use of the artifacts with appropriation of their schemes of use. The professors we dealt with had a strong belief about teaching math (core in the MTSK model [19], together with math belief): that lecturing is the only way to teach mathematics. For instance, a professor stated: "*I do not have a writing tablet, blackboards, or anything else so the only way is to write by hand before the lesson, scan the sheets that are many and insert them on the PC to share during the lesson: hard work*." They thus continued in the "same way", by using different artifacts, technological ones. Writing tablets and other strategies were used to show their personal handwriting, because almost 60% believed that it was important to improve teaching effectiveness and content exposure (and not only to recreate a sort of classroom environment). No one claimed to have chosen the writing tablet so that they did not have to prepare the lectures in advance and so to save time, suggesting that the use of personal writing was not a comfort choice but rather a didactic one, due to personal beliefs about mathematics, according to this belief which has to be written, and written by hand, because "*I believe that the professor's personal writing makes the text "less cold" and more effective from a didactic point of view*". The use of slides and mathematical software also seems to have been a didactic choice, and not a comfort choice. It required an extra effort, especially in terms of the details to be prepared for the lessons. Nevertheless, professors preparing the lectures in all the details increased from 39.5% to 68.4%. It was probably anxiety and worry that drove them to make detailed preparations, to prevent possible trouble. We want to stress that 81.8% of professors who started to prepare their lessons in detail during the emergency scored their worry about distance teaching as 3 or 4 on a Likert scale from 1 (not worried) to 4 (very worried).

The use of handwriting, slides, and software discussed so far is especially valid for "blackboard teachers" [14], those who, for instance, did not activate their camera because they "*prefer that students focus on the content of the presentation*". As for the "body teachers" [14], those who, for instance think that "*it is important that students see me, both to create a 'classroom' relationship and because I often show object or 'help' myself with gestures*", we find out that only 5.3% used gestures more often than before, regardless of the number of students. Those with a higher percentage of students use them in the same way and no less than before. Therefore, to answer our second research question, the number of students does not apparently affect the use of gestures. Using natural language in an informal way, mathematical language and the iconic representations was also independent of the number of students attending that particular course.

As for the disadvantages of distance teaching, 97.2% of answers reported having lost interaction for human exchange or learning purposes. Today, we are very used to technological devices, and we use them both for personal and didactic reasons: artifacts [12] can mediate mathematical topics, exactly as musical instruments can mediate the composer's feelings when we listen to music. In the situation illustrated in this paper, we had "instruments", but the players and the audience were so far from each other that we wonder whether the concert will be a success or not. We think that face-to-face communication is important in mathematics education, as in musical concerts, from both points of view: that of the students (the audience) and the teachers (the players). Attending a concert is not the same as watching it on the television, even if it is a live concert, and it is not the same thing to play in front of a reactive audience or in an empty theatre. We want to emphasize that there is a big difference between thinking about a course formatted as an on-line course and adapting a course designed to be a face-to-face course as a distance course. In the musical metaphor, a player who goes to record a new disk is alone in the recording studio, and can play the music until the record is perfect (on-line courses). Alone in the theatre, a player can also execute a perfect performance, but without infusing the audience with the feelings involved in the music (distance courses in the emergency). Looking into the eyes of "audience" enable an understanding of whether teaching is effective or not. Some professors "lost the joy of having been able to fill those eyes". Another said "*I like the idea of eye contact*".

The final and central question to be answered is about the benefits of distance teaching and the opportunities that arise from difficulty. Fifteen point four percent of professors reported that extra time was a benefit (because, they said, you save the time traveling to and from the office) or comfort (because, they said, you are at home). Twenty-five point six percent claimed to have gained nothing. We want to emphasize that the other 59% found benefits in terms of better teaching or learning. In particular, 20.5% found an improvement in their didactical or technological skills. Fifty-eight percent wished to continue using the Teams platform, which no one had used before the emergency and everybody learned without any training. As shown in the previous section, the choice, as expected, is affected by age (the older professors are the least willing to use digital platforms). We hope that those professors who want to use the artifact will develop an instrumentation phase in the instrumental genesis process.

It is said that a crisis is a terrible opportunity to learn and grow up, and we ask whether we, as academics, were able to take this as an opportunity. We think that the professors we analyzed, starting from a worrying situation, showed a competence of vicariance, trying to solve unexpected problems, trying to change their habits, and trying to find something to learn. In fact, a gain took place when they acquired new skills that they will use in the future.

Several professors who helped in the research were available to be contacted again for further research. Our aim is to validate our results with them through interviews and focus groups. This further step will also take into account the fact that the COVID-19 pandemic situation is still ongoing and that they are still teaching at a distance.

We would also like to point out that in the same period during which we administered the questionnaires to university professors, a specular questionnaire was administered to the students of the three Sicilian universities (Catania, Messina, Palermo), with the aim of analyzing the distance teaching from the students' point of view in terms of emotions, learning, and advantages/disadvantages. We therefore intend to engage with the subsequent analysis to show the other side of the coin.

The game is not over!

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Article

Challenges and Opportunities for Russian Higher Education amid COVID-19: Teachers' Perspective

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Abstract: The COVID-19 pandemic has tremendously affected higher education systems in Russia and all over the world, forcing to transform curriculum into an online format, which is a challenge for all the educational process participants. The current study discusses the implementation of online learning amid the COVID-19 pandemic in the Russian higher education context and investigates the challenges experienced by university teachers during this period to define their readiness for online education. To address the above-mentioned issues, a study was conducted in Peter the Great St. Petersburg Polytechnic University. A variety of methods of scientific and pedagogical research were used including systematic structural analysis, synthesis, work with research papers, the generalization of experience and experimental work, observation, surveys, etc., with 87 university teachers asked to respond to several sets of questions describing their online teaching experience after the launch of online education amid the COVID-19 pandemic. The analysis of the participants' answers helped to identify the following main challenges experienced by university teachers: computer literacy level, the university electronic environment and support, academic staff readiness and students' readiness for online learning, the last two being the most important hindering the implementation of the efficient online education process. It was also underlined by most respondents that methodological work of a teacher in a digital educational environment differs from conventional teaching methods. Thus, psychological, technological, methodological support and teachers' professional development programs are of vital importance to minimize the negative impact of the rapid changes of the educational process and to ensure efficient online education.

Keywords: COVID-19 pandemic; electronic educational environment; online education; online teaching challenges

1. Introduction

The COVID-19 pandemic has affected the higher education system in Russia, which has led to a massive shift to online education, influencing students, teachers and educational establishments greatly. Higher educational institutions did their best to transform curriculum into an online format, trying to minimize the negative impact of the rapid changes on the educational process and to ensure nonstop teaching and learning. The transformation of all the existing courses online simultaneously within days literally is a test of organizational agility [1] and a challenge for all the educational process participants.

E-learning is not a new concept for Russian higher education. The Decree of the President of the Russian Federation dated 7 May 2018 No. 204 "On National Goals and Strategic Tasks of the Development of the Russian Federation for the Period until 2024" set the task of creating a modern digital educational environment by 2024, ensuring high quality and accessibility of all forms and levels of education. The priority goals of creating a digital educational environment are described in the federal educational standards of higher education, at all levels of higher and postgraduate education, as the main priorities of the modernization of the institution of Russian national education. Several leading universities took part in the development of academic educational projects, national open education platforms relying on mass open online courses (MOOCs), learning management systems (LMS), etc.

Many scholars noted the positive impact of the electronic educational environment on improving the quality of the educational process. Thus, it enhances the efficacy of knowledge, fosters critical thinking and an aptitude for life-long learning, develops self-education and information processing skills, making the process of learning more active, interesting and enjoyable [2–6] and enabling a higher degree of interactivity and collaboration among teachers and students [6–9].

However, it should be underlined that the above-mentioned studies were conducted in normal circumstances describing the implementation of online courses with lesson plans, teaching materials and technology support teams designed in advance.

Moreover, despite the constant development of technologies and the emergence of new educational web services, as well as many years of state policy on the formation of a digital educational environment, its potential has not been used at its full capacity by Russian universities. Only a third of university students study using e-learning technologies.

The outbreak of COVID-19 forced universities to transform curriculum into an online format that resulted in many challenges with the most important question remaining unanswered—is higher education prepared for the forthcoming digital era of learning [10]?

The implementation of online learning is closely connected with teacher's readiness to work in a digital educational environment [8,11,12]. According to Mtebe and Raphael [13], instructor quality has been found to have a significant effect on learners' satisfaction with an e-learning system.

Despite the widespread use of information communication technologies (ICTs) in the educational space, teachers' lack of skill to work in the new digital educational environment is an acute problem [14–17]. Some scholars underline a lack of "pedagogical digital competence" that is defined by J. From [18] as "the ability to facilitate students' learning in the best possible way by regularly applying the knowledge and skills in preparing and implementing ICT supported teaching based on theory, best-validated experiences". Thus, a teacher in the current situation should be able to organize his own teaching activities by making effective use of modern technologies, i.e., understanding pedagogical issues of organizing an online lesson, discussions during a webinar, etc. That is why it is of vital importance to study teachers' readiness to work in a digital educational environment.

The current study will focus on the problems mentioned above, discuss the implementation of online teaching and learning amid the COVID-19 pandemic in the Russian higher education context, and investigate the challenges experienced by university teachers during this period to define their readiness for online teaching and learning.

2. Study Background

It should be mentioned that Peter the Great St. Petersburg Polytechnic University has gained extensive experience in organizing educational activities in an electronic format. The digital educational environment of the university includes electronic information resources, electronic educational resources, a combination of information technologies and telecommunication technologies, ensuring the successful mastering of educational programs by students online. The university took part in the creation of the national portal "Open Education"—a modern educational platform that offers online courses in basic disciplines studied at Russian universities. At the beginning of 2016, the university received the status of partner of Coursera, the largest international project in the field of education. It also offers a number of MOOCs. There are a number of training programs offered for teachers, such as "Tools and services for digital content development and e-learning organization", "The design of educational materials for an online course", etc.

The outbreak of COVID-19 forced Peter the Great St. Petersburg Polytechnic University to transform all the existing courses for bachelor and master degree students online. Online learning and teaching are implemented on several platforms, including LMS Moodle. Several MOOCs are also offered. For all disciplines (modules) of the current term, online courses have been created. To ensure interaction between students and teachers, MS Teams platform is used, where webinar rooms for each discipline were created with automatic generation of webinar sessions.

To facilitate the transition to online teaching, step-by-step instructions (teaching materials, including videos) were developed to help the teachers. Additionally, training webinars are held on a regular basis, and a helpline and IT support teams were organized.

The effectiveness of the educational process in a given format is enhanced by productive use of teaching materials (electronic textbooks, study guides, tests, methodological recommendations, etc.) of the university's electronic document base, which is open to students, teachers and university staff. The academic staff work is aimed at adapting the basic approaches of education and teaching methods to the existing realities of online learning and interaction with students during the COVID-19 pandemic.

3. Materials and Methods

The objective of our study is to empirically identify and study the challenges experienced by teachers in Peter the Great St. Petersburg Polytechnic University after the launch of online programs amid the COVID-19 pandemic in order to define teachers' readiness to implement e-learning efficiently. Methods of scientific and pedagogical research are widely used in this paper: systematic structural analysis, synthesis, work with papers, generalization of experience and experimental work, observation, surveys, etc. The authors of this article, as actors included in new forms of organization of the educational process, have received and are gaining experience, which can be defined as *participant observation* of the development and consequences of the radical introduction of online education.

In this study, 87 university teachers took part. The present study targeted respondents who belonged to different generations: 20 young scientists aged under 35, 52 teachers aged 36–55 years old and 15 teachers 55+. The study started in March 2020 when the lockdown in Russia began and finished in May 2020, including several stages of experimental research.

The first step of the research dealt with studying the respondents' background and working out several sets of questions to assess university teachers' readiness to teach online efficiently. The choice of the questions was based on literature review describing online teaching challenges and barriers during the COVID-19 pandemic and personal teaching experience of the authors [19–24].

The next step of the study included a number of online individual interviews with the participants of the study to define their perceptions of online teaching advantages and disadvantages. Microsoft Teams was used to conduct the interviews.

The third stage dealt with the results' analysis. The obtained results were summarized using descriptive statistics, as appropriate.

4. Results

This section describes the results of the study conducted in Peter the Great St. Petersburg Polytechnic University to define teachers' perceptions of online teaching and learning during COVID-19, the challenges they faced and the Russian higher education readiness level to implement online teaching.

In this study, 87 university teachers aged 25 to 65 with teaching experience from 3 to 35 years took part; 75% of respondents have a degree ("candidate/doctor of sciences"); most conduct classes for both bachelor and master students majoring in Engineering and Humanitarian Sciences. The details of the background of the participants are presented in Table 1.

Table 1. Summary of participants' characteristics.

		Number of Participants	Percentage
Age	25–35	20	23%
	36–45	30	35%
	46–55	22	25%
	56–65	15	17%
Education	Postgraduate degree	15	17%
	Candidate of sciences	50	58%
	Doctor of sciences	22	25%
Teaching Experience	3–10	15	17%
	11–20	25	29%
	21–30	32	37%
	31–40	15	17%
Gender	Male	37	42%
	Female	50	58%

The teachers' readiness for online teaching and learning is largely determined by computer literacy skills and the ability to use ICTs in the educational process efficiently. The questionnaire included a self-assessment task, according to which the teachers were able to assess the level of their computer literacy on a 5-point scale which ranged from 1 (poor) to 5 (excellent) (Table 2).

Table 2. The assessment of teachers' computer literacy level.

	Skills	N	Mean	St. Dev.
1	Ability to use search engines	87	4.30	0.70
2	Ability to install software	87	4.30	0.80
3	Access to high-speed internet at home	87	4.80	0.70
4	Ability to use the internet for academic research purposes	87	4.20	0.70
5	Word Processing	87	4.60	0.50
6	PowerPoint Processing	87	4.50	0.60
7	Ability to use the network to communicate and share data with others	87	4.30	0.80
8	Familiarity with Learning Management System (LMS)	87	4.10	1.09

Computer literacy skills level received a high evaluation from the participants—ability to use search engines (mean = 4.3), word processing (mean = 4.6), ability to use the network to communicate and share data with others (mean = 4.3). Regarding familiarity with Learning Management Systems (mean = 4.1), most respondents had experience working with LMS Moodle only. Cronbach's Alpha scored 0.78 which shows that the questionnaire was reliable.

Evaluating teachers' readiness to implement online teaching and learning during the COVID-19 pandemic and their attitudes to it, participants of the study were asked to respond to several questions (Table 3). The 5-point Likert scale ranging from 1 (completely disagree) to 5 (completely agree) was used.

Table 3. Teacher's readiness to implement e-learning.

	Questions	N	Mean	St. Dev.
1	I have sufficient knowledge and skill to use e-teaching during the COVID-19 pandemic	87	3.70	0.70
2	I have experience in using e-learning	87	3.80	0.90
3	I prefer conventional learning than e-learning	87	4.30	0.80
4	I need to learn how to use my computer for e-learning	87	2.60	1.07
5	The use of e-learning during this pandemic is not convenient for me	87	4.30	0.80
6	My discipline is suitable for e-learning	87	3.80	0.80
7	E-learning is a waste of time during this pandemic	87	1.90	1.13
8	Teaching online differs greatly from conventional teaching	87	4.70	0.50
9	I have troubles designing learning materials for an electronic environment	87	4.10	0.90
10	I lack skills of efficient communication with my students online	87	3.50	1.14
11	The University provides technical support for e-learning	87	4.30	0.50
12	The platforms chosen by the University to support e-learning are easy to use	87	3.50	1.04
13	The platforms chosen by the University include the necessary features and functions I need	87	3.30	1.07
14	There are enough and clear instructions/training about how to organize a digital educational process	87	3.80	0.80
15	I receive a satisfactory and timely response from the IT services staff	87	4.20	0.80
16	I feel the lack of computer literacy skills	87	3.60	1.01
17	The preparation of electronic education content is very time-consuming	87	4.70	0.30
18	It is difficult to adopt new teaching methods within days	87	4.60	0.40
19	I feel the need to be taught how to work in a digital educational environment	87	3.90	1.04
20	E-teaching and learning during the coronavirus outbreak brings more advantages than disadvantages	87	2.20	1.17

The respondents were almost unanimous in stating that teaching online differs greatly from conventional teaching (mean = 4.7) and that preparation of electronic education content is very time-consuming (mean = 4.7). The participants were positive about their knowledge and skill to use e-learning and teaching during the COVID-19 pandemic (mean = 3.7). Most of them have some experience in using e-learning in their background (mean = 3.8). The need to be taught how to work in a digital educational environment was also expressed by most of the respondents (mean = 3.9). The Cronbach's Alpha was 0.82, showing the reliability of the results.

According to Almazova et al. [25], "e-learning implementation into the educational process entails not only the development of new interactive methods of teaching, but also changes pedagogical process concerning students who are accustomed to the traditional full-time education system. The lack of students' skills for the intensive use of information technology in the educational process can be one of the obstacles to the successful application of e-learning". That is why participants of the study were asked to evaluate their students' performance in a digital educational environment on a 5-point scale—from 1 (completely disagree) to 5 (completely agree) (Table 4).

Table 4. Students' performance online during the COVID-19 pandemic.

	Questions	N	Mean	St Dev.
1	My students have sufficient knowledge and skill in the use of e-learning during the COVID-19 pandemic	87	3.80	1.15
2	My students are able to perform tasks in the platforms chosen for e-learning	87	4.40	0.60
3	My students face some technological problems when taking part in the electronic educational process	87	4.30	1.04
4	My students lack motivation to study online	87	4.10	0.70
5	My students are enthusiastic to take part in webinars and online discussions	87	3.00	0.90
6	My students fail to meet deadlines	87	4.30	0.60
7	My students experience psychological discomfort studying online during the COVID-19 pandemic	87	3.00	0.90
8	My students do not have devices/high-speed Internet connection for the use of e-learning	87	2.30	0.50
9	I feel that my communication with the students online is not productive	87	2.40	1.23

Describing students' performance online during the COVID-19 pandemic, the participants underlined the following issues: the students have sufficient knowledge and IT skills in the use of e-learning (mean = 3.8), most students fail to meet deadlines (mean = 4.3) and lack motivation to study online (mean = 4.1). Cronbach's Alpha scored 0.89 which shows that the questionnaire was reliable.

The final part of the survey was connected with the identification of the problems, challenges and general perceptions of the teachers concerning online learning during the COVID-19 pandemic. The participants responded to open-ended questions during online individual interviews organized in Microsoft Teams. Summarizing their answers, it should be noted that teachers were active and motivated to maintain students' interest in studying, to transform traditional curriculum so that conducting classes was not just a formality, but a productive process of knowledge acquisition. Among the factors that motivate teachers to participate in online learning are the intellectual challenge, and personal motivation to master online technologies.

At the same time, the analysis has shown that the participants are almost unanimous in the opinion that conventional teaching competencies and skills do not guarantee the success of the online educational process. Thus, one of the respondents, describing the advantages of online teaching, mentioned the following: "A teacher's role is changing. A teacher becomes a facilitator who has an opportunity to use different online platforms to upload study material, multimedia resources, set deadlines, conduct different kinds of activities and communicate with students 24/7". As for the disadvantages, one of the respondents underlined the following: "When teaching humanitarian disciplines and foreign languages, there is a strong need for collaborative tasks for students—pair work, small group discussions, etc. Given the fact that we use LMS Moodle and Microsoft Teams to conduct online classes, it seems next to impossible to organize this face-to-face productive communication". One more opinion deals with the following: "To teach online efficiently, one should be ready to use a great number of online applications to organize a productive lesson, including different LMSs, web applications, etc. We have a lot to explore, which take much time and effort". Describing advantages, disadvantages, and their perceptions of online teaching and learning, the following issues were named by respondents (Table 5).

Table 5. Advantages and disadvantages of online teaching.

Advantages	Disadvantages
Educational process flexibility (68%)	Inability to use a number of educational methods available in an offline class (discussion in small groups, group discussions, etc.) (77%)
An opportunity to reuse recorded educational material (videos, presentations, etc.) (46%)	Limited communication with students (71%)
Professional development (46%)	Online/video classes are not an effective alternative to the conventional educational process (61%)
Interactive format (32%)	
An opportunity to try new technologies (15%)	

However, as the results of the survey have shown, when implementing online teaching, most respondents experienced certain difficulties which become a serious obstacle to the efficient digital learning process:

- Lack of digital literacy;
- Lack of time for self-education, for the creation of electronic educational materials, etc. Teachers emphasized the significant time spent on preparing online educational content. It was found that it takes twice as much time as to design traditional educational materials.

Several more issues underlined by the teachers included:

- Inability to organize productive interaction with students online;
- Inability to use active/collaborative teaching methods;
- Conservatism, lack of flexibility.

5. Discussion

The present study was undertaken to investigate the level of university teachers' readiness to implement e-learning during the COVID-19 pandemic in Russia as well as the challenges they faced. Taking into consideration the above-mentioned, the following important points should be discussed.

The analysis of the survey answers shows that even having a fairly high level of computer literacy and IT support from the university, most teachers still encounter some difficulties that are relevant for the study case. The following challenges were identified—computer literacy level, the university electronic environment and support, academic staff readiness and students' readiness for online learning. These findings are in line with previous studies that define a number of online teaching barriers. According to Rogers [26], the following barriers that prevent academic staff from implementing online education effectively are socio-cultural related factors (e.g., economics and location), personality-related factors (e.g., age, gender, attitudes and beliefs), and the extent of the exposure (including support and training) to new technologies. Jones [27], in his studies, differentiated teacher-level and institutional-level barriers. Hew and Brush [28], in their study, named several issues preventing effective online teaching implementation including resources, technology, time, and technical support; technology-based teaching knowledge and skills; institution barriers; staff attitude and beliefs, and subject culture.

As for computer literacy-level barriers, some issues were mentioned by the teachers who are older than 55 years old, including the need for more instruction and extra support from IT teams. This is also in line with the findings from Al-Fadhli [29] and Al-Sarrini [30] who concluded that 45+ faculty members were less willing to employ e-learning in their teaching and learning practice.

Crucial challenges (barriers) experienced by teachers in Peter the Great St. Petersburg Polytechnic University, according to the study findings, were academic staff readiness and students' readiness for online learning and teaching during the COVID-19 pandemic. Most respondents underlined that the methodological work of a teacher in a digital educational environment is significantly different from conventional forms of teaching—87% of respondents agreed with this statement.

A teacher must practice active collaborative teaching methods and help students to form their own learning styles online; study the possibilities of online learning platforms and overcome difficulties and barriers of electronic communication. To manage an online course efficiently, teachers should know how to encourage students to learn independently, develop self-discipline and planning, provide timely assessment of student work and provide prompt feedback. In a digital educational environment, a teacher should ensure that students concentrate on learning tasks, develop critical thinking skills, reflect on achievements and failures, and encourage students to share their experience with peers online.

A teacher's role is of vital importance, influencing the quality of the online teaching and learning process [31]. With the introduction of modern technologies in the educational process, a teacher's work—its structure, content, etc., are changing. The methodological work of the teacher in a digital educational environment differs from conventional teaching methods [32]. It is noted that teachers traditionally have extensive knowledge in the field of their subjects and much less knowledge in the field of information technology and electronic pedagogy. This is an obstacle to effective online teaching and learning.

To be able to teach online successfully and efficiently, it is not enough to have computer literacy skills and excellent knowledge of one's subject. One should master online pedagogy involving a combination of knowledge and skills in providing the ability to design electronic educational courses; implementation of distance and online education; organization of efficient online interaction and collaboration between a teacher and a student. The importance of the development of online pedagogy skills with social interactions and online discussions is underlined by Cantamessa [33], Mandernach et al. [34], Steele et al. [35], Kilgour et al. [36] and Green et al. [37]. According to Houlden and Veletsianos [10], "the clear need for post-secondary online learning expertise in the COVID-19 pandemic crisis should serve as a reminder that institutions need to cultivate this competency".

Thus, a teacher's objectives when organizing online teaching and learning are the following:

- creating conditions for students to master online learning skills;
- providing methodological support for students working with electronic educational materials;
- formation of critical and creative thinking skills among students, and information processing skills;
- actualization of students' self-education needs and skills to use modern technologies to optimize the educational process;
- development of students' sustainable motivation to study.

As for students' readiness for online learning, it was noted by the respondents that due to general high technical literacy of modern "digital natives", it is not difficult for them to master the technical side of online education quickly. However, according to teachers' responses, most students face a lack of organizational and planning skills and face self-regulation challenges [38–40]. Inability to meet deadlines influences students' level of motivation [19,22]. At the same time, the teachers should not forget that this whole situation is new and challenging for students, too, and that they should be given time and help to become used to it [41].

Thus, efficient transformation of curriculum into an online format during the COVID-19 pandemic in Russia will be possible under the following conditions:

- assistance with coping with psychological barriers when implementing teaching activities online;

- a developed material and technical base, including both hardware (computers, high-speed Internet access, etc.) and software (LMS, electronic textbooks and educational materials, diagnostic and knowledge control systems, etc.);
- organizational and methodological support, including recommendations connected with implementing teaching activities in a digital educational environment;
- teachers' professional development programs;
- provision of regulatory support from the university focusing on determining the academic workload of a university teacher when working online.

The above-mentioned goes in line with Al-Oteawi [42] and Keengwe et al.'s [43] findings who stated that staff professional development programs are of high importance.

6. Conclusions

Today, higher education in Russia and all over the world is in a situation of a high degree of uncertainty, which makes it necessary to purposefully increase the level of technological and methodological readiness of university teachers for online teaching and learning.

The higher educational system in Russia faced great challenges that require the psychological, technological and methodological restructuring of conventional teaching. The organization of the educational process in a digital educational environment involves innovative teaching activities, based on collaboration among teachers and students, and efficient use of modern technologies.

Thus, during the COVID-19 pandemic, university teachers should be ready to organize and conduct the educational and scientific research activities of students remotely by applying LMS, ICT tools, etc.; to control and evaluate students' educational activities online, and to conduct online conferences, webinars, etc.

Potential problems with the transformation of the curriculum into an online format are connected both with pedagogical and university management issues. According to the findings of the current study, the most important included teachers' and students' readiness level to implement online education. There are many questions, and they have to be resolved quickly. In the context of the COVID-19 pandemic, online education becomes a way to protect the health and life of all participants of the educational process. If the Russian educational system is ready for this quick transformation online, only time will tell. This study is one of the first steps to analyze the situation and find possible solutions to the current problems.

The present study has several limitations, the most important concerning the participants of the study. Only the teachers were involved. We want to underline that it is crucial to know the challenges experienced by teachers when implementing online learning and teaching in order to be ready to deal with them. Further research should deal with students' perceptions of online learning as well.

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education sciences

Review

Asynchronous Environment Assessment: A Pertinent Option for Medical and Allied Health Profession Education During the COVID-19 Pandemic

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Abstract: The emergence and global spread of COVID-19 has disrupted the traditional mechanisms of education throughout the world. Institutions of learning were caught unprepared and this jeopardised the face-to-face method of curriculum delivery and assessment. Teaching institutions have shifted to an asynchronous mode whilst attempting to preserve the principles of integrity, equity, inclusiveness, fairness, ethics, and safety. A framework of assessment that enables educators to utilise appropriate methods in measuring a student's progress is crucial for the success of teaching and learning, especially in health education that demands high standards and comprises consistent scientific content. Within such a framework, this paper aims to present a narrative review of the currently utilised methods of assessment in health education and recommend selected modalities that could be administered in an asynchronous mode during the COVID-19 pandemic. Assessment methods such as open-ended short answer questions, problem-based questions, oral exams, and recorded objective structured clinical exams (OSCE) would be appropriate for use in an asynchronous environment to assess the knowledge and competence of health professional students during COVID-19. Fairness and integrity can be ensured by using technological tools such as video and audio recording surveillance.

Keywords: asynchronous assessment; health education; eLearning; online classes; examination system

1. Introduction

The COVID-19 pandemic is also known as the coronavirus pandemic. It is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) that was first identified in December 2019 in Wuhan, China. The outbreak was declared a Public Health Emergency of International Concern in January 2020, and a pandemic in March 2020. Countries around the world closed educational institutions in an attempt to contain the spread of the virus and approximately 70% of the world's student population from primary to tertiary education (over 1.5 billion learners) were affected by the temporary closure of schools, colleges, and universities owing to COVID-19. The United Nations Educational, Scientific and Cultural Organization (UNESCO) is supporting countries in their efforts to mitigate the immediate impact of school closures, especially more vulnerable and disadvantaged communities, by facilitating the continuity of education for all through remote learning. This pandemic has exposed many inequities and inadequacies in the diverse education systems across the globe. Some education systems are still struggling to convert to a completely online platform due to issues of internet connectivity and a lack of devices and resources for online education systems. The most critical is the misalignment between resources and the needs for teaching and learning. During the pandemic, learners from the marginalised groups are plagued with digital poverty and lack basic access to learning resources and facilities. The lack of a self-directed learning impetus/ interest could leave this group staggering behind their peers. The need to convert traditional classes into a fully online digital platform should ensure that no students are left behind in the process [1–3].

The emergence and spread of COVID-19 has disrupted education at a critical time. In the Northern Hemisphere, the disruptions impacted the second half of the academic year, including the final assessments. The long summer break in the school/post-school education setting provided an opportunity for teachers to prepare for the ongoing changes forced by the COVID-19 pandemic. In the Southern Hemisphere, the academic year had just begun when the pandemic was announced. This situation impacted learning, teaching, and assessment throughout the Southern Hemisphere, and educators were without the advantage of the time to reassess systems in the middle of the calendar year. In the COVID era, the world's universities shifted curriculum delivery to online platforms such as Moodle, Google Classroom, and Blackboard Collaborate, etc., to cater to the students' needs whilst ensuring that academic progress was not hindered. Institutions that offer online classes face many challenges in determining the methods to assess the students' knowledge, skill, and competency via an internet-based approach.

Medical education involves the application of educational theories, principles, and concepts, while delivering the knowledge of theory, practical and clinical components to prepare future physicians and health professionals. The terms medical education and allied health professional education have been used interchangeably [4]. This review is concerned with the impacts of the COVID-19 pandemic on systems associated with the delivery of education and training of medical and allied health care professionals. Assessment is an integral aspect of any teaching and learning system. Learning outcomes drive assessment measures and are critical for the design and structure of a learning environment. The final assessment is a cumulative activity that gives an accurate reflection of whether the learner was able to attain the course learning outcomes. The implementation of high-quality assessment acts as a catalyst and motivates students to perform at a higher standard in the future, by providing an idea of their current strengths and weaknesses. To establish how effectively the learning has taken place, a valid, reliable, cost-effective, acceptable, and impactful assessment is indispensable. Some challenges encountered in the asynchronous assessment include miscommunication/misunderstanding and limited feedback due to a lack of real-time/live interaction with the students. For laboratory and clinical examinations, it is difficult to assess the student's skill and attitude through the asynchronous assessment [5–7]. This paper focuses on asynchronous environment assessment methods in medical and allied health professional education and the limitations associated with its use.

2. The Framework of a Good Assessment

An assessment framework provides a robust roadmap of areas to assess. This framework clarifies the learning outcomes to be accomplished by medical graduates and reflects the areas to be assessed. The framework provides basic grounds for subsequent development, along with technical and practical considerations of appropriateness and feasibility of the assessment. No single method of assessment measures all the learning outcomes equally. The most appropriate assessment methods must be selected, which are aligned with the learning outcomes being tested. An assessment framework enables educators to determine appropriate methods of evaluation that aids in measuring students' learning outcomes. Medical and allied health professional education demands high standards of practice and comprises consistent scientific content. The use of a framework as the foundation for developing assessment is necessary for educators [6,7].

The cognitive domain as per Bloom's taxonomy forms the basis of assessment, however, where the psychomotor and affective domains play a critical role in the training and education of medical and allied health professionals. According to Miller's pyramid, a learner's competence can be evaluated at different levels of proficiency: knowledge (knows), followed by competence (know-how), performance (show how), and action (does) [8,9].

The assessment framework also takes into account the elements and characteristics of a good evaluation, which is defined as the value of an assessment, which is a function of Reliability, Validity, Feasibility, Educational Impact, Cost-Effectiveness. While adhering to the asynchronous assessment framework, it is essential to preserve the principles of integrity, equity, inclusiveness, fairness, ethics, and safety [10–13].

3. Assessment in a Synchronous and Asynchronous Environment

Assessment can be conducted in a synchronous and asynchronous environment. Assessment in a synchronous environment is conducted in real-time and can be face-to-face or online, whereas asynchronous environment interaction does not take place in real-time can be via virtual or any other mode. Difference between synchronous and asynchronous environment assessment is given in Table 1.

Table 1. Difference between synchronous and asynchronous environment assessment.

Synchronous	Asynchronous
Real-time—time bounded	Anytime—the flexibility of time
Less time available for the student to respond to the question	More time available for the student to respond to the question
Exam at one location	Exam at multiple locations—more convenient to the student

During COVID-19, social distancing has become the "new normal" and it is difficult to conduct synchronous examinations face-to-face because they are complex and require significant infrastructural development. Although this is challenging in the immediate pandemic period, many modifications are being tested. This has led to innovations in teaching, learning, and assessment such that asynchronous learning, interactive visuals, or graphics can play a significant role in stimulating the learning process to reach higher-order thinking.

The asynchronous method allows more flexibility regarding time and space. Several online assessment methods are flexible, where the interaction of participants may not occur at the same time. The asynchronous online examination can offer a practicable solution for a fair assessment of the students by providing complex problems where the application of theoretical knowledge is required. The structure allows adequate time for research and response and is a suitable method of assessment in the present situation. In light of COVID-19, the conventional assessment appears far from feasible and we are left with little choice but to implement the online asynchronous assessment methods [10,12,14].

4. Development of Assessment for an Asynchronous Environment

Assessment in an asynchronous environment can be given to the students by posting the material online and allowing students the freedom to research and complete the assignment within the allotted period. It broadens the assessment possibilities and offers the teacher an opportunity to explore innovative tools, because it represents the open book format of an examination but suffers from drawbacks of plagiarism and copying, especially in mathematical subjects. There are also information technology, issues such as software availability and internet connectivity (Figure 1) [12,15,16].

In medical education, asynchronous assessment modalities should require the application of theoretical knowledge as well as critical thinking while interpreting clinical data. These could be realised by case studies and problem-based questions.

A valid, fair, and reliable asynchronous assessment method can only be designed and developed by considering the level of target students, curricular difficulty, and the pattern of knowledge, skill, and competence levels to be assessed. The level of target students refers to the target group, i.e., whether the examination paper is intended for undergraduate or postgraduate students. Checking the knowledge of the undergraduate students' exam papers will be based on their year of study. Students in the first year of study will be assessed on theoretical knowledge, while final year students will be faced with questions that require more clinical-based knowledge.

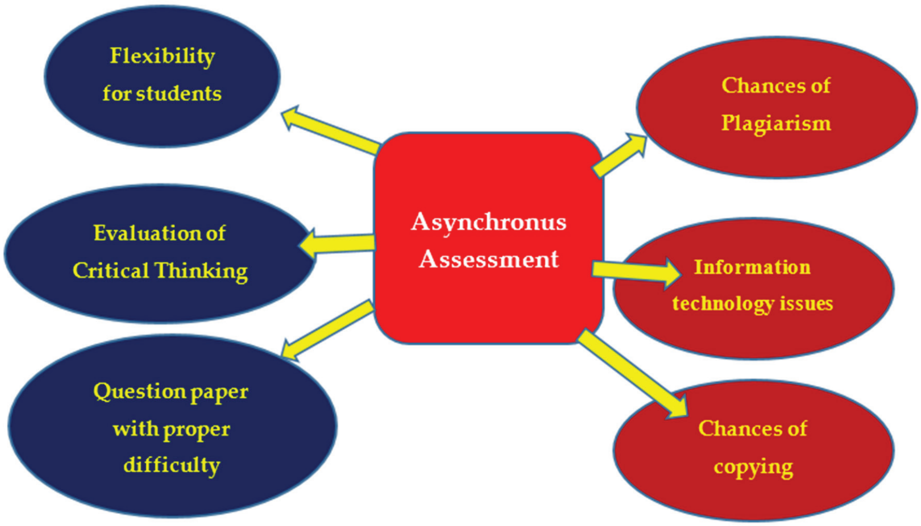

Figure 1. Asynchronous assessment method.

The validation of the assessment method should be done on a trial basis before it is approved for implementation. Evaluation should be conducted based on item analysis of student performance and the difficulty index of questions to differentiate excellent, good, and poor students [13,14,16]. For asynchronous assessment, the teacher utilises various tools to diagnose the knowledge, skill, and competence of students; some of these modalities include open-ended questions, problem-based questions, virtual OSCE (Objective structural Clinical Examination), and an oral examination. A well-designed course with the competencies and measurable learning outcomes helps determine the modes of assessment. Upon choosing a mode of assessment, the questions are developed considering the criteria of reliability, validity, and accuracy. After the questions are prepared and administered to the students, the final step is to evaluate their performance (Figure 2) [15–17].

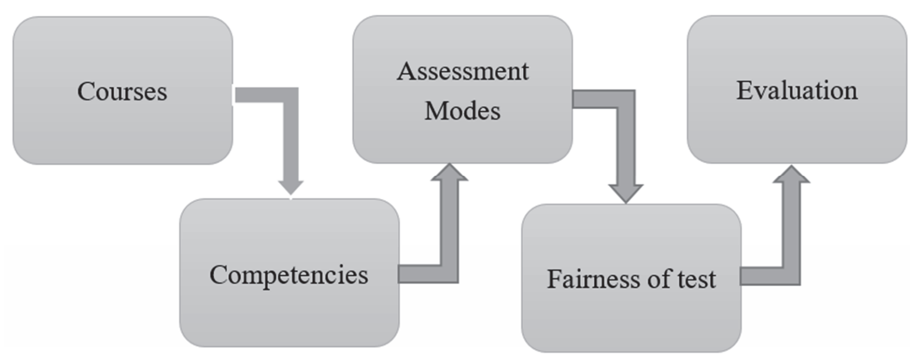

Figure 2. Online assessment and its parameters.

4.1. Open-Ended Questions

Open-ended questions are useful when a teacher wants insight into the learner's view and to gather a more elaborate response about the problem (instead of a "yes" or "no" answer). The response to open-ended questions is dynamic and allows the student to express their answer with more information or new solutions to the problem. An open-ended question allows the teacher to check the critical thinking power of the students by applying why, where, how, and when type questions, that encourage critical thinking. The teacher is open to and expects different possible solutions to a single problem with justifiable reasoning. The advantage of open-ended questions over multiple-choice questions (MCQs) is that it is suitable to test deep learning. The MCQ format is limited to assess the facts only, whereas open-ended questions evaluate the students' understanding of a concept. Open-ended questions help students to build confidence by naturally solving the problem. It allows teachers to evaluate students' abilities to apply information to clinical and scientific problems, and also reveal their misunderstandings about essential content. If open-ended questions are properly structured as per the rubrics, it can allow students to include their feelings, attitudes, and understanding about the problem statement which requires ample research and justifications, but this may not be applicable in all cases, e.g., 'What are the excipients required to prepare a pharmaceutical tablet?'—in this case, only a student's knowledge can be evaluated. Marking open-ended questions is also a strenuous and time-consuming job for the teachers because it increases their workload. Open-ended questions have lower reliability than those of MCQs. The teacher has to consider all these points carefully and develop well-structured open-ended questions to assess the higher-order thinking of the students A teacher can assess student knowledge and ability to critically evaluate a given situation through such questions, e.g., 'What is the solution to convert a poorly flowable drug powder into a good flowable crystal for pharmaceutical tablet formulation?' [17–23].

4.2. Modified Essay Questions

A widely used format in medical education is the modified essay question (MEQ), where a clinical scenario is followed by a series of sequential questions requiring short answers. This is a compromise approach between multiple-choice and short answer questions (SAQ) because it tests higher-order cognitive skills when compared to MCQs, while allowing for more standardised marking than the conventional open-ended question [20–22].

Example 1: A 66-year-old Indian male is presented to the emergency department with a complaint of worsening shortness of breath and cough for one week. He smokes two packs of cigarettes per month. His past medical history includes hypertension, diabetes, chronic obstructive pulmonary disease (COPD), and obstructive sleep apnoea. What are the laboratory tests needed to confirm the diagnosis, and what should be the best initial treatment plan? After four days the patient's condition is stable; what is the best discharge treatment plan for this patient?

Example 2: You are working as a research scientist in a pharmaceutical company and your team is involved in the formulation development of controlled-release tablets for hypertension. After an initial trial, you found that almost 90% of the drug is released within 6 h. How can this problem be overcome, and what type of formulation change would you suggest so that drug release will occur over 24 h instead of 6 h?

4.3. "Key Featured" Questions

In such a question, a description of a realistic case is followed by a small number of questions that require only essential decisions. These questions may be either multiple-choice or open-ended depending on the content of the question. Key feature questions (KFQs) measure problem-solving and clinical decision-making ability validly and reliably. The questions in KFQs mainly focus on critical areas such diagnosis and management of clinical problems The construction of the questions is time-consuming, with inexperienced teachers needing up to three hours to produce a single key feature case with questions, while experienced ones may produce up to four an hour. Key feature questions are best used for testing the application of knowledge and problem solving in "high stake" examinations [23–25].

4.4. Script Concordance Test

Script concordance test (SCT) is a case-based assessment format of clinical reasoning in which questions are nested into several cases and intended to reflect the students' competence in interpreting clinical data under circumstances of uncertainty [25,26]. A case with its related questions constitutes an item. Scenarios are followed by a series of questions, presented in three parts. The first part ("if you were thinking of") contains a relevant diagnostic or management option. The second part ("and then you were to find") presents a new clinical finding, such as a physical sign, a pre-existing condition, an imaging study, or a laboratory test result. The third part ("this option would become") is a five-point Likert scale that captures examinees' decisions. The task for examinees is to decide what effect the new finding will have on the status of the option in direction (positive, negative, or neutral) and intensity. This effect is captured with a Likert scale because script theory assumes that clinical reasoning is composed of a series of qualitative judgments. This is an appropriate approach for asynchronous environment assessment because it demands both critical and clinical thinking [27–29].

4.5. Problem-Based Questions

Problem-based learning is an increasingly integral part of higher education across the world, especially in healthcare training programs. It is a widely popular and effective small group learning approach that enhances the application of knowledge, higher-order thinking, and self-directed learning skills. It is a student-centred teaching approach that exposes students to real-world scenarios that need to be solved using reasoning skills and existing theoretical knowledge. Students are encouraged to utilise their higher thinking faculty, according to Bloom's classification, to prove their understanding and appreciation of a given subject area. Where the physical presence of students in the laboratory is not feasible, assessment can be conducted by providing challenging problem-based case studies (as per the level of the student). The problem-based questions can be an individual/group assignment, and the teacher can use a discussion forum on the learning management system (LMS) online platform, allowing students to post their views and possible solutions to the problem. The asynchronous communication environment is suitable for problems based on case studies because it provides sufficient time for the learner to gather resources in the search for solutions [24,25,28].

Teachers can engage online learners for their weekly assessments on discussion boards using their LMS. A subject-related issue based on lessons of the previous week can be created to allow student interaction and enhance problem-solving, skills e.g., pharmaceutical formulation problems with pre-formulation study data, clinical cases with disease symptoms, diagnostic, therapeutic data, and patient medication history. Another method is to divide the problem into various facets and assign each part to a separate group of students. At the end of the individual session, all groups are asked to interact to solve the main issue by putting their pieces together in an amicable way. Students must be given clear timelines for responses and a well-structured question which is substantial, concise, provocative, timely, logical, grammatically sound, and clear [26,27,30]. The structure should afford a stimulus to initiate the thinking process and offer possible options or methods that can be justified. It should allow students to achieve the goal depending on their interpretation of the data provided and the imagination of each responder to predict different possible solutions. The participants need to complement and challenge each other to think deeper by asking for explanations, examples, checking facts, considering extreme conditions, and extrapolating conclusions. The moderator should post the questions promptly and allow sufficient time for responders to post their responses. The moderator then facilitates the conversations, and intervenes only if required to obtain greater insight, stimulate, or guide further responses. The subject teacher moderates the interactions between the groups and their competence can be adjudged based on individual contributions [25,26,28]. A format of assessment rubrics is given in Table 2.

Table 2. Assessment rubric for discussion board.

Element	Proficient 3 Points	Progressing 2 Points	Basic 1 Point	Needs Improvement 0 Point	Score
The post addresses the question	Makes an initial post that addresses all parts	Makes an initial post that addresses most parts	Makes an initial post that addresses some parts	Makes initial post without understanding question	
Substantive nature of the post	Substantive and in-depth with advanced examples	Substantive and clear detail with basic examples	Less substantive and fails to explain with examples	Not substantive at all	
Organisation and clarity	Extremely organised, clear, and concise throughout	Organised and clear	Somewhat organised but unclear at times	Not organised and lacks clarity	
Response	Responds to posts of all peers	Responds to 50–75% of posts	Responds to 25–50% of posts	Responds to fewer than 25% of posts	
Mechanics and communication	Careful editing and independent communication	Errors not distracting and engages in peer communication	Fails to use proper grammar and engages when prompted	No or irrelevant engagement with peers	
				Total points	__/15

The discussion board is to be managed and monitored for valid users in a closed forum from a registered device through an official IP address. The integrity issue raised is really difficult and the examiner has to rely on the ethical commitment of the examinee.

4.6. Virtual OSCE

Over recent years, we have seen an increasing use of Objective Structured Clinical Examinations (OSCEs) in the health professional training to ensure that students achieve minimum clinical standards. In OSCE, simulated patients are useful assessment tools that evaluate student–patient interactions related to clinical and medical issues. In the current COVID-19 crisis, students will not be able to appear for the traditional physical OSCE, and a more practicable approach is based on their interaction with the virtual patient. The use of a high-fidelity virtual patient-based learning tool in OSCE is useful for medical and healthcare students for clinical training assessment [30–32].

High fidelity patients use simulators with programmable physiologic responses to disease states, interventions, and medications. Some examples of situations where faculty members can provide a standardised experience with simulation include cardiac arrest, respiratory arrest, surgeries, allergic reactions, cardiac pulmonary resuscitation, basic first aid, myocardial infarction, stroke procedures, renal failure, bleeding, and trauma. Although simulation should not replace students spending time with real patients, it provides an opportunity to prepare students, complements classroom learning, fulfils curricular goals, standardises experiences, and enhances assessment opportunities in times when physical face-to-face interaction is not possible. Virtual simulation tools are also available for various pharmaceutical, analytical, synthetic, clinical experimental environments, and industry operations [31–33].

4.7. Oral Examination

The oral exam is a commonly used mode of evaluation to assess competencies, including knowledge, communication skills, and critical thinking ability. It is a significant evaluation tool for a comprehensive assessment of the clinical competence of a student in the health profession. The oral assessment involves student's verbal response to questions asked, and its dimensions include primary content type (object of assessment), interaction (between the examiner and student), authenticity (validity), structure (organised questions), examiners (evaluators), and orality (oral format). All six dimensions are equally important in the oral examination where the mode of communication between examiners and students will be purely online instead of physical face-to-face interaction. Clear instructions regarding the purpose and time limit shall be important to make the online oral examination relevant and effective [32–35].

Oral examination can be conducted with the use of Blackboard Collaborate, Zoom, Cisco Webex, and other online platforms. As indicated in Table 3, not all the assessment modalities discussed above are relevant in the present pandemic situation.

Table 3. Assessment Modalities and their Relevance.

Assessment Modalities	Effective Delivery		Criteria of Good Assessment					Domain			COVID-19 Relevant
	Synchronous	**Asynchronous**	**R**	**V**	**CE**	**EI**	**A**	**Knowledge**	**Skills**	**Attitude**	
MCQ	✓	×	✓	✓	✓	✓	✓	✓	×	×	No
EMQ	✓	×	✓	✓	✓	✓	✓	✓	×	×	No
Short-answer Questions	✓	✓	✓	✓	✓	✓	✓	✓	×	×	Yes
Script concordance test	✓	✓	✓	✓	✓	✓	✓	✓	✓		Yes
Open-ended Essay Questions	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	Yes
Oral Examination	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	Yes
Virtual OSCE	✓	✓	✓	✓	✓	×	×	✓	✓	×	Yes
True/False question	✓	×	✓	✓	✓		✓	✓	×	×	No
Mini-Clinical Evaluation Exercise (Mini-CEX)	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	No
Direct Observation of Procedural Skills (DOPS)	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	No
Problem-based Questions	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Yes

R, Reliability; V, Validity; CE, Cost Effectiveness; EI, Educational Impact; A, Acceptability; MCQ, Multiple-choice Question; EMQ, Extended Matching Question.

As indicated in Table 3, not all the asynchronous assessment modalities discussed are practicable in the COVID-19 pandemic. Short questions, open-ended questions, and problem-based questions are relevant and effective asynchronous means to assess the knowledge, skill, and attitude of the students because these types of questions require critical thinking, and can act as a catalyst for the students to provide new ideas in problem-solving. Although MCQs, extended matching questions (EMQs), and true/false questions possess all psychometric properties of a good assessment, these modalities may not be recommended for online asynchronous assessment because they are more subjected to cheating which can have serious implications on the validity of examinations. However, they can be appropriately adapted for time-bound assessments for continuous evaluation. Mini-CEX, DOPS, OSCE assessment are not feasible during a pandemic because face-to-face interaction is required at the site, which is not permissible due to gathering restrictions and social distancing. When the physical presence of the student is not feasible at the hospital or laboratory site, virtual oral examination and virtual OSCE becomes more relevant because the examiner can interact with the students via a suitable platform and ask questions relevant to the experiment/topic. In virtual OSCE, students will be evaluated based on their interactions with virtual patients [32,33,36–43].

There are some benefits as well as challenges for both synchronous and asynchronous assessment method (Table 4)

Table 4. Benefits and challenges of synchronous and asynchronous environment assessment.

	Synchronous		Asynchronous	
	Benefits	**Challenges**	**Benefits**	**Challenges**
Experience	Real-time interaction with lecturer and peers. Less feeling of isolation	Scheduling challenges, internet connectivity	Students learn at their own pace. Flexibility in hours of study	No live interaction. Can result in miscommunication and misunderstanding
Delivery	Instructional delivery similar to face-to-face sessions with the use of polls/quizzes in the classroom	Glitches in the use of online tools. Takes time for users to adapt to new tools	Videos available to the user to view at their own pace	No live interaction, limited feedback. A slower process as the question is answered by email
Technology	Large number of available software can be integrated into teaching sessions	Internet connectivity issues	Large amounts of information are made available with ease of access	Difficulty with self-learning because quantity may be too much to cover in a given time frame.
Learning outcomes	Outcomes can be adapted to online learning. Facilitates instant feedback and student networking	Achievement of learning outcome is difficult to assess	Material easily available to achieve course learning outcomes	Lack of formative assessment to check students' understanding

5. Assessment Modalities in Online Assessment

MCQ, EMQ, and true/false, questions though not relevant for the online final examination, can be appropriately adapted for time-bound assessments for continuous evaluation. Quizzes can be utilised after a regular lecture or practical demonstration with a short time limit that precludes the chances of integrity infringement. When an online discussion is used as a grading tool, there is usually a timeline for posting comments for grading. Often there is the possibility that students may post comments close to the deadline date which makes it difficult to engage the comments into the discussion. There is also the possibility of robust discussions, which means that students will have to keep up with voluminous responses which can be time-consuming [34–36,44]. This also adds to the burden of the academic staff who must read all contributions and guide the discussion. In these sessions where a timeline for responses is indicated, technology failure at the tutor or student side will negatively impact the quality of the discussion. This can create further anxiety in the student because these activities count to their final grade. On the other hand, when online discussions are created to assist the development of competence in the subject area without contributing to a grade, there is a possibility that the exercise may be ignored because it would not affect their final mark [36,37,45].

Self-check quizzes can be used as an informal method to gauge student knowledge and understanding whilst providing appropriate feedback to help them correct misconceptions about the topic. Another method employs a flipped blended classroom where students are provided with a reading assignment and they take an ungraded online exam which can comprise true/false or multiple-choice questions. When the session is complete, feedback is provided to them along with the correct answers. This allows for valuable self-assessment and even though the quiz does not contribute to their final grade, the score is entered into the grade book within the LMS for both the student and instructor to review.

6. Challenges Faced in Asynchronous Environment Assessment

Due to the current COVID-19 crisis, all courses are being conducted virtually which has led to the dissemination of medical information to health sciences students through various LMS and online platforms. It encourages students to familiarise themselves and engage with online learning tools whilst understanding the concepts from their homes. The improvisation of the home is multifaceted, with challenges ranging from technical issues, distractions from family members, availability of online devices, and broadband connectivity issues. Many students lack personal devices and often utilise on-campus devices to aid in their study. The difficulty with unpredictable changes in broadband frequency can lead to abrupt disruption of classes, which would require additional time to re-join the session. This can lead to frustration with dysfunctional electronic devices, making it more difficult to engage and actively participate in online sessions. Coupled with the challenges of technological integration, is the social aspect of home-based learning which can be easily overlooked. Students at home may be faced with added distractions from family members and younger siblings. With the challenges faced by parents/caregivers to provide financially during the pandemic, students may have additional household responsibilities and chores which would reduce the time for school interaction and review of course material. The lack of face-to-face interaction can precipitate uncertainty and the inability to fully understand course expectations. Although faced with many challenges, online classes from their home remain the most feasible option during a pandemic when face-to-face interaction is restricted. In the new normal with restricted interaction, their homes represent a haven for students to pursue their academic goals. Though not ideal, it presents the most viable option in the present pandemic scenario [39,42,45–50]. Moreover, they can watch recorded videos, classroom lectures, and review them again to understand core concepts. Asynchronous learning skills offer advantages to pursue coursework and prepare students for licensing exams in the future. The attendance for virtual classes has significantly increased, which demonstrates a preference for the asynchronous mode of learning [30,40,41].

There are numerous challenges during the asynchronous assessment which include the impact of physical distance between instructors and students and adaptations due to the use of technology for communicating with students and managing workload and time efficiently. It is important to realise that it is not simply assessing the final performance of the student, there is a need to monitor the students' progress throughout the semester, culminating in the assessment examination. By using asynchronous examinations, it is often difficult to gauge the progress of the student because the instructor cannot be certain that the work submitted represents the true student effort. Some asynchronous assignments involve complex problem-solving tasks which are often conducted via a stepwise approach. In face-to-face sessions, understanding and mastery of the topic can be established, and feedback provided accordingly. In asynchronous modes, it would become necessary to divide the task into smaller sections which enables the teacher to assess the students at different time points. The instructor would have to make an effort to utilise Vygotsky's concept of scaffolding by developing mini-tutorials or have regular sessions to meet with students, ensuring student progress in the specified field. Although feedback is of paramount importance, preparing such feedback for many questions across multiple programs/courses would require a significant amount of time [36,42,43].

Both students and instructors need to adapt to technical proficiency to decode the course materials and fully utilise the available LMS. Issues related to adaptability can arise while switching from face-to-face to online teaching. It takes time to adapt to computer-based eLearning and LMS. The asynchronous assessment offers various options such as recorded video presentations, online feedback, video tutorials, presentation assessment, online quizzes, multiple-choice questions, and short answer questions. Quick adaptability and accepting a new learning environment is required for students to prepare themselves for online classes and assessments. The use of these methods may require more planning and time, because lecturers would need to include formative assessments to test student understanding [42–44]. Formative assessment is an essential component of medical and allied health profession education. It provides feedback to the students about their strengths and weaknesses in learning. The main advantage of this assessment is that students gain the opportunity to know about their performance compared to the standard at regular intervals. It does not only help to guide students in their continuous progress during the training, but also helps educators to know the improvement and shortcomings of their students. However, the students may not see the value of formative assessment if it does not contribute to the grade. The absence of continuous feedback culture by the lecturers is another setback to formative assessment. When a deadline for submission is provided, high usage of the LMS for submission across the entire institution may result in higher internet usage with obvious bandwidth issues for some students who may experience lag times and difficulty in uploading their assignments. The examination sections must institute proper protocols that allow students the ability to upload assignments after the due time once an acceptable reason has been provided for their failure to do so. It is a major issue for students living on-campus where high-speed internet is in-demand and shared by multiple individuals, with increased usage during the COVID-19 crisis. Apart from that, many students seek technical assistance to navigate their way through the LMS. To ease learning through asynchronous assessment, students should be equipped with guided tutorials and manuals for successful course completion [38,46,47].

There are a variety of online tools available for formative assessment that can be easily utilised to check student understanding of a topic. These tools are highly interactive, and students often enjoy the experience due to their game-based approaches. *Poll everywhere* is a free online tool for classes of 30 students or fewer, and utilises an online polling platform for students to vote on polls generated by the teacher through text messaging (SMS), smartphone, or a computer by visiting the website. For assessment purposes several useful tools are available. Socrative, Kahoot, Quiz revolution, Quibblo, Quizpedia, and Moodle are but a few of the online tools available for administering quizzes. These applications are free for a maximum of 30–50 users and premium members have access to additional features such as performance tracking, and the ability to generate progress reports. These tools can be used for formative assessments in the classroom where users can participate in the game using their mobile phones. It creates a fun learning environment where students can reflect on the material taught during the lecture session. When used for summative synchronous assessments, some offer options for the randomisation of questions to minimise sharing and deliberation of answers amongst students. Time and resource management when using asynchronous assessments is of critical importance both to the student and the academic staff. The use of online technologies means higher output is required for both parties with strict time limits as universities attempt to maintain their students' academic progress. Academic staff will be required to provide examinations and grades within a stipulated time, and multiple examinations should not be administered simultaneously to ensure that students can focus on the assessment at hand without being distracted by another submission that may be required within the same period. Careful planning is required by examination sections to ensure student examinations are scheduled appropriately to allow sufficient time for preparation and submission of the final response [35,46].

7. Conclusions

In the present COVID-19 pandemic, face-to-face interaction with the student in a physical space (classroom, laboratory, hospital setup) is not possible. In the interim, the knowledge, skill, and attitude of the learner can be conveniently assessed by the asynchronous assessment methods using online platforms. This system offers a variety of question types, such as open-ended, short answer, and problem-based questions that can be used for asynchronous assessment. Online platforms can also be used for assessing student competence in domains of the practical component of the subject through asynchronous oral examination and virtual OSCE. Some challenges of fairness and integrity can be suitably addressed by implementing technological tools such as video and audio recording surveillance software. Alternative online strategies to assess the knowledge, skill, and attitude of the learner need to be developed and validated that will not only provide the back up in an emergency but also involve more students in the education system due to its convenience in teaching, learning and assessment.

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Implementing Alternative Assessment Strategies in Chemistry Amidst COVID-19: Tensions and Reflections

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Abstract: The COVID-19 pandemic in the first quarter of 2020 resulted in the worldwide disruption of teaching and learning in main stream schools and in institutes of higher learning. Singapore was not spared. With the closure of schools in early April, it was imminent that the delivery and assessment of our freshman general chemistry course must be overhauled for the new semester. While the delivery of Home-based Learning (HBL) was a challenge for all educators, it was a mammoth roadblock for chemistry courses because of laboratory classes. Besides being thrusted to learn and use new technology tools for online lessons, instructors also had to quickly explore and design alternative assessments to substitute in-person written examinations and tests. This paper documents the struggles that played out in the decision to implement concept map assessments and "split-half" laboratory classes for safe distancing. Although these interventions are not novel, we confronted tensions as we sought to address academic integrity, administrative guidelines, and our own inadequacy particularly in concept map assessments. In light of positive and negative feedback from both staff and students, lessons were drawn to enhance future implementation and for further research.

Keywords: general chemistry; curriculum; assessment; laboratory learning; higher education

1. Introduction

Never in our boldest ambition did the authors dared to implement a 100% online course in general chemistry. While we had previously experimented with a blended approach of offering face-to-face lessons with pre-recorded lectures to meet academic quality and requirements, online learning was always viewed with skepticism: How do we motivate and keep an eye on lagging online learners, and how could we run laboratory classes if chemistry is fully taught online? A "normal" semester would typically see 20 to 30% of physical hours substituted by online learning, with the presence of in-person assessments and examinations. COVID-19 changed a significant part of our thinking and teaching practices.

This paper presents our experiences designing alternative assessment for learning using concept map assignments for a general physical and inorganic chemistry course. This course was taught in the semester of April 2020, and so was caught right in the peak of the COVID-19 pandemic. It was read by 504 students (majority are freshmen with a small minority of repeat students) enrolled into the diploma courses of chemical engineering, pharmaceutical, food, and biological sciences.

Spread over 14 weeks, this 60 h subject addresses fundamental concepts in atomic and electronic structure, chemical bonding, stoichiometry, basics of chemical kinetics, and ionic equilibria. There were 18 h of laboratory instruction (six face-to-face sessions) focusing on preparation of stock and standard solutions, titration stoichiometry, choice of indicators, and an introduction to the autotitrator. At the point of writing this paper, the semester was coming to an end. With the winding down, it was timely to look back at what was implemented. As we document our journey towards online delivery of classes and implementing alternative forms of assessments to replace high-stakes examinations and tests, we encountered several sources of tension. We believe that COVID-19 provided a catalyst to rethink assessment strategies in higher education. In this paper, we would attempt to address the following questions:

- What were some of the major factors (both high-level administrative guidelines and on-the-ground considerations) we balanced for assessment designs?
- How did the need for safe distancing impact laboratory scheduling and learning?
- What were staff and students' qualitative perceptions of concept maps as an alternative assessment strategy?
- What could we do better in future implementation, and what are some unanswered questions which could be grounds for continued research?

2. Pivoting to Home-Based Learning (HBL)

As the COVID-19 situation evolved in the first quarter of 2020 in Singapore, the academic management team initially held up hopes that it would be "business as usual" for the April semester. It was all "antenna up" as the team monitored the situation and discussed possible contingencies across the whole institute. We were initially expecting a partial closure of campus, causing a delay of at most a few weeks. However, when the authorities announced Phase 1 of the "circuit breaker" (CB) beginning from 7 April to 4 May 2020, it became clear that our academic calendar would be severely impacted. The education ministry announced home-based learning (HBL) as the default schooling mode for all schools and tertiary institutes. With the extension of Phase 1 to 2 June, all hopes of a normal semester vanished completely.

Institutional technological resources were very adequate in helping staff to pivot to HBL rapidly. About one month before the start of the semester, professional development and preparedness were well underway. Our main platforms for content creation and delivery are Panopto, Microsoft Teams, and Blackboard Learning Management System (LMS). The chemistry team has also previously produced lecture recordings for use in the earlier semesters, which we could quickly deploy for HBL. When the administration mandated that either lecture recordings or live lecturing was allowed in Microsoft Teams, the instructors wasted no time to complete all the lecture recordings. Based on recommended institutional guidelines that were in place before the pandemic, we incorporated the best practices and best-effort design as quickly as possible to prepare for this unprecedented semester. For example, the contents were chunked into shorter sub-topics to accommodate shorter attention spans of digital natives [1]. To scaffold the learning process and provide interactivity, formative self-check quizzes with auto-feedback were provided [2–4]. The second author (the course coordinator) recorded a video clip to familiarize freshmen with the teaching schedule and overall architecture of the LMS site. Tutorials were mandated to be conducted real-time on Microsoft Teams to maximize student engagement and attendance. Staff were then confronted with a steep learning curve to learn how to conduct tutorials online and in real-time. In the first two weeks of the semester, tutorials had not begun yet and so the instructors took the opportunity to contact their tutorial groups through an informal check-in call. This also provided an opportunity for both instructors and students to "touch base" informally online.

Besides learning how to conduct synchronous lesson on Microsoft Teams within a short period of time, the teaching team had to quickly decide how to manage and re-design assessment plans due to the disruption of on-site assessment and laboratory classes.

3. Dilemmas and Tensions

3.1. Tension between Safe Distancing and Scheduling: The "Split-Half" Laboratory Classes

The disruption of laboratory classes presented a severe existential crisis for science educators. While virtual or simulation laboratory instruction could provide a viable substitute with comparable student outcomes [5–9] ([10] p. 53), we had neither the time nor expertise to rapidly design these bespoke resources. Other formats were mooted. These included using (easier) asynchronous demonstration videos, accompanied by assessing planning or data analysis skills, a strategy widely adopted during campus closure in the pandemic [11]. These were eventually abandoned as the administration was also cognizant of the fact that on-site skills training remains a core mission of the institute. With the deterioration of the pandemic situation, it was clear that we had to make a decision fast. Then, we toyed with the idea of "kitchen science" ([10] p. 57) or home-based laboratory activities, where students could produce digital contents to demonstrate learning [3,12] ([10] p. 93). However, practically speaking, this approach was appropriate either for experienced students [13] who were familiar with the theory and safety guidelines, or non-chemistry majors ([10] p. 57), [14]. The freshmen in our chemistry course were neither, forcing us to again abandon this approach. The idea of live-streaming our laboratory classes [15] did not come to mind as the campus was closed, cutting off access to chemicals and glassware. In addition, quite a majority of them did not have prior titration experience in their high school education. For example, about 50% of the students in the main author's chemical engineering classes had not done titration before, thus a substitution with other distant learning format would not be optimal. Looking at our options and our teaching schedule, we decided to delay the in-person laboratory classes until the end of Phase 1, while awaiting further instructions from the education ministry and the administration. Refer to Appendix A, Table A1.

A reprieve came when the education ministry announced, towards the end of Phase 1, that laboratory or studio classes may resume on-campus due to the need to access equipment and materials. However, safe distancing must be observed during lessons. Critical planning considerations were (1) a lead-time was needed to prepare chemicals and distribute PPE, given all supply deliveries had virtually ceased during the CB period, (2) safe distancing of at least 1 m (about 3 feet) in the laboratory venue between persons, and (3) how to prepare students to return to campus after almost eight weeks of HBL. Towards the end of phase 1, the administration immediately granted laboratory technicians to return to campus for preparation, after 2 June. Staff members in the orientation committee contacted PPE suppliers and coordinated the distribution to the laboratory instructors. In a normal semester, each laboratory class comprised around 25 students and one instructor in the laboratory, occurring once every two weeks. Knowing that we could not meet safe distancing if we kept to the old schedules, the administration and course chairs decided to split laboratory classes into two groups (the "split-half" lab). For chemistry, it meant that classes now took place every week. Each instructor met half the class on the same day, on different (consecutive) weeks for the same laboratory task. This had no doubt placed constraints on timetabling, venues, and manpower.

Two weeks before classes began, all students were required to complete a 20-item basic safety quiz (normally completed in-person to ensure adherence), and watch a video on lab safety on the LMS. To emphasize the importance of safety, tutors constantly monitored the submission and marks in the LMS and reminded all students to complete and pass the quiz. With much stress, anxiety, and anticipation, our first laboratory session began on the 8th week, delayed by one month. Laboratory classes continued on into the mid-term break to make up for lost time. In the meantime, lectures and tutorials were progressing as scheduled.

Our LMS repository of pre-lab packages built up over the semesters are now proving their value more than before. For every task, the LMS package consists of a pre-lab assignment with short, open-ended questions related to the theoretical principles of the task, and video resources curated by the team. The latter were self-made, complemented with other Youtube clips. For example, we had our own video to demonstrate the use of the analytical balance, FLASH-designed packages, or powerpoint recordings with narration on titration tasks and color changes of common indicators used in the practical work. The duration of the video clips was between one to 10 min, addressing the theory, experimental techniques, and data recording. We were also able to substitute an in-person class with another online package, prepared for blended learning in earlier semesters. It comprised a 4.5 min video to review key titration skills and a formative, LMS assignment with five open-ended questions. This resource was flexibly deployed during the revision week in week 14, where all on-campus and online lessons stopped temporarily. The questions were intended to probe deeper level understanding. For example, why it is not advisable to add too much indicator during the titration, and why the titrant concentration should be moderate (not too high or low) to ensure a practical, readable titer value.

3.2. Our First Bold Experimentation: Concept Maps as Assessment for Learning

With the CB underway, the administration announced the removal of end-semester examinations and mid-terms, forcing all courses to adopt continuous assessment (CA). Before the semester rolled on and even as it commenced, there were intense discussions between the academic heads and management, deliberating the needful adjustments to assessment plans, while ensuring academic rigor and integrity. The instructions and broad guidelines were then relayed to the instructors on the ground, allowing for customization to meet specific subject needs. Needless to say, our assessment plans changed constantly during that challenging period as we continuously aligned curriculum delivery to the national pandemic posture.

In a normal semester, the mid-term and end-of semester examination accounted for more than 50% of the subject grade. It was fortunate that we could still grade the existing post-lab tests and datasheets in our laboratory classes, but we still had to design assessments to substitute examinations and tests. There were several tensions experienced. The most obvious choice was to pivot to the online LMS quiz system. These quizzes can be easily graded. However, administrative guidelines capped the weightages of online assessments, on valid grounds to uphold academic integrity. This is because online test environment were viewed to be more vulnerable to academic misconduct [16–20]. Thus, the subject team decided that it was not worth the effort to design online tests as these could not fully replace the lost assessments. Students' assessment workload was also subjected to an administrative cap and thus limiting our options to break up the weightages into smaller tasks. Weighing in on the pros and cons of different options and guidelines to comply with, the teaching team decided on concept map assignments.

Concept maps are known to promote deep and meaningful learning, a precept born out of cognitive and developmental psychology, seen in the seminal work by Novak [21,22]. A concept map is a visual representation of basic conceptual units called nodes, connected by lines to show the relationship between them. Nodes with labeled relational connections are called proposition. Nodes and propositions are then organized in a hierarchical manner to show the unfolding of macroscopic to grainy, underlying substructures [21]. Where assessment of learning is concerned, concept mapping is known to also expose misconceptions in them [21,23]. As an educational institute, we cannot ignore assessment *for* learning. The literature shows that concept mapping abilities are weakly related to performance test scores [24–26]. Some found a facilitative effect [27], while others found a correlation with more traditional tests when used as tool for talent selection into niche curriculum [28]. Another critical consideration was how to uphold academic integrity in whatever we assessed. Unlike online tests, we thought concept maps required more customization efforts and were thus harder to plagiarize. Moreover, any form of direct copying from the lecture materials can be easily spotted.

3.2.1. Design of the Concept Map Tasks

The topics chosen for this assignment were atomic structure, chemical bonding, chemical kinetics, and equilibria. Atomic structure and chemical bonding were bundled as one assignment set, while kinetics and equilibria were bundled as the second. In both assignments, we included a short practice question worth about 20% of the maximum marks. The objective of the practice question was to allow students to apply basic concepts to a "test-style" question. We chose these topics for two reasons. Firstly, atomic structure can be readily integrated with chemical bonding; similarly, for reaction kinetics and equilibrium. The second reason was because topics on solution preparation and stoichiometry were already extensively assessed in the laboratory. A concept map assignment focusing on these four topics would address the learning outcomes.

Concept mapping has a long history of application in science education and professional development [22,24–27,29–31]. However, this tool was entirely new to us. None of the authors had prior experience using concept maps for teaching and assessment. It was unsurprising that some colleagues were initially uncomfortable with grading an open-ended piece of work, with no telling how varied students' responses could be. One other concern was that students would simply have no idea how to design a concept map. These are valid issues since concept map grading require student training, is rather time-consuming and subjective [21,32].

To implement the assessment, we also needed to articulate the task, response format, and grading system [33]. We implemented a constrained task [33] by providing key phrases and concepts for students to map. For example, in atomic structure and chemical bonding, we asked for summaries on atomic and electronic structure, molecular shapes, intermolecular forces, and chemical bonding, and to show how these core concepts were linked. For the kinetics and equilibria assignment, we required students to map out how rate and equilibrium expressions are written and also the factors affecting rate and equilibrium. In terms of the mode, given the pandemic, we chose hand-written or computer-typed responses [33]; oral interview was not practical given the cohort size. Though we initially allowed photographed work to be submitted, these were eventually returned to students (post-CB) in exchange for the originals, on the grounds of academic integrity. To address the possibility that students are not experienced mappers, we incorporated a very simplified, partial concept map on atomic structure (see Figure 1). In addition, we also relaxed the task demands to allow students to submit alternative formats, such as bulleted or table form of notes or as a hybrid.

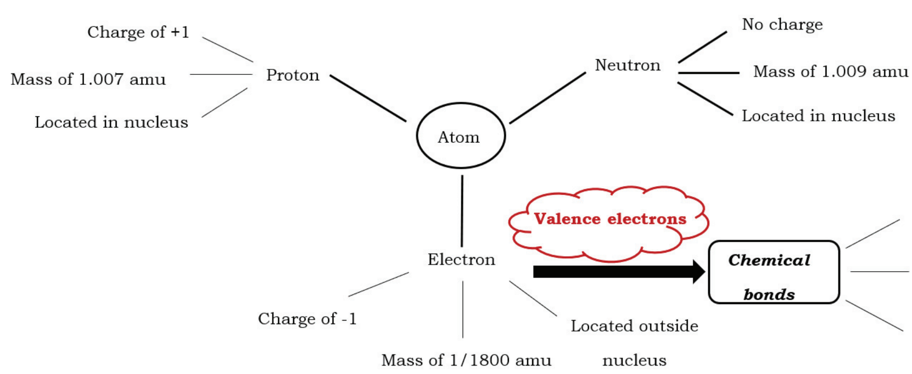

Figure 1. A Partial Concept Map in the Student Briefing Package.

We customized a generic grading template provided by school academic advisors and various colleagues outside the chemistry team, to suit the needs of the course. The generic rubric included criteria that were literature-based best practices [21], such as grading for connected nodes with labelled lines, valid propositions, and hierarchical structuring of concepts from broad to narrow. Based on this, the subject team customized a 3-band rubric ("Excellent", "Good" and "Poor") to grade the validity of the core concepts, the extent of connectedness between core concepts and also the sequencing of presentation. Table 1 showed a summary of the grading rubric. Within the "Excellent" and "Good" band, we allowed for a one to two-point variation for scoring. "Poor" was easier to score and thus an absolute zero was used. As seen from the rubric, we intentionally chose to put more weightage in the proposition criteria as we were aware that students did not have much practice on concept mapping. Complex skills such as hierarchical structuring and sequencing might be challenging at the first attempt.

Table 1. Summarized concept map grading rubric.

Attributes	Excellent [1]	Good	Poor
Validity of core concepts (70%)	All core ideas are expressed correctly	Some or partial correct expressions	Not shown
Extent of connections (15%)	Majority of the connections are clearly labelled	Some or partial connections are labelled	None connected or no labelling
Sequencing (15%)	Logical flow of concepts from broad to narrow or vice versa	Somewhat logical flow of concepts	No flow, confusing to follow

[1] Except for "Poor", a one to two-point range was used in the "Excellent" and "Good" bands.

The first assignment brief on atomic structure and chemical bonding was released as a video clip on the LMS on week 5, around the middle of May 2020. This was timed purposely such that students would have already viewed the required lecture videos. The grading rubrics and academic discipline rules were also communicated to the students. To deter plagiarism, students were required to submit a declaration of originality with their work. Students were given four weeks to submit their work in person during the laboratory sessions in week 8 or 9. Refer to Appendix A, Table A1.

3.2.2. Data Collection and Analysis

Two of the co-authors co-graded the first assignment. A month later around week 15, grading was completed and samples of students' work were discussed and shared amongst the authors in a meeting. The intention was to flesh out what we thought were strong and weak maps, and to discuss how to help the students make a better map in the second assignment. One of co-author then made a 11-min review video clip to bring students through the mistakes in the practice question. A logical sequencing between atomic structure and chemical bonding concepts was also presented to the students. An exemplar map submitted by a student was shown in the review clip. The second assignment brief on reaction rates and equilibrium was released on Week 13 and students were again given four weeks to turn in their work in person during one of the laboratory classes. The main author and one other co-author joined in the grading work. The marking team thus comprised the two experienced co-authors who had earlier marked the first map, plus two new ones. The instructors exchanged notes to briefly calibrate grading expectations after trial marking one to two classes.

Given that concept maps were a very new form of assessment for us, it was decided to implement a very quick "dip-stick" survey to determine students' perception. The survey was distributed using the Microsoft Forms platform, which all students had access to using their institutional accounts. This took place after the release of assignment 1 review clip. A Yes/No question was first posed to students, and depending on their response, they were routed to an open-ended question to elicit positive or negative comments. The questions were:

- I found the concept map assignment useful in consolidating my learning (Yes/No).
- I found the concept map assignment useful in consolidating my learning because _____.
- I did not find the concept map assignment useful in consolidating my learning because _____.

To complete our assessment plan, we graded a set of post-laboratory tests (open-book) and fill-in-the-blanks reports. In addition, we also implemented one written, 15-mark short test to assess the last topic on ionic equilibria during one of the laboratory lessons. To prevent students from circulating the test contents to the next group of peers, we designed three versions per assessment, matched to the same level of difficulty. Instructors were allowed to randomly select a particular test version for a particular class in the week.

Frequency responses from the first Yes/No question were tabulated by diploma courses. The open-ended comments from the two free-responses questions were qualitatively gleaned to obtain high-level perceptions on the utility of the tasks. As the focus of this paper was about perceptions of the concept map task, we presented a qualitative sketch of the work quality, instead of undertaking a quantitative analysis of students' performance.

4. Staff and Student Experiences

4.1. Findings of Concept Map Survey and Informal Student Feedback

The perception survey garnered 351 responses, or a responses rate of approximately 69.6%. Chemical engineering freshmen made up about 29%, with each of the other diploma courses accounting for about 16% to 19%. This profile is fairly representative of the subject cohort as there are usually six classes of chemical engineering classes, while the rest of the courses typically make up three to four classes each. Table 2 presents the breakdown of survey responses by courses.

Table 2. Profile of survey responses by diploma courses (N = 351).

Diploma Course	n
Chemical Engineering	102 (29.1%)
Food Nutrition and Culinary Science	59 (16.8%)
Medical Biotechnology	67 (19.1%)
Pharmaceutical Science	67 (19.1%)
Veterinary Technology	56 (16.0%)

Overall, 87.7% of the respondents felt that the concept map assignment was useful to them. Table 3 provides the breakdown of "Yes" and "No" response into the five diploma courses.

Table 3. "Yes" (N = 308) and "No" (N = 43) responses by diploma courses.

Diploma Course	Yes	No
Chemical Engineering	87 (28.2%)	15 (4.9%)
Food Nutrition and Culinary Science	51 (16.6%)	8 (2.6%)
Medical Biotechnology	61 (19.8%)	6 (1.9%)
Pharmaceutical Science	60 (19.5%)	7 (2.6%
Veterinary Technology	49 (15.9%)	7 (2.6%)

Students who found concept map useful often mentioned that it enabled them to re-organize their learning into something visual. Comments also showed that some students understood linkages between concepts as they wrote up their assignment. Some comments also revealed the underlying "cognitive struggle" that students were engaged in. Not only do students need to grasp the domain knowledge, concept mapping requires thought organization, presentation, and language skills to convey meaning to another map reader ([21] p. 17). Representative comments reflecting such sentiments are provided in Appendix B.

On negative comments, some students felt that they had other study styles and making a concept map felt incongruent. With this, some students felt that the assignment constricted them to a particular style; others even felt that it was a waste of time, as they were simply "regurgitating" contents from the notes and paraphrasing into a certain structure. Some comments alluded to cognitive or language challenges such as the inability to link concepts together, expending effort to design a map, or to succinctly paraphrase their work. Some of the comments also showed that students prefer a more traditional mode of assessing domain knowledge, such as quizzes or practice questions. Some also commented that concept maps are best used as study techniques, rather than graded assessments. In the students' view, the ability to answer traditional assessment questions was a better indicator of their academic achievement. Representative comments reflecting these sentiments are shown in Appendix C.

Clearly, the positive comments attest to the strengths of concept maps to assist learners in consolidating and organizing content across different media (be in print or video) and then re-representing these structures logically. This finding was consistent with earlier studies [24,30]. Interestingly, even for some nay-sayers, mapping still played a facilitative role as the task itself forces them to confront and resolve their learning gaps by reviewing study materials. As one student wrote: "*for those parts of the topic where I was unsure, I still felt equally unsure after completing the summary assignment. Only after re-watching the lecture videos and watching some educational videos online was when I fully understood the topics*." From the comments, students appeared to be more actively engaged in making efforts to grasp the content or to represent their knowledge structures visibly. Proponents of concept mapping admitted that concept mapping is not an easy task. It requires intentional effort and intrinsic motivation, just like how active learning should be [21,25].

Negative comments were symptomatic of the cognitive challenges of the task, and were similar to literature findings [24,25,30]. It was unsurprising that some students encountered difficulties in linking concepts together, found concept maps a waste of time or time-consuming to do, or was incompatible with their learning style. It was also fairly evident that students were more comfortable being assessed with familiar assessments such as written tests and quizzes, for they felt that concept mapping was unrepresentative of their academic performance. Interestingly, student perceptions appeared to echo past work, in that mapping skills are not related to test-taking abilities [24–26].

Given the deep-rooted role of assessment in the course of students' educational experience, it was not surprising that they came with an exam-oriented mindset. The fixation with examinations and tests might also have made it more challenging to convince students of the long-term benefits of concept mapping skills. In one interesting exchange, a student messaged the main author to ask how student's knowledge was assessed, with no written tests or examinations. The student was reminded by the main author that the laboratory post-lab tests, concept map assignments, and the short written test would have addressed all the concepts. Perhaps the final reply of this student reflected the impact of educational conditioning: "*Mmm yeah i get it now thank you. I was thinking this way because i tend to do better in exams haha*".

4.2. Qualitative Feedback and Perceptions of Staff on Student Performance

As expected, staff noted that indeed, students were unable to make deep connections and linkages. Most of the linkages were shallow, where lecture notes contents were paraphrased or presented in another way. From the quality of the work submitted, it appeared that there was a lack of integrative reconciliation ([21] p. 104)**.** Integrative reconciliation occurs when the learner recognized the relationship between related concepts, resulting in fine, differentiated levels of understanding. For example, one way we could have seen integrative reconciliation was to compare similarities or differences between the factors that affected rate versus equilibrium. Very few students picked this up. Another extension along the same idea was the fact that solid reactant concentrations are excluded in rate and equilibrium constant expressions. The practice question involved a computational problem where a solid reactant was used. The concept of omitting solid reactants in equilibrium expressions was not explicitly taught in the lecture material, so students had to do some research and reading up independently. The instructors noted that many students sought guidance on how to tackle the question. However, very few students extended their learning from the computational problem to their concept map, to realize that solid concentrations are excluded from both rate and equilibrium considerations. Integrative reconciliation is a good indicator of deep learning and could trigger an "aha" moment, or "felt significance" that comes with gaining profound insights ([21] p. 18).

In terms of sequencing of ideas, few had unique or novel structures. The most common one was simply a node of "rate" or "equilibrium", which directly branched out to factors such as "reactant concentrations", "temperature", and "catalyst". One student struck a deep impression because this student started the map at the top level with "Reactions", followed by "reversible" and "irreversible". This student then proceeded to connect rate and equilibrium from these nodes. This was perhaps the most representative of a well-defined logic of sequencing, starting from the macro idea down to the grainier concepts. See Figure 2 for the reproduced schematic map by the student. There were also a few misconceptions which surfaced. For example, one student thought that activation energy was linked to temperature and reactant concentrations (by connecting a bubble labelled as "factors that lower activation energy" to these factors). Another thought that a catalyst allowed the activation energy to be achieved faster, and so more products could be obtained. These misconceptions were obvious only if students explicitly used language or arrows to communicate their (flawed) ideas. Thus, language is a double-edged sword in that it either reflects correct understanding or exposes misconception. Language expression is part of the critical learning experience from concept map ([21] p. 17).

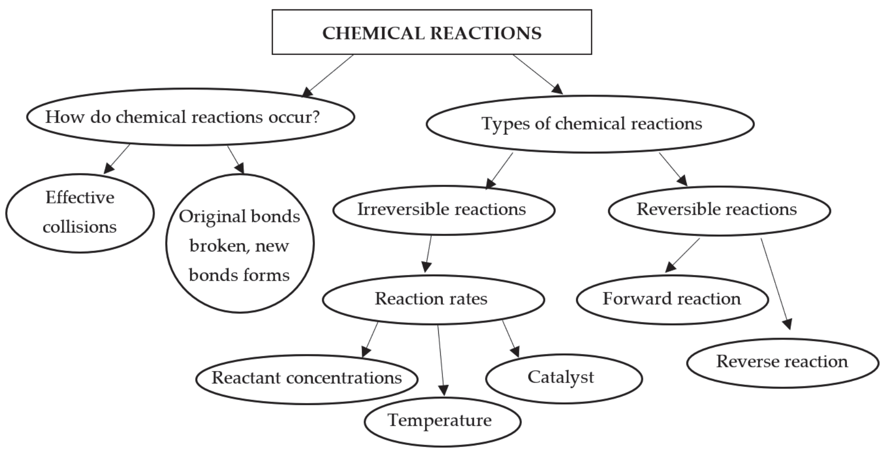

Figure 2. Schematics of a Student Map Showing Hierarchical Sequencing.

One unsettling observation emerged as the assessments unfolded progressively. Staff noted that although the concept map scores were acceptable, students did not do as well in the other written assessments such as the post-laboratory tests and the short test. This was perhaps expected, since literature showed that concept map skills were not clearly associated with test performance [24–26]. However, this observation warrants more detailed research work for two reasons. Firstly, this was because the (more favorable) weightage allocated to valid expressions of core concepts could have led to this self-fulfilling outcome. This was an aspect where we expected students to cope better with, as the quality of work did show. Another caution was that the concept map assessed different contents from all the written tests, so a direct comparison may not be meaningful. As a future practice, we could follow up with a written test to assess concepts directly related to the concept map assignment. This is to help students perceive the (assessment) value and importance of the concept map so as to increase acceptance.

Intentionally downplaying the connection and hierarchy scores served a pragmatic purpose for assessment parity, but resulted in poorer differentiation of learning quality, as noted by one of the co-authors. This practice could also mar its educative validity. It is proposed that a tiered, factor-scoring approach be adopted to place a premium grade on hierarchy and integrative reconciliation. For example, for every valid hierarchy, score 3 to 10 times that of the associated valid proposition. For every valid integrated concept, score two to three times the point assigned to the hierarchy ([21] p. 107). Giving correct examples could also be scored positively. In future, we could also conduct online consultation during the lecture periods to provide training and support for students. For example, we could give guided practice on map construction, show examples of strong and weak maps, or expose them to online concept mapping tools like Bubbl.us.

4.3. Impact of "Split-Lab" on Student Learning

The impact of safe distancing on laboratory scheduling and student engagement was another note-worthy lesson. We were largely able to continue on with the current laboratory curriculum during the pandemic, while adhering to safe distancing guidelines. These primarily meant that classes do not mingle during transition, particularly at dismissal and arrival. By splitting up one class of 25 students into two laboratory sessions timed one week apart, instructors noticed that they were more engaged and proactive in their laboratory work. This was because in previous semesters, students worked in pairs. It was entirely possible that students might assume a "free rider" attitude by depending entirely on their more competent buddy. COVID-19 has also squarely placed a learning challenge on the students. Now, they handle and manage all the bench work individually. With a smaller class size, instructors also reported less stress in classroom management and were able to focus more time and attention to provide skills guidance. The instructor team also thought that this scheduling facilitates future implementation of a skills observation test. While the "split-lab" scheduling arrangements had added more strain to laboratory support resources, it has enhanced student learning expectedly. On hindsight, waiting out for face-to-face classes, coupled with this scheduling option (with no other choice in sight) reaped benefits for both instructors and students.

5. What is Next: Unanswered Questions in Higher Education Assessment Practices Post-COVID

Our experiences directly informed us that buy-in from students could influence perceived efficacy of new forms of assessment. However, the dilemma was that during COVID implementation, it was impossible for us to change mindsets quickly. Students, through their high school years, have encountered mainly written examinations and tests as an indicator of their academic achievements. Almost overnight, their first lesson experience in our freshman course was thrown into disarray. Their suspicions of the validity of the assessment is understandable. In addition, student motivation and readiness is crucial in an online course, a finding that is already well-documented in online education literature [4,34].

Deploying four instructors to mark the second assignment had eased the marking load. However, we did not specifically harmonize the grading of each individual piece of work, except to set some broad guidelines. We found it difficult to design an instructor exemplar map for validation purposes, a practice recommended by some authors [32]. Likewise, it was not possible to exhaustively identify all the combinations of hierarchy and the connections of concepts. This means then that the tiered, factor-based grading approach ([21] p. 107) was of limited practical use, as of now. It also means that concept maps are inherently not capped by a maximum score [28], and perhaps do not lend themselves very well to traditional scoring methods. They are highly individualized pieces of expression akin to a painting, whose value and beauty lies in the eyes of the beholder ([21] p. 97). In assessment and evaluation, this is a potentially discomforting tension for institutions. Though the proponents of concept maps contended that there is some subjectivity, this weakness does not compromise construct validity; the concept map gives a fairly good indication of deep, interleaved learning ([21] p. 105). Our current work could not provide an answer to the issue on score consistency and validity as yet. Perhaps for concept maps to be more widely accepted by all the stakeholders (students, instructors, and institutions) more research work should be performed. Such research could look into ways to enhance student receptivity or in the design of a standardized marking rubric that clearly accounts for the multi-dimensional flavor of concept maps. Taking a step further, how about a possible further future where the race to the top of academic performance is not capped by a ceiling? After all, since talent has no limits [28], this scenario is not totally unfathomable.

COVID-19 has also challenged institutional resources in terms of laboratory scheduling and support. As we move into the fall semester, the plan is to continue with asynchronous lectures and synchronous tutorial lessons. However, the "split-lab" continues to be enforced for adherence to national guidelines. Safety consideration remains top priority, and thus precluded all other scheduling options. Clearly, with a smaller laboratory class size, there are beneficial outcomes in both student learning and classroom management. The key question is how long the institution can sustain this format. While the team could explore live streaming of laboratory classes [15], the manpower set-up is also fairly laborious and even more challenging to manage. As of now, we are hopeful to continue with on-campus classes. We are still caught in the tension between economic efficiency and student outcomes, of which there is no direct answer yet.

6. Conclusions

This reflection paper describes the team's experiences in managing the HBL implementation and assessment of a freshman-level general chemistry course during the COVID-19 pandemic in Singapore in the April semester of 2020. Besides the steep learning curve to produce recorded contents and deliver synchronous lessons on newly learned technology platforms, the team had to grapple with how to conduct laboratory classes under safe distancing and to substitute traditional, high-stakes written assessments. While the "split-lab" had unsurprisingly improved student engagement and classroom management, it also comes at the expense of manpower resources and teaching facilities.

Although the use of concept map is not a novel idea in science education, the team had no prior experience. In the eventual decision to roll out this assessment approach, we had to balance administrative guidelines concerning academic integrity, student workload, and how much we can realistically manage as we race on to continue with "business as usual". The outcomes informed us that we could better scaffold students' development in concept mapping skills in future rounds of implementation, and integrate concept maps as part our existing assessment approaches. These are issues we can address at the ground level. However, there are others that are more challenging to resolve, which originate largely from pragmatic, age-old mindsets and practices from various stakeholders. For example, students' perception of alternative assessments, putting a maximum mark on grading, possible institutional misgivings about the inherent variability in this assessment approach and effort required for grading. These concerns provide grounds for meaningful research in the future, as we hopefully pray for a fast return to a new-normal.

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Appendix A

Table A1. April 2020 semester teaching schedule.

Week	Recorded Lecture	Synchronous Tutorial	In-Person Laboratory	Critical Events
1 (20 April)	Topic 1: Fundamentals of Chemistry	-	-	Phase 1 CB
2 (27 April)	Topic 2: Chemical Bonding	-	-	Phase 1 CB
3 (4 May)	Topic 2: Chemical Bonding	Session 1	-	Phase 1 CB
4 (11 May)	Topic 3: Stoichiometry	Session 2	-	Phase 1 CB
5 (18 May)	Self-study 1			Phase 1 CB; release assignment 1
6 (25 May)	Topic 4: Solutions	Session 3	-	Phase 1 CB
7 (1 June)	Topic 4: Solutions	Session 4	-	Phase 1 CB ends 2 June, Phase 2 begins

Table A1. *Cont.*

Week	Recorded Lecture	Synchronous Tutorial	In-Person Laboratory	Critical Events
8 (8 June)	Topic 5: Kinetics and Equilibria	Session 5	Lab 1, Group 1 (Intro to lab safety and titration)	In-person lab begins Group 1 submit Assignment 1
9 (15 June)	Term break	-	Lab 1, Group 2	Group 2 submit Assignment 1
10 (22 June)	Term break	-	Lab 2, Group 1 (Solution prep)	
11 (29 June)	Topic 5: Kinetics and Equilibria	Session 6	Lab 2, Group 2	
12 (6 July)	Topic 6: Introduction to ionic equilibrium	Session 7	Lab 3, Group 1 (Titration I)	
13 (13 July)	Topic 6: Introduction to ionic equilibrium	Session 8	Lab 3, Group 2	Assignment 1 debrief; release assignment 2
14 (20 July)	Self-study 2		Online lab 4	Concept map survey
15 (27 July)	-	Session 9	Lab 5, Group 1 (Titration II)	
16 (3 August)	-	Session 10	Lab 5, Group 2	Group 2 submit Assignment 2
17 (10 August)	-	-	Lab 6, Group 1 (Titration III)	Group 1 submit Assignment 2; In-class quiz
18 (17 August)	-	-	Lab 6, Group 2	In-class quiz
19 (24 August)	-	-	Lab 7, Group 1 (Titration IV)	-
20 (31 August)	-	-	Lab 7, Group 2	-

Appendix B

Examples of positive comments from the concept map survey (all grammatical or spelling errors are verbatim):

- *"it an easier way for me to study because its more visual and organized"*
- *"the content is more organised and visual"*
- *"it allows me to revise my notes and make it more compact so its easier"*
- *"it gave an overview of how the topics are connected"*
- *"it allows me to recap on the topics being taught to me and circulating my thoughts on how to convey it."*
- *"it pushed me to make my own notes instead of using the notes provided to me."*
- *"It made me relook at my notes, lectures and tutorials, and I have to rewrite them down into my own words, so it made me more familiar with the topic"*
- *"it summarises what ive learnt and allows me to view the topic as a whole. In addition, it allows me to pin point the important details"*
- *"it made me think and analyse more deeply about how the different topics are connected"*
- *"it structures my thoughts, allowing me to have a clear picture"*
- *"it gives me the opportunity to find out and know what are the important concepts rather than learning every words mentioned in the lecture video by heart. in other words, it helps me to differentiate between what is relevant and what is not."*

Appendix C

Examples of negative comments from the concept map survey (all grammatical or spelling errors are verbatim):

- *"trying to connect everything through mindmaps or point form don't make it easier to understand, it actually makes it more confusing for learning"*

- *"I do not know how to link them together"*
- *"I felt that I didn't properly understand how to do the linking between topics to make them interconnected and hence got stuck at that part"*
- *"It proved difficult for me to try and link main concepts of different topics together and also, the outcome of the concept map was too messy, with too many words and arrows linking to each other, which made me even more confused"*
- *"it took me very long to plan and think of what to pick and type/write out."*
- *"it was difficult to paraphrase in our own words, since it is science usually keywords and sentences are fixed. It may have been mistaken for plagiarising but in reality we were just writing proper scientific sentences"*
- *"I would prefer it not to be graded as I think concept maps and notes are done to help with my own revision and not done for a graded assignment."*
- *"its a summary and i do my own notes so this is kind of wasting my time"*
- *"i already have a preferred learning method so while i dont think the summary assignment way of learning if bad, its not something i would take over what i usually do."*
- *"im suppose to follow a certain format to consolidate my learning instead of doing it the way i want to. Thus, my primary focus for this assignment is to get the format right, instead of focusing on the content that ive learnt is"*
- *"is just copying of the slides waste a lot time can just read the slide and understand plus some people do their own notes also then need do this notes again waste a lot time.*
- *"the idea of a concept map assignment is pointless and stupidly time consuming, we shouldnt be graded by how much information we can write down in a summarized form when what actually matters is our understanding of the subject. having concept map assignments is a nod to the fact that the school has run out of ways to allocate our grade and therefore uses this approach to tabulate our grade for the semester. its pointless to grade us on our ability to rephrase and regurgitate the lecture notes onto a piece of paper or a blank document."*
- *"i prefer more practice questions"*
- *"i prefer worksheets"*
- *"I felt like there was a better way to ensure that we are up to topic"*
- *"I don't think seeing how the concepts link together helps me in memorizing the content."*
- *"I think it would be more beneficial to answer structured questions instead."*
- *"Personally concept maps do not reflect my understanding of a topic. I think that small quizzes are more useful when it comes to consolidating my learning, but that is just my learning style."*

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Article

Compassionate Flexibility and Self-Discipline: Student Adaptation to Emergency Remote Teaching in an Integrated Engineering Energy Course during COVID-19

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Abstract: The global pandemic of COVID-19 brought about the transition to Emergency Remote Teaching (ERT) at higher education institutions across the United States, prompting both students and the faculty to rapidly adjust to a different modality of teaching and learning. Other crises have induced disruptions to academic continuity (e.g., earthquakes, hurricanes), but not to the same extent as COVID-19, which has affected universities on a global scale. In this paper, we describe a qualitative case study where we interviewed 11 second-year Integrated Engineering students during the Spring 2020 semester to explore how they adapted to the transition to remote learning. Our results revealed several student challenges, how they used self-discipline strategies to overcome them, and how the faculty supported students in the classroom through a compassionate and flexible pedagogy. Faculty members showed compassion and flexibility by adjusting the curriculum and assessment and effectively communicating with students. This was especially important for the women participants in this study, who more frequently expressed utilizing pass/fail grading and the personal and gendered challenges they faced due to the pandemic. During this unprecedented crisis, we found that a key element for supporting students' well-being and success is the faculty members communicating care and incorporating flexibility into their courses.

Keywords: emergency remote teaching; compassion; engineering; student experience; undergraduate students; qualitative research

1. Introduction

The outbreak of the novel coronavirus around the world has dramatically affected all aspects of daily life and caused institutions of higher education to move towards remote learning. On 6 March 2020, the University of Washington became the first university to cancel in-person classes [1]. On 11 March 2020, the World Health Organization designated COVID-19 a global pandemic [2]. In response to this and other data, institutions of higher education shuttered their universities and announced mandates to transition to online-only education to protect the health and safety of students, staff, and faculty. Study abroad programs, university events, sports, graduation ceremonies, and other large gatherings were cancelled as the general public was advised to shelter in place and to limit or remove their contact with individuals outside of their household. Students were required to rapidly respond to these mandates by relocating from campus and preparing for remote learning with little time to adjust, sometimes at great personal or financial hardship. As students physically relocated, university faculty, staff, and administrators adapted their in-person curriculum to Emergency Remote Teaching (ERT) while they sheltered at home.

Institutions have used multiple terms (e.g., online learning, remote learning, distance education) to describe the rapid transition to teaching remotely during quarantines and stay at home orders (i.e., ERT). However, these different learning modalities such as online learning typically allow for planning, student autonomy and flexibility, establishing teaching presence, care in developing digital literacy and netiquette, managing student expectations, and resolving technical difficulties beforehand [3]. The primary differences between ERT and online and remote learning are that ERT is intended to be temporary, is enacted in response to a crisis, requires a rapid response in order to develop and implement adjusted course content, and does not offer curriculum in its intended modality [4]. While online or remote learning may be offered in similar ways and with similar technologies to those used in ERT, unlike ERT these classes were purposively designed to be online and/or remote. Because ERT uses similar tools and methods to online or remote learning, some faculty members have experience with aspects of online teaching or remote working tools, such as learning management systems (e.g., Blackboard) and video conferencing applications (e.g., Skype, Zoom) [5]. Often, universities already have these tools at their disposal, with some faculty members choosing to utilize them in their in-person classes to support in-person learning. However, because of the crisis, even faculty members who were highly resistant to these technologies have had to use them to finish instruction for the Spring 2020 semester. Additionally, the faculty quickly discovered that ERT has different challenges than planned online learning or teaching in-person (e.g., constrained resources). While universities offered what resources they had to help faculty adapt to the technical aspects of their new reality, they could not completely prepare them for the pedagogical challenges that result from teaching remotely during a crisis.

While faculty members were quickly trying to pivot to ERT, students were simultaneously affected by corresponding difficulties. Some students had limited or inadequate access to resources such as computers, webcams, reliable internet, and learning spaces free of distractions [6]. Students faced job loss or housing insecurity, or were sent home to unsafe and unsupportive homes [7]. Other students were in completely different time zones and could not attend class synchronously. Many found remote learning impersonal and challenging. During this time, students still needed resources such as academic advising, career guidance, and mental health support, but there may have been inadequate technological or human infrastructure to scale these resources to an online environment [8]. Without informal in-person interactions between their peers, students were reliant on the sometimes limited and confusing communication from the university, university staff, and their professors for any information regarding how the remainder of the Spring 2020 semester would be handled, how they would be assessed, and any resources or flexible grading policies (e.g., pass/fail grading) that could benefit them.

These are not novel issues, but they are now occurring at an unprecedented scale and exacerbating disparities that were too often ignored when all students were expected to be within a classroom. As COVID-19 has revealed and heightened existing inequities within society, so too are these imbalances magnified during the global pandemic within higher education. Solutions for providing resources and accommodating students already exist, but barriers can inhibit students from accessing these resources which are exacerbated by the crisis. For example, students with (dis)abilities are able to make accommodation requests for equal access to education (e.g., given more time to complete exams, lecture notes); however, barriers such as stigma, discrimination, lack of awareness of resources, and unwillingness to accommodate students can still prevent students from accessing these resources [9]. A report by the National Center for Learning Disabilities states that only 17% of college students with (dis)abilities reported utilizing these resources [10]. After the Spring 2020 semester and rapid pivot to ERT, disability advocates are questioning why remote learning requests were not accommodated for students with disabilities before the pandemic [11]. As with material resources, students also needed more attention, clear communication, and care during the crisis. The crisis and abrupt shift to online learning have magnified these issues to the point that they must be addressed. How, then, can students and faculty members adapt in this time of crisis?

In this paper, we sought to investigate the ways in which students and faculty members responded to the transition to ERT within a case study of a second-year undergraduate engineering class. We describe the approach the faculty of IntE took in response to the emergency, the pedagogical adjustments intended to make teaching and learning more effective, the compassion-driven approach to education adopted by the department, and the ways in which students responded to these abrupt alterations.

2. Literature Review

2.1. Crisis Management and Reaction in Higher Education

While COVID-19 caused a major large-scale disruption to higher education, it is not the first time a crisis has prompted the shift to online learning. Academic continuity disruptions have occurred as a result of natural disasters such as hurricanes [12–15], earthquakes [16–19], large-scale student protests [20,21], and war and conflict [22], which have also resulted in a temporary and sometimes long-term shift to online and remote learning. While student and university employee responses to pandemics such as H1N1 influenza virus (also known as "swine flu") have been studied [23], class cancellation has been advised [24] and academic continuity plans created which advise online teaching [23]; these outbreaks have not been as severe as COVID-19 in both the magnitude of people who are affected and how long the crisis has lasted. Crises with an extensive spatial and temporal extent inherently have more uncertainty as to when there can be a return to normalcy and thus can severely disrupt academic continuity [25]. While, in the past, pandemics such as H1N1 have only caused weeks of disruption on regional scales, the current global pandemic has affected entire nations for months with no clear end in sight [26] and have been accompanied by state-mandated transitions to online or remote learning.

Several themes have emerged within the literature about higher education responses to these disasters and their transition to online or remote learning. These include the rapid adaptation of e-learning/online learning [17,18], the importance of clear and transparent communication from the university to students [12,13,16,18,21], issues of equity and ethics [21], faculty care (e.g., emotional support) for students [12,15,21], and students showing empathy (i.e., compassion) for their instructors [16,25].

2.2. Higher Education Rapid Response and Adaptation to Crisis

Hurricane Katrina was a category 5 hurricane that struck the Mississippi/Louisiana Gulf Coast in August 2005, causing over 1200 deaths and billions of USA dollars in damage. Many people were forced to evacuate or relocate in the aftermath of Hurricane Katrina, including an estimated 100,000 college students after the continuing crisis also caused long shutdowns on college campuses [27]. Universities in the area quickly responded to the crisis, prioritizing the safe relocation of students, clear and frequent communication, and enhanced assistance from information technology (IT) personnel [19]. In response to students not being able to attend in-person classes in affected institutions, a nationwide effort of a consortium of 153 higher education institutions, the Southern Regional Education Board, and the Alfred P. Sloan Foundation provided online education to the thousands of students who had been displaced by the disaster by creating the Sloan Semester project [15]. This team had made prior preparations in the event that a pandemic such as the H5N1 influenza, also known as the avian flu (which affected China during 2005), caused a campus-wide shut down. The Sloan Semester began offering classes online to affected students 16 days after the levees broke due to Hurricane Katrina [15]. The lessons learned from this rapid adaptation include: developing or adapting existing delivery frameworks for online instruction (e.g., learning management systems); constantly communicating to students, faculty, and staff using multiple paths of communication such as email, text messages, or social media; and prioritizing the greatest issues first [28]. A limitation of rapidly responding to a crisis, however, is that initiatives such as the Sloan Semester focused on the logistical challenges of how to implement ERT rather than effective pedagogy during the crisis. Despite overcoming many logistical implementation issues, the students enrolled in the Sloan Semester still struggled with access to resources such as power and internet, had limited time and energy to focus on classwork, navigated trauma and mental health issues, and dropped out of classes [29].

2.3. Importance of Frequent and Transparent Communication

The 2011 Great East Japan Earthquake struck the Pacific coast of Tōhoku and caused a tsunami and nuclear accidents, including level 7 meltdowns at three reactors in the Fukushima Daiichi Nuclear Power Plant. Gómez describes the reaction of international students at the Engineering School of Tohoku University to this event [16]. First, the university immediately sought to confirm the safety of their students, however in the aftermath of the earthquake, international students were left with tenuous shelter and resources and many decided to return home. These students primarily relied on non-university sources of information such as family, friends, and people of their own nationality to inform their decision. After the fact, students reported that the most negative aspects of the university's response were slowness in decision making and providing information. When finally returning to the university, the students' discussions with professors were the most important factor in deciding their return date. Professors offered the students a sense of security and reliable information. On the other hand, publishing important information only on websites was not enough to inform students [16].

2.4. Issues of Equity When Transitioning to Emergency Remote Teaching

In South Africa, recent large-scale student protests about the lack of accessibility to higher education (exacerbated by high tuition fees and exclusionary policies) and demands to decolonize the curriculum caused disruption at universities for two years [20,21]. In response to the continuing disruption, universities adopted blended/online learning, amplifying the issue of inequity as not all students had access to the resources necessary for online learning or were not fluent in digital literacies [21]. In response, online/blended learning was perceived as undermining student protests. Likewise, in other crisis events such as Hurricane Katrina, access to reliable internet has also been revealed to be an equity issue [30]. This has been a critique of online learning as a form of distance learning where access is restricted by internet and computer resources [31]. Though online education could potentially support marginalized communities and provide wider access to education, too often individuals who face equity issues within traditional educational settings also face similar issues within online education [32]. The continued lack of equitable access to educational tools and technologies exacerbates the already-existing inequity gap.

2.5. Faculty and Students Showing Compassion and Care During Crisis

In the event of a crisis prompting a transition to ERT, both faculty and students encounter uncertainty and the need to adapt. Students bear the responsibility of adjusting to and being successful in this new modality of learning and quickly adopting and navigating a panoply of new applications and technologies for communicating and learning that are required across multiple classes. At the same time, faculty members are responsible for quickly redesigning and adjusting curriculum, learning new technologies and programs, and learning how to best teach in the new virtual format where students do not react or respond in the same way as before [21]. During times of crisis, both faculty and students require support in managing these forced transitions [18]. Showing compassion and care for students can be more difficult when there is physical and social distance.

Compassion is recognizing the suffering of others and taking action to help. While empathy and compassion are similar, compassion may be thought of as an aspect of empathy that includes action and response to having empathy. Empathy has a cognitive component of knowing how someone else feels, an emotional component of feeling what the other person is feeling, and then a responding component of showing empathy (i.e., compassion) [33]. The individual showing compassion understands the emotional state of others, feels their emotion, and is moved to action based upon those emotions and awareness [34]. To show that they care, instructors have to be attentive and receptive to the student by first listening and reflecting on their needs and then responding positively to the student's expressed need or, if that is not possible, in a way that maintains the caring relation [35]. Faculty have shown care during ERT through the way they communicate with and respond to students. Specifically, they have elicited frequent feedback, responded to curricular and personal concerns, offered more choice and autonomy in assessment, utilized applications that were more accessible, and repeatedly updated and adapted course material based on student feedback [21]. Students relied on and trusted information provided by faculty during times of crisis and, despite the issues they faced, expressed that they understood that the university did the best they could in the situation [16]. Even on a smaller scale, where a personal situation prompted ERT for a week, students showed compassion, empathy, and forgiveness for their professor when information was communicated clearly [25].

2.6. Emergency Remote Teaching during COVID-19

In a survey of 897 faculty members and administrators at 672 U.S. higher education institutions and their response to COVID-19, faculty members reported having to alter their exams or assignments (64%), lowering the amount of work given to students (46%), adjusting their expectations for students (48%), and allowing students to choose pass/fail grading (49%) [5]. Another study of over 1000 undergraduates who went online due to COVID-19 found that students "struggled to stay motivated and missed receiving feedback from instructors and collaborating with fellow students" [36] (p. 3). An example specific to engineering was the University of Georgia's Engineering Education Transformative Initiative's (EETI) recently published reports for their National Science Foundation (NSF) grant for Rapid Response Research (RAPID) on their findings on student and faculty experiences during ERT [37,38]. They found that, while both students and staff reported difficulties working from home, faculty members and staff were adapting well to the crisis by exercising agency, while undergraduates self-rated their experiences as highly negative and reported that they were treated with indifference and disrespect by people in power [37]. Students also reported feeling ill-prepared for the transition, having difficulty communicating with professors, and how impersonal instruction was. In response, the authors recommended that the College of Engineering's instructional focus should shift from being rigorous to being compassionate [37], and that compassion could be manifested through flexibility [38]. They recommended ways for faculty members to show compassion, including eliciting student input about course workload and assignment due dates and changing how students are assessed (e.g., flexible projects with autonomy instead of exams) [38].

Because of the quick pivot, the emergency context, and ongoing uncertainty, learners enrolled during the Spring 2020 semester had no choice but to deal with remote learning in contrast to making the decision to take an online class [39]. Institutions had contextually specific reactions and adaptations to the global pandemic during the Spring 2020 semester, and the lessons learned echo the themes of other crisis responses. Specifically, preliminary findings point to the need for compassion, care, and empathy for students during crisis situations [5,36,37,39,40].

3. Methodology

We selected a case study as the qualitative methodology for this study. Case studies are used to explore a phenomenon within a bounded system so that an in-depth understanding emerges from examining an individual, bounded case [41], and take into consideration the "particular idiosyncrasies of the institution, its resources, teachers and students, as well as its overall culture" [42] (p. 191). While institutions of higher education across the U.S. experienced the phenomenon of COVID-19 and the rapid implementation of ERT, based upon the literature on crisis management in higher education we believe that the particular way faculty members and students adapted within the department of

Integrated Engineering at the University of San Diego (USD) within the United States is a compelling case that it is important to highlight. Given the disciplinary culture of engineering, which is highly technical, emotionless, rigorous, meritocratic, and depoliticized [43,44], we wanted to provide a counter to traditional engineering pedagogy that is sociotechnical and grounded in compassion [45–48]. Given the large number of engineering students that have reported negative reactions to ERT during COVID-19 [36,37], we describe an approach that provides valuable insights about the culture of care and compassion not only during uncertain times but permanently in engineering education.

3.1. Purpose

The purpose of this case study was to illustrate what engineering faculty can do to support students during ERT and, correspondingly, what methods students used to adapt in this crisis. In doing so, we aim to provide engineering educators with insight into what they can do to support students in their classroom as the global pandemic continues to disrupt higher education. As with all case study approaches, the results are not generalizable to all engineering classrooms, however the lessons learned from this case can be adaptable to many different contexts [42].

3.2. Case Study Context

For this study, we explored the case of a single second-year undergraduate engineering class, "An Integrated Approach to Energy", within the Integrated Engineering (IntE) department at USD, a private Roman Catholic institution in the western USA where engineering students receive a BS/BA and take the same liberal arts core curriculum as all other undergraduates. USD has a high tuition and small class sizes, and students expect to receive personalized attention from their instructors. The university strives to develop ethical leaders and compassionate citizens with a global perspective who will make a positive difference in the world. We have included a description of the context of our university's response to COVID-19 and transitioning to remote teaching, IntE's response and reactions, and the response of the faculty member who taught the class that bounds this case study.

3.2.1. University Response to COVID-19

The leadership at our university, like most across the USA, struggled to respond to the COVID-19 pandemic during the Spring 2020 semester. Constantly evolving information from the Centers for Disease Control and Prevention (CDC) and other federal and state agencies required rapid decision-making, prompting the creation of the university's COVID-19 Action Team, which did not include faculty representation. A timeline of relevant events before and during the transition to ERT at USD is provided in Figure 1.

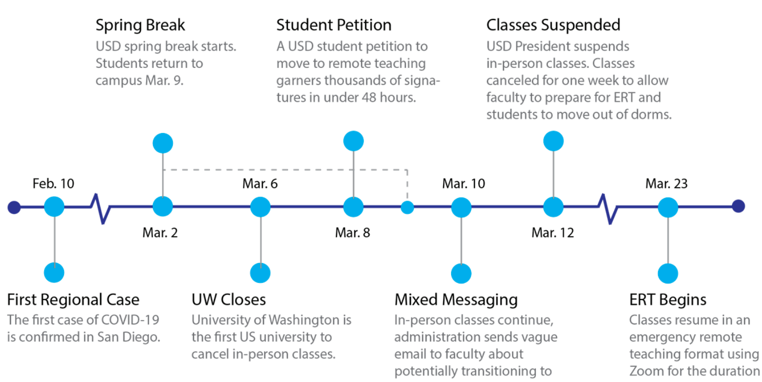

Figure 1. Timeline of the USD's response before and during the transition to ERT due to COVID-19.

Overall, communication from the administration was sometimes unclear. In early March, the lack of detail and quickly evolving messaging was confusing, contradictory, and heightened the anxiety of faculty and students. Further, official communication from the university through emails and a virtual presidential forum focused on the bleak potential financial implications and a deficit framing of future student enrollments' impact on the university. The next major issue our university grappled with was the ambiguous implementation of the pass/fail (P/F) option for course grading for the Spring 2020 semester (note that our university traditionally had letter grades of A, B, C, D, and F for most classes required for graduation). In the Spring 2020 semester, if students chose "P/F" and received a grade of "pass" for any class, they received credit towards degree requirements for graduation. If they received a "fail," they would not receive credit and would need to repeat the class to satisfy degree requirements. Many students were concerned that taking a class with P/F would look bad to employers or were unsure how it would affect scholarships. Compounding on this, inconsistent messages were given to students by faculty (mostly due to the limited information received by the faculty), which led to considerable confusion and anxiety. Some students felt pressured into choosing P/F by faculty members, while other faculty members stigmatized the P/F as failing.

3.2.2. IntE's Response to COVID-19 and ERT

IntE is a new department within the School of Engineering which includes four untenured faculty and one tenured faculty, who is the chair of the department. The faculty include one Asian woman, one Latino, two White men, and one White woman. This department reframes engineering as a sociotechnical endeavor, places a high value on inclusion in engineering education, and deliberately fosters strong relationships with students to support the academic and personal success of their small student population (the largest cohort being the sophomores described in this paper, which has 18 students). During the week when classes were cancelled to aid in transitioning to ERT, IntE quickly established an online community of practice. The department created new communication pathways to meet both formal and informal, social, and professional needs. They also held sessions to practice new technology such as Zoom to learn together how to better facilitate remote teaching. The department was intentional in their student facing efforts, creating informal and low-barrier ways for students to access them in ways that simulated "popping into office hours" when on campus. The IntE faculty members presented a united front by utilizing the same technologies (e.g., creating a Slack workspace for each of their classes for students); utilizing existing structures that students were familiar with prior to ERT (e.g., Blackboard); and collaborating on a survey to assess students' remote learning resource needs (e.g., access to internet and webcams), logistical challenges (e.g., different time zones), and well-being (e.g., how they were coping). Concurrently, this also allowed a platform for students to express their concerns and voice their questions before the official start of remote learning. Based on the results from this survey, the IntE faculty developed a comprehensive plan to ease students' transition to remote instruction.

3.2.3. GENG 294: "An Integrated Approach to Energy" Response to COVID-19 and ERT

When the transition to ERT was made official, the course instructor (GDH) shared a remote learning plan for his course, "An Integrated Approach to Energy", with his students, which included revisions to the course syllabus, expectations, and procedures for communication. The class was structured with an active learning approach that incorporated groupwork in breakout rooms that GDH could monitor and unobtrusively interact with over Google documents. GDH was flexible in response to the difficulties the students faced during the pandemic. He removed and adjusted the course requirements (e.g., attendance) and provided access to course content both synchronously and asynchronously. He checked in with students to see how they were doing both formally (e.g., surveys, reflections) and informally (e.g., Slack). Through daily student reflections, the students revealed the incredible pressure they were under (e.g., they had family members who were first responders, had lost their jobs, or had passed away). In response to students feeling overwhelmed, he changed his no late assignments policy and allowed more time to complete exams. When students were unsure whether to utilize P/F grading due to the confusion and stigma created by the university, GDH spent class time unpacking what the P/F option meant and clearly communicated students expected grade at the end of the semester. He encouraged students to choose that option if it would benefit them in any way.

3.3. Researcher Position in the Case

The authors of this study consist of four faculty members from the Integrated Engineering department (SML, GDH, DAC, JAM) and the first author (LAG), who is a postdoctoral research associate hired under an NSF Revolutionizing Engineering and Computer Science Departments (RED) grant that the school of engineering received to develop "Changemaking" engineers by redefining the engineering canon as sociotechnical [49]. LAG was situated closely to the IntE department both in proximity (e.g., housed in the same building before the stay at home order) and in curricular and research interests [50–52]. As such, LAG's expertise has been utilized to conduct observations, interviews, and focus groups for IntE faculty. As a postdoc, the first author did not teach any classes during ERT, but rather observed how the IntE department prepared and adapted to ERT and interviewed students about the class and their response to the COVID-19 pandemic. Coincidentally, the new communication pathways created by IntE in response to ERT also facilitated easier connection and the inclusion of LAG.

For the class, "An Integrated Approach to Energy", the students had been formally introduced to LAG's presence by the instructor on the first day of the Spring 2020 semester as a researcher who would be conducting classroom observations. LAG was in the classroom on a weekly basis until the transition to ERT. This presence in class along with the instructor acting as a gatekeeper to the students about her presence and role allowed for a measure of trust, credibility, and rapport from the students [41,53]. This initial trust was further cultivated into rapport during interviews so that students saw the researcher as an empathetic listener rather than as a detached evaluator [53].

3.4. Participants and Recruitment

Participants were purposively recruited [54] in April 2020 for semi-structured interviews using convenience sampling [41], based upon being enrolled in "An Integrated Approach to Energy" in the Spring 2020 semester. Convenience sampling was utilized because research interviews were already being conducted for research on other aspects of the class [52]. The instructor informed the class over Zoom about the research study and provided them with a link to a Google form where they could sign up to participate in a research interview. The first author individually contacted the respondents who wished to participate through email and scheduled Zoom interviews. After the conclusion of all scheduled interviews, the participants were compensated with a $50 Amazon gift card.

Eleven second-year undergraduate engineering students out of the 18 in "An Integrated Approach to Energy" during the Spring 2020 semester participated in this study. A summary of these students using their pseudonyms is provided in Table 1. Additional demographic information within the table about the students was elicited through a voluntary survey using Google forms or described within their interviews.

3.5. Interview Procedure

The interview protocol was initially piloted with a fourth-year undergraduate engineering student researcher who was also experiencing ERT at the time and provided relevant feedback. Questions about students' response to COVID-19 and ERT were added to an existing interview protocol due to the timing of the ERT. Interviews were semi-structured and split into two sections; the first was about their experiences in the GENG 294 class and the second part was specific to their experiences of COVID-19 and remote learning at their university. The second part of the interview was structured to first allow the participants to say anything they wanted to or "vent" about their experiences to develop rapport and promote a therapeutic effect by providing participants with an active listener who was nonjudgmental, neutral, and did not interrupt [55,56]. The first author conducted all semi-structured interviews over Zoom in response to the pandemic and stay at home orders. The participants were already familiar with using Zoom because it was utilized for ERT. Interviews were recorded using Zoom's built-in recording function with an audio-recorder as a backup. Interviews were transcribed using TranscribeMe!, an online transcription service.

Table 1. List of participant pseudonyms, gender, and whether they utilized pass/fail grading.

Pseudonym	Gender	Utilized Pass/Fail
Chandler	M	Yes
Clara	F	Yes
Gloria	F	Yes
James	M	Did not disclose
Lexie	F	Did not disclose
Luigi	M	Yes
Peter	M	No
Rachel	F	Yes
Raymond	M	Did not disclose
Rebecca	F	No
Tito	M	Did not disclose

3.6. Ethics in Data Collection and Analysis Procedures

This study was situated in a larger research project occurring with the class. Informed consent was obtained at the start of the semester when the class was observed in person. Measures to ensure the confidentiality of participants were utilized throughout data collection and analysis [41]. The pandemic required several unanticipated changes not covered in the initial informed consent, such as interviews being conducted over Zoom. Before the interviews, the students were briefed about the structure of the interview, informed that their participation was voluntary, informed that they had the right to not answer questions and to rescind participation at any time, and informed that participation had no effect on their grade. The participants were made aware verbally and visually (by the recording icon in Zoom) when and how their responses were recorded and when the recording was stopped.

Pseudonyms were assigned at the start of the semester for classroom observations to preserve anonymity [57]. Because this is a narrow case study, the participants were also given the option of checking any direct quotes used in the manuscript to ensure that they were not misrepresented or overly identifiable [58].

3.7. Data Analysis

Interview data were qualitatively coded and thematically analyzed using memoing, concept mapping, and multiple coding methods [41]. After each interview, the first author wrote a summary and reflective memo. Memoing was used as a critical reflective process to describe the emergent patterns, themes, and concepts that arose in the analysis [59,60]. Following each reflective memo, the interviews were read in their entirety several times while utilizing concept mapping to visually analyze complex emergent phenomena [61,62]. This concept map was iterated several times as the data was coded. Open coding was used to explore the data in order to remain open to multiple interpretations and nuances in the data [59]. This coding was exploratory, utilizing descriptive and process coding to provide a detailed inventory of student responses and actions [59]. In combination with descriptive coding, concept mapping, and memoing, process coding allowed for the inclusion of actions in the data that can help explain how events dynamically unfold and evolve [63]. This was important to the coding process because student participants are not passive recipients of ERT but rather dynamic actors in defining how they responded to ERT and the global pandemic.

After initial coding, a codebook was developed by categorizing and reorganizing the concept map into larger categories with codes and subcodes. These categories and codes were discussed iteratively among the authors to provide different perspectives and expertise in the analysis. This process refined the codebook. The data was recoded with the refined codebook using Dedoose, an online application for collaboratively analyzing qualitative data. The results of these coding processes were then thematically analyzed to further winnow codes and categories into larger themes that reflect a more nuanced and summarized meaning than individual codes [59]. The results of this thematic analysis were triangulated with the undergraduate researchers [41], who were third-year IntE students who also experienced remote learning within the context of the university and the department.

3.8. Limitations

This study was limited in that it was conducted on a small population at a private institution within the Western USA and the results cannot be generalizable to all undergraduate engineering students. Larger engineering departments at public institutions will have different challenges, but some of the lessons may be transferable and adaptable to their context. Most of the participants were White, and thus the results may not be as applicable to students of other races and ethnicities [64] and the unique challenges they faced during ERT. Our sample size was too small to fully explore variation in experiences due to gender, race, socioeconomic status, etc. Nonetheless, the goal of this study was not to create a comparative study but to describe how the students experienced ERT. Additionally, the global pandemic necessitated conducting virtual interviews. While this made the interviews accessible both to the participants and the researcher, it was more difficult to develop the same level of rapport as an in-person interview. Finally, the results described in this paper are part of a summative evaluation and not a formative evaluation. Students' reactions to ERT were not captured in situ due to the lack of online observations. Therefore, instances where students were not responsive to in-class prompts, active participation in online synchronous discussions, or apprehensiveness created by being on camera constantly were not part of the data collection. These factors should be included in future studies that seek to evaluate students' response to ERT.

4. Results

The analysis of the student data revealed four themes in how students responded to ERT and how faculty can help students' ability to adapt. These four themes are: (1) challenges with remote learning, (2) compassionate flexibility of faculty, (3) student self-discipline, and (4) gendered response to ERT.

4.1. Challenges with Remote Learning

Students were given an open prompt to describe how ERT and the COVID-19 pandemic affected them. They did not have to tailor their responses specifically to class, but they offered their perspective of how ERT was handled in different classes, including "An Integrated Approach to Energy". Their responses reflected unique situations and challenges that affected their ability to learn in this remote setting. For example, some students described how COVID-19 had affected their immediate family members who were essential or front-line healthcare workers and how that translated to increased worry and stress. Not all students elected to share about their home and personal life but instead focused on the challenges specific to remote learning. These challenges were individually specific, and the results will focus on the three cross-cutting challenges: (a) increased workload, (b) inconducive learning environments, and (c) miscommunication.

The participants described their perception of increased workload in a variety of ways, but also struggled to pinpoint why they felt the workload had increased. When asked about how faculty have helped or hindered his ability to adapt to remote learning, Luigi stated that:

> "I've noticed, the homeworks, even for the energy class, have increased in length. And I don't know if that was originally planned and that was just going to happen anyway or if that's a result of the online stuff. But the kind of way that's kind of worked out isn't ideal. I noticed a very similar thing with all the other classes. Even when maybe a project at end of

> the school year is cut off, that percentage of our grade, instead of just them kind of taking that out, they're like, "Oh, well, we have to still add that in somewhere." And so that stress really doesn't go anywhere. They're still adding to the pile."

Some students perceived that they were getting more "busywork" and assignments to make up for the week they lost in the transition to ERT. They thought that faculty were continuing their classes as normal with a typical workload, without adjusting their schedules to reflect the current pandemic conditions. When asked about how faculty had helped or hindered her ability to adapt, Lexie stated that faculty hindered her when they "[...] gave us the same amount of expectations. Or tried to make up for the lost time that we had." Other students hinted that they thought faculty members perceived they had more free time because of the stay at home order, sometimes not even recognizing the pressure the students were under after some of them were asked to leave their dormitories and facing the uncertainty of housing issues. Some students described that they had an implicit expectation that the workload would be lessened because of the pandemic. While the participants struggled to find the root cause of why their workload had increased, Peter offered some insight into the issue—tasks took longer now than they did before. He stated:

> "I think in some of my other classes, both labs, they just take longer because you can't ask professors for help in class. Just figuring stuff out yourself. Like my Circuits lab takes almost twice as long now that we're just trying to grind it out and figure everything out for ourselves. And I'm sure we're learning better, but it's just like I have a lot less free time. Yeah. So, it does feel like stuff takes longer but I have a feeling they're the same assignments, we just don't have the same kind of help."

Another student described that they had to watch asynchronous class recordings multiple times to get the same amount of learning to pass their exams.

This perception that students could not get the same level of help they used to is also tied to another challenge of the **inconducive learning environment** that remote learning created. The students found it hard to focus during synchronous and especially asynchronous settings. They experienced frequent distractions by roommates or family, and some students described how they would fall asleep as they attended synchronous Zoom classes. What was most prevalent to the participants was how student–teacher and student–student interactions had changed as a result of ERT. The participants described the decrease in student participation. For example, Gloria remarked, "It is kind of weird that no one talks in class. I don't know. But I don't feel like ... the environment isn't super like, 'Oh, let's just talk about these things.' And I don't know how we could change that, but that's just how it is." Rachel seconded this feeling and said, "It's harder to be more interactive and participate. Because it just all goes to silence sometimes and it's kind of hard to break."

Zoom was described as being both too informal (e.g., "feels like Facetiming [your professor]") and formal at the same time and "awkward". This awkwardness was most apparent when professors pointed out how students are not engaging in class. For example, Gloria said, "I feel bad when the teachers are like, 'Why isn't anyone talking?' But then it's like- I don't know—they're uncomfortable, and I'm uncomfortable [...] I don't really feel that welcome to talk even though I know I should." The students also described the hypervisibility they experience if they speak in some classes and how asking questions interrupts the flow of the lesson. Peter remarked on this by saying, "To ask a question, you have to unmute yourself and then the whole class stops and everyone's listening to your question." The participants contrasted this to their previous classroom experiences where they were constantly working in groups and could easily and unobtrusively raise their hand to ask the professor for help at any time. While students were aware that the faculty members were trying to increase class participation, the new setting was difficult for them to overcome.

The most difficult experience students described was that, because of this new learning environment, they felt they could not get help. This was especially prominent for classes where the students could not attend synchronously whether through their personal situations or because the professor only posted asynchronous recordings. Lexie summarized this by saying, "I think recorded lectures have their benefits but also drawbacks because you can't ask questions if you're confused. It's very much just like reading a book, except someone's speaking it to you, so you can't really ... I mean, you're on your own."

The other major challenge students described was **miscommunication** from faculty and from the university. The abrupt transition to remote learning caused widespread confusion for students, which was exacerbated by the conflicting communication from the university and their professors. They described the confusion they felt when they received abrupt communication that they had to evacuate their dorms and misleading, confusing, and contradicting information about P/F grading. For individual instructors, they experienced limited (and sometimes zero) communication about assignment deadlines and what to expect during the transition to remote learning. Some professors, Rebecca noted, "didn't even reach out to us or anything at all." The majority of these challenges students described in relation to other classes at their university. In contrast, they had highly positive experiences with the IntE faculty.

4.2. Compassionate Flexibility of Faculty

While there was no shortage of challenges for students during ERT, the participants were more than willing to describe how faculty had helped them adapt and persevere. The students mainly focused on IntE professors and the actions they took. For the Spring 2020 semester, all the participants were students in "An Integrated Approach to Energy" taught by GDH and another engineering class taught by SML. The students noticed how IntE faculty attempted to make ERT effective, despite how little time they had to prepare. The faculty not only had to learn new technologies and tools, but also learn how to best teach using them. As Rachel shared:

> "Overall, I think, [SML] and [GDH], they've done a good job ... the breakout rooms were really helpful because it was just more interactive and helped me be not as distracted. Whereas, in my other classes, it's just a bunch of students watching a video."

While the students admitted that remote learning was not the same as learning in person, they appreciated the effort and how adaptable the IntE faculty were. This type of pedagogy was fortified with faculty showing compassion and care for students by emotionally supporting them, being flexible in grading and assignments, providing accommodations (e.g., grading policy changes), and being accessible to students. The students described how they believed that IntE faculty authentically cared not only about their academic success but as individuals. Faculty could show this in many ways, one of which was actually asking their students how they were doing. In response to their perceived higher workload, Rachel noted, "[IntE faculty] send out surveys, they see how the online learning experience is going. Based on the surveys, they'll change their schedule or the workload they give each of us [...] my other teachers kind of don't do that." Rebecca echoed this by saying that IntE faculty assigned daily reflections to ensure they were not "pressuring us or overwhelming us with too much information or workload."

The students also appreciated accommodations made by the university or faculty. Accommodations, in this paper, include any official policy changes to classes or grading (e.g., changing assignment grading policies, P/F grading). The main accommodation students mentioned was the P/F grading option. For example, when prompted to "vent" about anything they wanted, Clara described the difficult situation her family was in because of the pandemic and added, "I appreciate that the school's allowing pass/fail options for classes. I'm taking two classes as pass/fail. ... So that's been helpful, I think, in relieving stress." Other students mentioned P/F grading and how this option reduced their stress about classes they were uncertain about their grades in. Other ways to accommodate students were to provide more time to complete assignments or tests and grading based upon "effort" or "completion".

Some faculty showed flexibility by altering their class in response to the new learning format and in recognition of the hardship the global pandemic brought. The students described how some faculty adjusted their expectations or showed leniency. This flexibility even translated to being more accessible to students virtually. For example, when asked how faculty have helped him adapt to remote learning, Luigi responded:

> "I know a lot of professors have been more lenient with due dates and stuff, which has really been nice. And a lot of professors that I currently have are very flexible with office hours. If you want to talk about something, you can just email them and then just have a more of a private date if needed."

The faculty increasing accessibility to students (both in providing curriculum and giving students avenues to access their expertise) was valuable to students. However, accessibility was contingent on how the faculty communicated with students. Students were appreciative of faculty who responded to email promptly, who provided clear and transparent information about their class and what they needed to do to be successful, who personally connected them to resources or people to help them, and for reaching out to them. All the participants described moments where the IntE faculty reached out to them in one way or another. For example, Rebecca ended her interview with:

> "I really value how [GDH], [SML], and I'm sure a lot of the faculty, have been really responsive and really emphasizing on student feedback and asking how we're doing and seeing what they can do for us. And I think that's something that's really important right now with our difficult transition."

Feedback became a way for the IntE faculty to get a better idea of what worked, what needed improvement, but also how to help students create community. Sometimes these conversations extended to how to implement compassionate teaching in other classes outside of IntE.

4.3. Student Self-Discipline

The faculty played a big role in helping students adapt, but the students also felt a responsibility for their own learning. The students had a variety of actions that best worked for them individually such as time management, being "present" in the ways that were possible with remote learning, removing distractions, and setting boundaries. All of these actions were rooted in the overarching strategy of being self-disciplined. Most students could identify time management as an integral part of self-discipline for remote learning. Students described creating and adhering to a schedule, finding ways to keep busy, getting work done right away, and batching time spent on schoolwork. One student, James, prided himself on his time management skills but indicated that remote learning required the additional development of those skills. He said:

> "So, I was already big on Google calendar. As soon as I get assigned a homework assignment, I put it as a mark in my Google calendar. And I've just been doing that way more forward than I usually like to. [. . .] I've been just taking the opportunity to try and learn better time management skills, especially with working in sequence with doing college. It's been a big experiment in how far I can push my time management skills."

Time management often went hand-in-hand with setting additional boundaries between school-time and free-time. This was achieved through various ways including attending class synchronously and removing distractions. Students tried to be "present" as much as was possible during ERT without being physically present. The students remarked how it was easier to stay motivated and pay attention if they attended class synchronously with their web cameras on. Peter remarked on the web cameras in particular:

> "I mean, think the webcam being on definitely. It just kind of makes you feel a little more present because when my webcam's off, it's just way easier to just go on my phone, but when

> my webcam's on, it's awkward to be on your phone in front of the professor. [...] I've noticed that just when I have mine on, not only do I learn better, but it's just easier to stay focused and I guess also be respectful to the professor because you have no idea what's happening when I do this."

This opinion was not universal, however. While for some students the presence of the camera made them feel like they could pay more attention and be present, other students felt like it was too invasive and contributed to an inconducive learning environment.

Lastly, an unexpected way students found to adapt to ERT was by showing compassion for faculty. The students expressed how they knew that faculty were also facing difficulty in adjusting to COVID-19 and ERT. When asked how faculty have helped or hindered him in adapting to remote learning, Chandler responded:

> "I think they've been very helpful. I mean, we're all kind of in it together, so yeah, the faculty have been helpful. They're just really understanding and trying to help us get the best we can, the best education we can out of this situation, which it makes sense. I totally understand. Yeah, but they're helpful and understanding, and I realize that they're going through the same thing too."

As indicated by Chandler's reflection, adapting to ERT sometimes required mutual compassion. The students realized that faculty experienced some of the same frustrations and were willing to show compassion in response to how the faculty showed them care and compassion.

4.4. Gendered Response to ERT

One theme that unexpectedly emerged from the data was a gendered response to ERT. The women in this study brought up compassionate and flexible pedagogy more often than men, while men focused on individual actions they could take and their personal responsibility. Women were more likely to mention and admit to utilizing P/F grading in their interviews of their own volition. Additionally, the women in this study described personal challenges they and their family were experiencing because of COVID-19 (e.g., anxiety over family members as frontline healthcare workers, family members potentially losing their jobs). Men described their experience of having more free time during the stay at home order while women found themselves increasingly responsible for domestic duties. When given the opportunity to vent about anything in relation to COVID-19 or remote learning, Lexie first focused on her increased workload but then described how personal issues such as living in a different state exacerbated her stress. She stated:

> "I just wish there was a little bit more lenience because if my mom does get sick, what am I going to do? I'm going to have to take care of her. My dad doesn't live with us, so I don't want him getting sick either if he comes over."

Clara also brought up her family and domestic responsibilities when allowed to freely vent about her experience of COVID-19 and remote learning. She said:

> "I'm at home. I'm safe. I'm healthy. And my family is healthy. And so, I think that that is the most important thing for sure. Being at home, a lot of people make it seem like you have more free time now that we're quarantined. That's not true. I don't. I think I even have less now. I'm cooking a lot for my family as my mom works [...] And so she's been working 24/7, on calls 24/7, working her butt off, working on the weekends. And it's been challenging. So, I've been there to support her the best I can."

As indicated by Clara, she felt responsible for providing emotional support for her mother who was also working extra hours. In contrast, Tito remarked "I do have a lot of time, but I don't want to spend all that time doing more work." Tito's experience was not unique. Several male students indicated that they were finding ways to stave off boredom or that they were "[. . .] always at home, not really doing anything else." Although the data indicated the emergence of gendered responses to ERT, this theme will require additional research to explore further.

5. Discussion

5.1. Challenges with ERT

The students faced many challenges during ERT, but the three most described by participants were (a) increased workload, (b) inconducive learning environments, and (c) miscommunication. It is not a surprise that the participants found ERT to be inferior to the face-to-face instruction they were familiar with. USD prides itself on small class sizes and personalized attention from faculty. This means that pedagogical expectations may have been high for ERT. The faculty were only given a week to completely change their class and the way they teach. Remote and fully online learning can be effective if adequately planned for and if expectations of both students and teachers are appropriate and well-defined [65]. However, in this crisis that required a rapid response, the faculty could only react to the best of their ability and available resources. Both the faculty and students had to find ways to adapt to their altered reality while managing their own fear, uncertainty, and inequities that were exacerbated by the global pandemic. To borrow a metaphor, this is like building a plane while flying it, with the plane also being on fire in this case.

The participants showed how they reacted to and navigated through inconducive learning environments that made it difficult to stay motivated and to be fully engaged in the virtual classroom. Some found that they had to go through the motions and make extra effort to feel like they were attending class in person. This included intentionally not lying in bed while attending class, keeping their web cameras active, and deliberately speaking up in class despite the hypervisibility that entailed. The majority of participants had to use time management skills such as making and adhering to a schedule and getting work done right away. At the same time, they perceived an increase in their workload even from faculty members who were flexible and empathetic to students' plight. Some of this could be due to the faculty trying to compensate for the lost week of instruction or focusing on things that the students could do on their own, such as homework assignments. Our analysis indicates that tasks now take students longer than they used to. This is supported by time management being the most mentioned method that the participants brought up. Not only do students have to be self-disciplined with the amorphous boundaries between school and free time, but they may also be expending considerable mental bandwidth on dealing with the stress and anxiety that the global pandemic has brought. Completing assignments and learning objectively takes longer to do during ERT, as was described by the student who had to watch asynchronous lectures more than once to understand them.

Compounding this issue is that students do not have the same level of access to faculty and their peers as they did face-to-face. The informal pathways to accessing information such as approaching a professor before class, stopping by for office hours, or talking to other students in and outside of class were removed. While formal pathways to access help exist, students may feel hesitance in utilizing them. In response, faculty members can be more explicit and transparent in their communication with students and provide opportunities such as arriving early or staying late after scheduled class time or offering to meet with students outside of normal office hours.

5.2. The Importance of Effective Communication

The literature is clear that effective communication is critical for institutions of higher education during a crisis that disrupts academic continuity [12,13,16,18,21]. The university plays a large role in communicating important information to students, but it is often left to individual faculty or staff to answer questions and to clarify any confusion. Faculty members can provide a sense of security and reliable information that students trust [16]. With this particular case, there was considerable confusion around P/F grading in how it would affect students' futures which was compounded by logistical failures in implementation. The participants described how the IntE faculty deliberately reached out to clarify information about P/F grading and set about removing any stigma associated with using it.

Students are not the only ones who are affected by ineffective communication. Faculty members also need official university communication to be translated, and often through the same informal peer communication pathways that were removed because of ERT. Informal communication is sometimes the most important and effective way in which junior, untenured faculty members gain institutional knowledge [66]. The IntE department established informal communication pathways between each other and their students. Moving to remote teaching created a distance with students, both physically and emotionally and presented new challenges to students on how to navigate professionalism in an online setting. The results indicate that the students were appreciative of the many ways that IntE faculty communicated with them before and during ERT, often because that communication went hand-in-hand with a message that the faculty cared about them as people. In this case, showing care began when faculty members surveyed student needs and provided them with avenues to speak about their difficulties. Care extended beyond that, by the faculty being flexible, adjusting expectations, making accommodations, and making information and themselves accessible to students.

There has been discussion within higher education since the Spring 2020 semester ended about losing rigor by adjusting student expectations during this challenging time [5,6,67]. This is especially salient within the discipline of engineering, which often defines itself through rigor [44]. Making courses rigorous (often operationalized as difficult) does not necessarily improve student learning and, especially during a global pandemic, may actually inhibit students' ability to develop as engineers or develop their own critical consciousness. Our results and other reports suggest that we need to shift the instructional focus from difficulty to compassion [36,39]. We do not need to "lower" expectations for students, but rather be clearer about our expectations. This requires constant communication through multiple means (e.g., LMS, email, synchronous instruction) and being more purposeful about sending reminders. In times of crisis, we put forward that communication is not just about effectively providing information in a timely manner, but also about conveying that we care about students.

5.3. Compassion and Care

Students in engineering can tell whether faculty members authentically show compassion and care through how faculty design and provide curriculum content and how they interact inside and outside of the classroom [68]. In the midst of a crisis such as a pandemic, extra attention needs to be paid to showing students empathy and care. This can be more difficult in times of physical separation, but can be mitigated through frequently assessing and responding to student concerns, offering students more autonomy in meeting the requirements of the course, reducing time pressures for assessment, and making course materials and the professor more accessible [21,36]. Despite their own feelings of anxiety and stress, during ERT the faculty deliberately sought to support students by responding to their needs and being flexible [5]. This is not a one-way street, however. The participants also displayed compassion for their professors, describing how they were all in this together. This compassion helped them adapt to the challenges of remote learning. The students also showed compassion for their professors during other times of crisis such as during the 2011 Great East Japan Earthquake [16]. Compassion, however, may require faculty members and students to be open and honest with each other through effective communication. If faculty members and students engage in two-way communication, show care, and are flexible in their curriculum, students are likely to respond with flexibility and understanding. It is important to remember that "when things go back to normal, people will not remember the educational content delivered, but they will remember how they felt, how we cared for them, and how we supported them" [39] (p. iii).

5.4. Student Motivation and Autonomy

The students in this study appreciated and thrived when faculty showed compassion and flexibility, but they also took responsibility for their learning and being self-disciplined. The students remained motivated to complete their semester despite their various challenges. This is reminiscent of the self-determination theory [69]. Simply stated, this theory posits that if students have their needs of autonomy (i.e., ability and willingness to make and carry out decisions), competence (i.e., understanding and being efficacious at performing tasks), and relatedness (i.e., positive, secure relationships) met, they will be highly motivated to perform well. In a study of engineering students, relatedness was found to be the most salient need for students in supporting their motivation and that relatedness provided space to build competence [70]. For the students in this case study, relatedness was already established during the in-person teaching at the beginning of the semester and continued into ERT. The participants exercised their autonomy through the strategy of self-discipline (e.g., time management, being "present"). Faculty members intentionally provided opportunities for autonomy through flexible due dates, choice of assignments, and different ways to participate in class (i.e., synchronous or asynchronous, Slack, email etc.) We have provided a few actions that both students and faculty members can take to adapt to the challenges of ERT in Table 2.

It is important to note that a missing piece from Table 2 is how to facilitate social connections between students during ERT. We reported on the most frequently mentioned strategies students utilized to adapt, and while some participants mentioned social activities such as engaging in online study groups, these students already had established friendships and this strategy was not prevalent across the entire participant population. This suggests that this may be a critical area that students need help with and that faculty members are unsure how to address. One way for faculty to motivate engineering students is by fostering relatedness through assigning team projects or homework assignments [70]. This is especially important for first-year students who may not have made connections with their peers and do not have a support system yet.

Table 2. Student adaptations and corresponding ways faculty can support students during Emergency Remote Teaching.

Challenge	Student Adaptation	Student Adaptation Examples	Faculty Support	Faculty Support Examples
Increased Workload	Self-Discipline: Time Management	Making and following a schedule, keeping busy, getting work done right away, time batching.	Showing Compassion and Empathy (e.g., Flexibility)	Begin ERT with lessons that help students develop time management (and digital literacy) skills, adjust expectations and provide leniency, remove time pressures from assessment, make accommodations (e.g., P/F grading), increase the accessibility of course content (e.g., synchronous and asynchronous).
Inconducive Learning Environment	Self-Discipline: Being "Present" and Setting Boundaries	Going through the motions of face-to-face instruction, getting out of bed, attending class synchronously, turning on webcam, choosing to interact in class, working in peer groups, removing distractions, putting phone in another room while attending virtual class, setting clear boundaries.	Adjusting Pedagogy	Increase online teaching proficiency, increase teacher and student social presence in the virtual classroom, be adaptable by using virtual tools to interact in real time with students (e.g., Slack, Google Docs), use available active learning methods (e.g., polls, breakout rooms, requiring student interaction).
Miscommunication	Having Compassion for Others	Understanding that others were affected by the crisis, being more forgiving or lenient, knowing that everyone is in this together.	Clear and Frequent Communication	Survey students about resource needs, provide avenues for students to bring up issues, reach out to students, provide timely and transparent information, connect students to resources, be more accessible to students (e.g., Slack, Zoom office hours).

6. Conclusions and Implications

At the beginning of the pandemic, people called COVID-19 the great equalizer because everyone, both rich and poor, young and old, could be affected by it. In truth, we quickly learned that the pandemic simply exacerbated existing inequities within society and within higher education. The university and IntE department pride themselves on being social justice-oriented, and with that comes pedagogies of compassion and care. COVID-19 and the transition to ERT showed us that we all have assumptions about the resources and skills that our students bring to class. When students were with us face-to-face, we did not have to consider that some students may not have technical resources such as personal laptops because they had access to computer labs on campus. We did not have to wonder if they had enough wi-fi bandwidth or cell phone data to meaningfully engage in class. We did not have to consider what time zone students were accessing synchronous instruction from. ERT created a physical divide between faculty and students, but it also required the faculty to pay more attention to their students' personal lives. This is something that, for many faculty members, is profoundly uncomfortable, but is key to setting students up for success in times of crisis. As educators oriented towards social justice, we aspire to be more aware of what assumptions we are unintentionally making about our students and act to make the classroom more equitable and accessible to all students. As engineering education continues to improve, so must the practices we integrate into our programs and, in particular, into our classrooms. Care and compassion in engineering education should not only be applicable to situations of extreme urgency, but they should become the new norm if we strive to make engineering a more inclusive space.

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education sciences

Article

A Student Primer on How to Thrive in Engineering Education during and beyond COVID-19

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Abstract: In this paper, we strive to provide a primer for students on how to thrive and learn effectively in engineering education in the volatile, uncertain, complex, and ambiguous (VUCA) times following the onset of the COVID-19 global pandemic, which has disrupted the educational enterprise massively with universities physically closing in many parts of the world and students and faculty transitioning to remote learning. Although the immediate audience assumed in this paper comprises engineering students (such as those enrolled in electrical, electronics, or computer engineering programs) studying in an outcome-based education (OBE) environment—the global educational paradigm mandated by the Washington Accord that aims to standardize engineering competencies in terms of the attained student learning outcomes—the presented ideas are more general and broadly useful for learners of all types. We will describe seven evidence-based steps that the students can adopt to thrive in OBE settings in these challenging times. The main contribution of this paper is practical: we present a synthesis of the vast research literature on effective student learning in normal, online, and disrupted settings to present practical insights that students can leverage to substantially improve their learning. At the end of the paper, we also present a discussion of important issues related to remote teaching and online education such as ensuring equity and the handling of lab work for engineers in such settings (e.g., through simulators and virtual labs).

Keywords: engineering education; electrical engineering education; COVID19; outcome-based education (OBE); learning sciences; pedagogy

1. Introduction

The COVID-19 pandemic, the biggest one since the Spanish Flu of 1918, is the biggest global pandemic for the last 100 years. Educational institutes the world over have physically closed with students and faculty transitioning to distance learning and working from home. As per UNESCO global statistics on 18 May 2020 (illustrated in Figure 1), the disruption of the COVID-19 pandemic is global with almost 70% of the total enrolled students around the globe being affected with more than 150 countries facing full-country school closures. As the world continues an ongoing battle with the COVID-19 pandemic, our daily lives and routines have changed dramatically and students and faculty members face an unprecedented situation. The fallout of the pandemic is yet to fully play out but it is fair to say that although the education sector has been jolted by this pandemic, it has not been brought to its knees due to the Internet and the online education revolution.

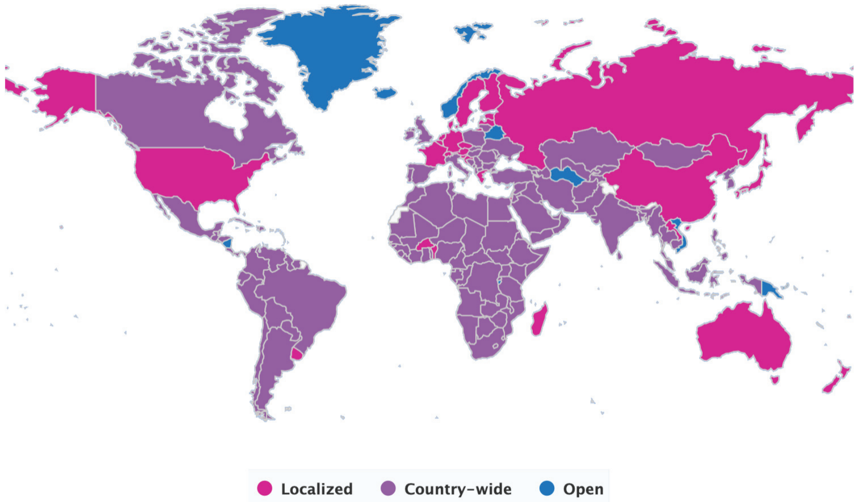

Figure 1. The global school shutdown effect caused by COVID-19 with 1,210,295,995 affected learners; 69.1% of total enrolled learners; 156 country-wide closures as of 18 May 2020 (Source: UNESCO [https://en.unesco.org/covid19/educationresponse]).

As we move into the third decade of the third millennium, the 2020s, we are well into the 21st century and the unprecedented rate of technological disruption and the ephemeral nature of the technological specifics of engineering state-of-the-art requires us to carefully evaluate what it takes to be an effective engineer in the volatile, uncertain, complex, and ambiguous (VUCA) times that we face during and beyond the COVID-19 pandemic. In our previous work [1], we have discussed the essential competencies for effective 21st century engineers as we enter the 2020s and have provided a broad overview of the various 21st century learning frameworks. 2020 might well turn out to be a tipping point in the history of education—in which the forced conversion of many traditional courses to online environments may be a fillip to the longer-term adoption of online and blended learning models.

In this paper, we aim to provide a student primer, particularly those pursuing engineering education, on how to thrive in an outcome-based education (OBE) environment during and beyond the COVID-19 times. Some experts refer to the wide adoption of OBE as one of the top five major changes in engineering education in the last 100 years [2] especially with OBE being the underlying paradigm followed by global accreditation efforts such as the Washington Accord. (The Washington Accord, originally signed in 1989, is an international agreement facilitated by the International Engineering Alliance between the accreditation bodies responsible for accrediting engineering degree programs in various parts of the world [3].) OBE is considered the brainchild of the sociologist William Spady [4,5], who defined "outcome" as a "culminating *demonstration* of learning" where *demonstration* is to be seen in the learner actually *doing* (e.g., *describe, explain, design, construct, produce, negotiate, operate*) something tangible, visible, and observable with the curricular concepts. In the OBE paradigm, the instructional and assessment/evaluation practices are explicitly designed for ensuring the attainment of predefined learning outcomes that are aligned to broader, long-term educational objectives. More pertinently for students and teachers, the modern outcome-based education paradigm is rooted in the same philosophy and operates by focusing on molding instruction and assessment according to the preplanned educational objectives and learning outcomes.

The paper is timely due to the disruption to the education sector caused by the COVID-19 pandemic [6], the gravest global health crisis the world has seen in the last 100 years, with 85% of the countries around the world closing their educational institutes resulting in more than 1.6 billion students being out-of-school (per statistics reported in a April 2020 report [7]). Compared to other sustainable development goals that COVID-19 has greatly impacted—such as SDG 1 (no poverty); SDG 2 (zero hunger); SDG 3 (good health and well-being)—SDG 4 (quality education) has seen moderately negative impact due to the presence of a backup option of online teaching. However, the dynamics of online schooling and physical schooling are starkly distinct and various issues (e.g., connectivity issues and lack of preparation and readiness for online schooling) has hindered the effectiveness of online learning.

Paradoxically as we keep advancing in technology, the importance of returning to the classical skills has increased. It is for this reason that while this paper is aimed at engineering education, the insights herein are quite general and apply more broadly to the broader Science, Technology, Engineering, and Mathematics (STEM) fields. Although a lot of technical knowledge has a half-life ("*Half-life*" refers to the time where half the knowledge becomes obsolete.) of the order of a few years, the core component of engineering knowledge has remained robust. In these times, a broad digital literacy that engineering education provides is being dubbed as the new liberal arts degree for the 21st century, particularly since it is expected that engineering will play a big role in the solution to the grand challenges facing the society [8]. For the most part, the essential 21st century skills [1] are classical techniques that are broadly applicable and are antifragile (Antifragile is a term coined by Nassim Nicholas Taleb who describes them as things that benefit from shocks and "*grow when exposed to volatility, randomness, disorder, and stressors and love adventure, risk, and uncertainty*." [9]) .

While acknowledging the fact that there are various factors outside the control of the students (e.g., the pedagogical approach adopted by the instructor and digital divide issues related to access to technology for connectivity and computing), we argue that there is much more that students can achieve than is commonly believed. In particular, with remote teaching and online learning becoming the norm, there is a greater expectation that learners will take greater ownership of their learning. To limit the scope and length of this paper, we focus our attention exclusively on what the students should do—discussion on what the educators should do is therefore brief (Section 9) and interested readers are referred to another paper we have authored in which these issues are discussed from the educator's perspective [10]). The purpose of this paper is entirely practical: we aim to present an accessible student primer on how students can thrive in such disrupted environments by synthesizing and presenting well-known insights reported in the literature in an easy-to-understand manner. To make the paper directly accessible to our target audience of students, we present the paper in a simple-to-understand self-contained manner in which the core idea is introduced without extraneous details (which can be looked up by the interested advanced readers through the provided references).

We structure our paper by describing the seven main steps that students can take to thrive in engineering education during and beyond COVID-19 (see Table 1), each step in a different section (Sections 2–8). While our focus is on engineering students, most of the ideas are general and apply more broadly. We discuss some practical issues related to implementing these ideas in practice in Section 9. We finally conclude the paper in Section 10.

Table 1. Seven Steps to Thriving in Education During and Beyond COVID-19.

(Step 1): Begin With The End In Mind (Section 2)
A: Knowing The Educational Objectives and Learning Outcomes **B**: Aligning Effort With Goals, Objectives, and Outcomes **C**: Motivation, Self-Efficacy, and Learning How to Prioritize
(Step 2): Upgrade Your Metacognitive Skills (Section 3)
A: Types and Levels of Learning **B**: Avoiding Common Learning Mistakes **C**: Learning 101: Learning How To Learn

Table 1. *Cont.*

(Step 3): Aim for Holistic Learning (Section 4)
A: Become A System Thinker **B**: Building A Lattice Work of Models **C**: Be Well-Rounded
(Step 4): Become Coachable (Section 5)
A: Seek Formative Assessment **B**: Learn to Think Like An Assessor **C**: Develop Self-Assessment Skills
(Step 5): Take Ownership of Learning (Section 6)
A: Active Learning **B**: Leverage What Can Be Leveraged **C**: Collaboration & Teamwork
(Step 6): Focus On Developing Authentic Skills (Section 7)
A: Develop An "Understanding" of the "Big Ideas" **B**: Transfer of Learning **C**: Uncoverage Rather than Coverage
(Step 7): Become a Lifelong Learner (Section 8)
A: Develop A Mindset For Continuous Lifelong Learning **B**: Master The Instrumental Knowledge For Lifelong Learning **C**: Develop by Practice the Skills for Lifelong Learning

2. Step 1: Begin with the End in Mind

> "*To 'Begin with the End in Mind' means to start with a clear understanding of your destination. It means to know where you're going so that you better understand where you are now and so that the steps you take are always in the right direction*"—Stephen Covey [11].

The economist Hal Varian, the author of multiple best-selling books and chief economist of Google, as part of his article on how to write successfully (http://people.ischool.berkeley.edu/~hal/Papers/writing-economics.html), recounts that the best advice he ever got about writing a textbook was from the Turing Award winner (The highest award in computer science considered similar in honor to the Nobel prize.) Richard Hamming, who said, "Get together the exercises and exams that you expect the students to be able to solve once they've read your book, then write the book that shows them how to solve them. *The great thing about this advice is that it focuses you on the outcome you want to produce*". This is excellent advice of course, but not only for textbook writers. This advice is equally beneficial for educators and there has been a mass shift in educational circles towards the upfront articulation of important objectives and outcomes and the design of instruction and assessment according to it. We discuss these ideas next.

2.1. Knowing the Educational Objectives and Learning Outcomes

> ''*We cannot say how to teach for understanding or which material and activities to use until we are quite clear about which specific understandings we are after and what such understandings look like in practice*."—Wiggins and McTighe [12]

Each educational endeavor (course, diploma, or degree) should have a clear end and the learning efforts of students should be focused on achieving these ends. These ends, depending on their time frame, are variously known as objectives and outcomes. In particular, *'objectives'* are envisioned for the long-term where *'outcomes'* are expected to be demonstrated at the time of the completion of the program or course. In OBE terminology, the most important objective-related term is *program educational objectives* (PEOs). When we come to *outcomes*, there are two principal types of outcomes:

(1) *program* learning outcomes (PLOs) and (2) *course* learning outcomes (CLOs) [5]. These terms are sometimes unfortunately used interchangeably but we note these distinctions as they are commonly understood in the OBE paradigm. We describe these terms next.

- ***Program Educational Objectives (PEOs)***: PEOs are *broad statements* that describe what graduates are expected to attain within a *few years of graduation* (and unlike the following two outcomes, these objectives are not necessarily expected at graduation time).
- ***Program Learning Outcomes (PLOs)***: PLOs are statements that describe what students are expected to know and be able to do by *the time of graduation*. PLOs are at some places referred to as graduate attributes (GAs) [in the Washington Accord] or as student outcomes (SOs) [e.g., with US Accreditation Board for Engineering and Technology (ABET)].
- ***Course Learning Outcomes (CLOs)***: CLOs refer to what students should be able to know, do, and value by the end of a course. CLOs are alternatively referred to as intended learning outcomes (ILOs) [e.g., in the UK] and subject learning outcomes (SLOs) [e.g., at Malaysia and Hong Kong].

Two other terms are commonly used in OBE-based accreditation: *vision* and *mission*. These are more related to the institute's purpose and its continuous quality improvement (CQI) process. The *vision statement* refers to the future that the institute envisions for itself and concisely describes its values and ultimate purpose. The *mission statement*, while closely related to the vision statement, provides a more detailed direction for its present and future. The related term *values* describes the principles upon which the institution seeks to achieve its vision and fulfill its mission. The intimate relation/interaction between the vision-mission-objectives (VMO) and outcomes can be seen in Figure 2.

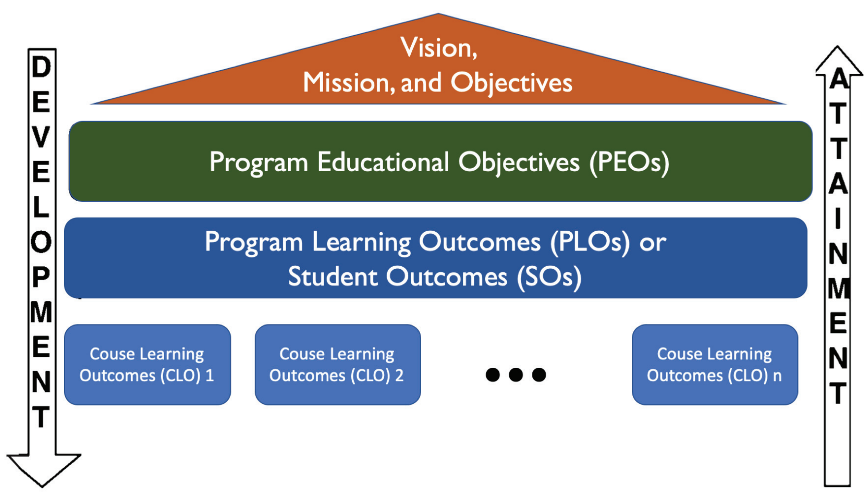

Figure 2. The outcomes pyramid. The desired outcomes towards the bottom are developed and shaped by those listed above. Also, the attainment of the bottom outcomes are necessary for attaining the outcomes/objectives listed on top.

2.2. Aligning Effort with Goals, Objectives, and Outcomes

"*The main thing is to keep the main thing the main thing.*"—Stephen Covey [11]

The word *align* derived from the French word *aligner* ("to put in line") has the connotation of arranging scattered elements such that they function as a whole that has a common purpose [13]. It is important for all learners to not lose track of the big picture and to align their efforts with the end goal. This alignment of teaching, learning, and assessment with the planned learning outcomes is an accepted pedagogical best practice (e.g., as recommended by the Biggs's theory of *Constructive Alignment* [14]), which is especially needed in times of disruption as we have in the current COVID-19 environment to avoid wasted effort.

2.3. Motivation, Self-Efficacy, and Learning How to Prioritize

> "*Explore the world. Nearly everything is really interesting if you go into it deeply enough.*"—Richard Feynman.

Stanford psychologist Albert Bandura called a person's belief system, or the personal conviction of what a person can do, "*self-efficacy*". In Henry Ford's words, '*Whether you think you can, or you think you can't—you're right*'. Bandura showed that people high self-efficacy aimed higher, and correspondingly tried harder, preserved more, and showed more resilience in the face of failure. As argued in the work [15] to learn well, one must work with zest, invest effort into learning, recognize and resist the illusions of learning (such as confusing fluency with mastery), and use optimal learning techniques such as retrieval test.

Stanislas Dehaene in his book "How We Learn" [16] describes attention as a pillar of learning and describes how by paying attention one locks on the human perception system on to a thing of interest allowing neural circuits to select, amplify, and propagate the signals we perceive as relevant increasing our learning efficient multifold. A successful student should learn how to prioritize and learn where to focus attention. In this regard, a student would do well to see the learning outcomes for the program, course, and the lesson, and plan accordingly. The student can look for the assessment criteria and rubrics that can shed light on how the outcomes will be assessed and plan and allocate time accordingly. Ruthless prioritization according to this criteria is often quoted to be the key to outstanding academic performance without burning out [17].

3. Step 2: Upgrade Your Metacognitive Skills

> "*One of the most important aspects of cognition is metacognition—the process of reflecting on and directing one's own thinking*"—Pellegrino et al. [18].

Metacognition—the ability to know one's thinking, to self-evaluate, to mentally simulate what would happen if one thought this way or that way, and the limits of one's thinking—plays a fundamental role in human learning. The teaching of metacognition is listed as the most successful educational intervention in a website put together by the British Education Endowment Foundation (EEF), (https://tinyurl.com/EEFTeachingLearningToolkit) where this intervention is described as *high impact for very low cost, based on extensive evidence*. This is because our mindset, or our belief system, fundamentally affects our actions, goals, and perception.

To enhance our metacognition and to acquire an improved understanding of our cognitive mental processes, the students are recommended to have a basic working knowledge of the advances in cognitive and educational psychology [19,20] and the learning sciences [16,21,22]. For example, students should know that learning is created in the brains when neurons are stimulated to form connections of neurons called synapses. These synapses are strengthened when that concept is retrieved. With thicker synapses, recalling memory becomes faster and clearer. Therefore, to retain a memory it is important to not only understand a concept once but to retrieve the memory periodically (e.g., by recalling the ideas after some time or through testing). Effective learning is effortful—i.e., learning that involves conscious effort is more long-lived [20]. On the flip side, effortless learning or fluency with a topic can create a dangerous illusion of mastery that can vanish into thin air unless the topic is strengthened through an effortful engagement—e.g., through retrieval practice. Previous research has shown that strategies that involve some effort is better than cognitively effortless exercises (e.g., it is better to practice retrieval or attempt an explanation to others for long-term retention compared to passive rereading or rewatching content) [15,20]. Experts have also figured out other details related to learning that were previously not as well known such as the importance of sleep for the consolidation of memories and the positive role exercise plays in enhancing cognitive performance.

3.1. Types and Levels of Learning

> *"By educational objectives, we mean formulation of the ways in which students are expected to be changed by the education process, i.e., the ways in which they will change in their* ***thinking****, their* ***feelings****, and their* ***actions****."*—Bloom et al. [23].

Most people will agree that learning success should not be measured just in the ability to remember—more importantly, we should focus on what the student can do with the knowledge. The most important skills of the 21st century (the so-called 21st century skills) are the non-routine creative skills and competencies—including skills for critical thinking, creativity, collaboration, communication, and metacognition. There is, therefore, a need to move away from an overriding focus on knowledge acquisition (which is now a web search away for most humans) and focus more on higher-order cognitive skills (such as the ability to understand, apply, synthesize, evaluate, and create). Furthermore, there is a need to emphasize the *affective* domain (dealing with emotions and feelings) and *psychomotor* domain (dealing with the hands-on motor skills) in addition to the traditional emphasis on cognitive skills. In this regard, Bloom's taxonomy and its revisions serve as the most popular de facto benchmark of levels of educational outcomes and objectives. In this section, we will introduce this taxonomy of learning outcomes to enhance student's awareness of levels of learning.

3.1.1. Bloom's Taxonomy

Bloom's taxonomy broadly refers to hierarchical models of educational objectives (or learning outcomes in modern OBE terminology (The term educational objectives was used by Bloom et al. beginning in 1956 and the term is akin to the modern OBE term "learning outcomes".)). These objectives are commonly organized in three hierarchies: corresponding to the cognitive, affective, and psychomotor domains roughly corresponding to knowledge, attitudes (or emotions), and skills. These models are named after Benjamin Bloom who chaired a committee of educators that devised the taxonomy [23] after years of consultation and deliberation. A revision of the taxonomy was performed in 2001 by Anderson and Krathwohl and we refer to this *Revised Bloom's Taxonomy* (Anderson and Krathwohl, 2001 [24]) in the remainder of the section.

3.1.2. Four Types of Knowledge

Anderson and Krathwohl's taxonomy [24] defines knowledge domain separately from the cognitive process domain and divides the former (i.e., knowledge domain) into four types of knowledge: factual, conceptual, procedural, and metacognitive.

- *Factual knowledge* refers to the basic knowledge students must know to be acquainted with a discipline or to solve a problem in that discipline.
- *Conceptual knowledge* refers to the interrelationship between the basic facts forming a bigger conceptual structure.
- *Procedural knowledge* refers to knowledge that relates to doing something and using developing skills, methods, techniques, and algorithms.
- *Metacognitive knowledge* involves broad knowledge of cognition in general as well as self-awareness.

3.1.3. Cognitive Activities

"Cognitive" process activities include remembering and recalling knowledge, thinking, problem solving, creating. The Revised Bloom's taxonomy [24] defines six level of increasingly sophisticated objectives in the cognitive process domain. In the revised version of taxonomy, the levels are known by the following verbs (base layer to higher layers): (1) *remember*; (2) *understand*; (3) *apply*; (4) *analyze*;

(5) *evaluation*; and (6) *create*. An illustration of these learning objectives arranged in the form of a hierarchical pyramid can be seen in Figure 3 while a detailed description of what these levels can be seen in Figure 4.

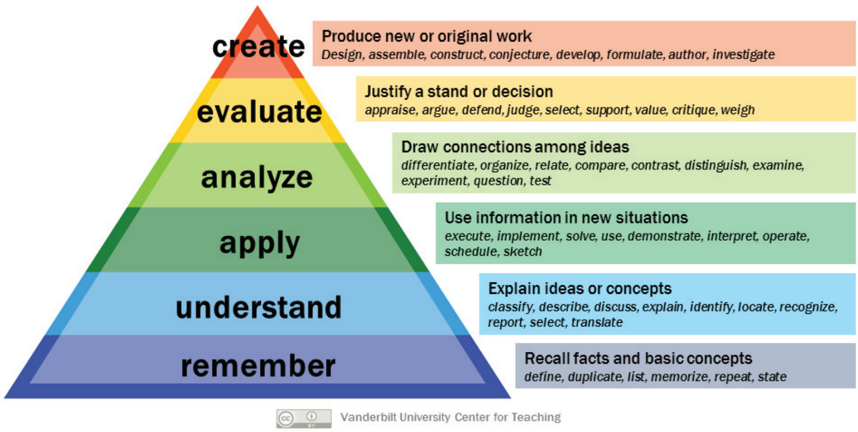

Figure 3. Bloom's Revised Taxonomy (2001) for the **cognitive domain** [Credit: Vanderbilt University Center for Teaching].

1.0 Remember—*Retrieving relevant knowledge from long-term memory.*
1.1 Recognizing
1.2 Recalling
2.0 Understand—*Determining the meaning of instructional messages, including oral, written, and graphic communication.*
2.1 Interpreting
2.2 Exemplifying
2.3 Classifying
2.4 Summarizing
2.5 Inferring
2.6 Comparing
2.7 Explaining
3.0 Apply—*Carrying out or using a procedure in a given situation.*
3.1 Executing
3.2 Implementing
4.0 Analyze—*Breaking material into its constituent parts and detecting how the parts relate to one another and to an overall structure or purpose.*
4.1 Differentiating
4.2 Organizing
4.3 Attributing
5.0 Evaluate—*Making judgments based on criteria and standards.*
5.1 Checking
5.2 Critiquing
6.0 Create—*Putting elements together to form a novel, coherent whole or make an original product.*
6.1 Generating
6.2 Planning
6.3 Producing

Figure 4. Structure of the Cognitive Process Dimension of the Revised Taxonomy (2001) [24] (*With Example Verbs Exemplifying Different Levels*).

3.1.4. Affective Emotion-Based and Psychomotor Action-Based Activities

Although it is common for some students to believe that academic success is all about cognitive competence and performance, experts have underlined the need for other types of learning activities and competencies. In particular, learning objectives belonging to the affective domain (dealing with objectives describing changes in interest, attitudes, and values, and the development of appreciations and adequate adjustment) and the psychomotor domain (dealing with physical activities related to manipulative or motor skill area, which describe hands-on skills) are deemed to be fundamental for effective learning. This has been recognized by educational experts and Bloom et al. also proposed a hierarchy of affective learning skills in their original taxonomy. The original taxonomy, however, did not propose a taxonomy for the psychomotor domain and the commonly used psychomotor domain taxonomy of learning skills was proposed in 1972 [25]. For students to thrive in OBE environments, it is important that they are aware of the different levels of learning objectives and that these objectives may relate to knowledge (cognitive domain), skills (psychomotor domain), or emotions or values (affect domain).

3.2. Avoiding Common Learning Mistakes

> "*To make no mistakes is not in the power of man; but from their errors and mistakes; the wise and good learn wisdom for the future*."—Plutarch.

One way to become good at learning is *via negativa*—i.e., by avoiding common learning impediments. In a previous work [26], Qadir has summarized some information that all students should know: what are the seven most common learning impediments and how can these impediments be surmounted. More specifically, seven major learning impediments were identified: (1) having a fixed mindset; (2) the failure to engage oneself in learning; (3) the failure to manage time; (4) the failure to realize that paradoxically failing (i.e., making mistakes) is the key to learning; (5) the failure to realize that learning is a social activity; (6) being a learning monogamist (i.e., learning from only one source/viewpoint); and (7) not learning how to learn. The author also proposed three remedies for each of the seven learning impediments (which is summarized in Figure 5; with full details available at [26]).

3.3. Learning 101: Learn How to Learn

> "*Is there anyone so wise as to learn by the experience of others?*"—Voltaire.

In the previous subsection, we discussed the *via negativa* approach: here we take the *via positiva* approach, which focuses on articulating some essential learning facts that are little known but have the power of vastly improving people's learning. A previous paper by Qadir & Imran [15] took this approach and scoured through the learning sciences literature to find important insights. The paper highlighted the counterintuitive insights discovered in the literature (see a gist of the discussion in Table 2) such as the fact that some difficulties are desirable in learning, and that not all learning fluencies are desirable, and finally talked about techniques (such as retrieval practice, spaced learning, interleaving, and aiming for mastery) that are very effective in practice. A general finding reported in the paper was that learning that is more effortful is also more durable and robust. The authors also made some evidence-based recommendations that go against conventional wisdom which we outline next (interested readers can see the full details in [15]).

1. *Spaced out learning*: instead of concentrating all your learning sessions together, you should space out your learning sessions over time.
2. *Interleaving*: instead of blocking practice sessions (i.e., revising one topic and then the other), practice interleaving (this will be more effortful but will help discriminate ideas resulting in more robust learning).
3. *Testing*: instead of rereading material, you should test yourself on the learned knowledge or practice mental *retrieval*.

4. *Variety*: instead of always learning in the same modality and environment, vary the conditions and the environmental context of your learning.

Impediment 1) Having a Fixed Mindset
Solution: Conquer your mind to realize your potential.
Remedy I: Have a growth mindset
Remedy II: Aim for Mastery
Remedy III Using Intrinsic Motivation

Impediment 2) the Failure to Engage 'Yourself' in Learning
Solution: Knowledge will not give a part of itself until you give to it all of yourself.
Remedy I: Ask Questions
Remedy II: Study More Actively
Remedy III: Make Efforts to Enjoy the Subject

Impediment 3) the Failure to Manage Time
Solution: Until we can manage time, we can manage nothing else.
Remedy I: Form Good Habits
Remedy II: Learn Mindfulness and the Art of Focusing
Remedy III: Practice Prioritization and Discipline

Impediment 4) Failing to Realize that Failing is Key
Solution: Err unabashedly and learn—like a child does.
Remedy I: Embrace Failure and Impediments
Remedy II: Make Peace with Confusion
Remedy III: Value Effort over Intelligence, and the Process over Extrinsic Reward

Impediment 5) Failing to Realize that Learning is Social
Solution: No one can do it for you, but you can't do it alone.
Remedy I: Have a Mentor
Remedy II: Seek Feedback
Remedy III: To Learn, Teach

Impediment 6) Being a Learning Monogamist
Solution: Encourage learning polygamy.
Remedy I: Avoid the Illusions of Learning
Remedy II: Seek Diverse Knowledge Sources
Remedy III: Adopt Diversity in Study Techniques

Impediment 7) Not Learning How to Learn
Solution: Don't be an highly qualified A grade sheep.
Remedy I: Develop Metacognitive Skills
Remedy II: Learn Critical Thinking
Remedy III: Become a Lifelong Learner

Figure 5. Common Learning Impediments and Their Remedies (Reproduced from [26]).

Table 2. Guidance on how to learn from "Learning 101: The Untaught Basics" (Qadir and Imran, 2018 [15]).

Pointers	*Explanatory Quote*
Desirable Difficulties:	
(1) Effortful learning is better learning	*"Practice that's spaced out, interleaved with other learning, and varied produces better mastery, longer retention, and more versatility. However, these benefits come at a price: when the practice is spaced, interleaved, and varied, it requires more effort."*—Brown, Roediger, and McDaniel [20]
(2) To learn, you must forget, then interrupt forgetting	*"It is only what breaks that grows."*— Unknown
(3) Disfluency/discomfort can be good for learning	*"That which does not kill us makes us stronger."*—Nietzsche
Undesirable fixations:	
(1) Fixating on perfection: Why mistakes are required	*"An expert is a man who has made all the mistakes which can be made, in a narrow field."*—Niels Bohr
(2) Fixating on fluency: Why fluency is not sufficient	*"Rising familiarity with a text and fluency in reading it can create an illusion of mastery."*—Brown, Roediger, and McDaniel [20]
(3) Fixating on discipline: The upside of variety	*"You don't understand anything until you learn it more than one way."*—Marvin Minsky
For efficient learning, use optimal learning techniques:	
(1) Testing/retrieval practice as a learning tool	*"In virtually all areas of learning, you build better mastery when you use testing as a tool to identify and bring up your areas of weakness."*—Brown, Roediger, and McDaniel [20]
(2) Spaced learning and interleaving	*"The truth is, nothing in learning science comes close [to spaced learning] in terms of immediate, significant, and reliable improvements to learning."*—Benedict Carey [21]
(3) Aiming for mastery	*"To be a sophisticated learner requires understanding that creating durable and flexible access to to-be-learned information is partly a matter of achieving a meaningful encoding of that information and partly a matter of exercising the retrieval process."*—Bjork, Dunlosky, and Kornell [27]

4. Step 3: Aim for Holistic Learning

"You don't understand anything until you learn it more than one way."—Marvin Minsky

The modern challenges facing us are complex, interconnected, ill-structured, and open-ended. These problems are multi-faceted and no single discipline or technology can tackle these problems satisfactorily in isolation. What is needed are multidisciplinary system-based approaches that look at the problem holistically instead of addressing parts of the overall problem amenable to the techniques of a single discipline without looking at the wider impact. We examine these challenges and propose solutions in the coming subsections.

4.1. Become a System Thinker

"We're blind to our blindness. We have very little idea of how little we know."—Daniel Kahneman.

To be a system thinker means to develop holistic thinking: i.e., to see any entity being studied not in isolation but as an entity related to other entities so that one can see the bigger picture by fitting pieces of a system together to form a whole [28]. Systems thinking implies a move away from myopically viewing things in isolation but seeing how system components interact with each other through *multi-loop nonlinear* feedback: this enables system thinkers to study how interventions in complex adaptive systems can have unpredicted and unintended consequences. With systems thinking, one begins to realize that we see the world through mental models and that our mental models may not be perfectly aligned with reality and that we can think better through diverse models (also called many model thinking [29]). In terms of education, becoming a systems thinker helps one in seeing how our engineering artifacts affect the world and society in multifarious ways and in becoming better designers of technology that has net positive social implications.

Previous research indicates that engineering education does not adequately prepare students to address complex, ill-structured, real-world problems, such as wicked problems such as sustainability, which has led to calls for systems-thinking-based approaches. For example, the National Engineering Academy (NEA), USA, highlighted "*a growing need for interdisciplinary and system-based approaches*" in the report on educating the engineer of 2020 [30]. Such an approach will also help an engineer to appreciate the broad impacts of technological artifacts on the environment, society, and the economy. The need for interdisciplinary system-based approaches is now emphasized by several accreditation boards including ABET, which lists "*the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context*" as a mandatory student outcome (i.e., learning outcome expected at the end of the graduation program).

4.2. Building a Lattice Work of Models

> "*You've got to have models in your head. In addition, you've got to array your experience both vicarious and direct on this latticework of models*."—Charlie Munger [31].

Engineering students should be, from the start, wary of a hubristic infatuation with a single model. George Box had famously said "all models are wrong, some are useful" to highlight the fact that models are useful in some contexts but should be equated with the entirety of the "truth" [32]. To believe that a single equation can always explain or predict real-world social phenomena is a failure to appreciate how unpredictable a complex adaptive system can be and how emergent behavior can develop in it. In the words of Noble prize-winning physicist Richard Feynman, "*The world is much more interesting than any one discipline*." When we do not encourage broad multidisciplinary learning, we develop blind spots of which we remain ignorant. We also run the risk of knowing no better than use inappropriate models at the wrong place for it is said that to a person with only a hammer, everything starts to appear like a nail.

4.3. Be Well-Rounded

> "*To rely on a single model is hubris. It invites disaster*."—Scott Page [29].

In the history of engineering education, there has been a perennial search for the right tradeoff between breadth and depth, generalization and specialization, and liberal arts/sciences and vocational training. In a volatile, uncertain, complex, and ambiguous (VUCA) 21st-century world, the deal seems to have swung squarely in the half of breadth, generalization, and liberal arts/sciences due to (1) a dramatic expansion of knowledge, (2) a diminishing half-life of engineering knowledge, (3) expanding lifetimes [1]. Many efforts at engineering education reform aiming to change education for the 21st century are proposing a focus on developing the diverse skills of the whole mind [8,33–35]. Engineering education in the 21st century requires both the quantitative and the qualitative. Engineers need to "*understand and appreciate history, philosophy, culture, and the arts, along with the creative elements of all of these disciplines*." (https://www.chronicle.com/article/Engineers-Need-the-Liberal/240125). By becoming more well-rounded, Goldberg talks of *engineering education* being the new liberal arts since it includes important technological literacy that is essential in today's world [8]. There is also wide agreement that relying merely on the hard science of engineering is no longer enough to meet the 21st century challenges [36] (e.g., see National Academy of Engineering's report "The Engineer of 2020" [37]). In the book Rebel Ideas, the author Matthew Syed describe how narrow skills and lack of diversity leads to numerous problems—homophily, dominance dynamics, and echo chambers—which characterizes some troubling characteristics of the modern polarized world [38]. Apart from engendering a more humane and empathetic society, developing diversity and breadth brings about scholarly benefits such as encouraging innovation through the diffusion of ideas across disciplinary boundaries. However, breadth should not come at the cost of depth: modern engineers need to have deep expertise in some core engineering fields apart from broad knowledge in several fields (some authors refer to such learning as T-shaped learning [39]).

5. Step 4: Become Coachable

> "*Try to learn. Be coachable. Try to learn from everybody, especially those who fail.*"—David Foster Wallace

A key skill that students can acquire to thrive in engineering education during and beyond COVID-19 is to become more coachable—by which we mean the ability to benefit from the knowledge, experience, and feedback of others. In particular, students can hone their self-assessment skills and learn how to invite and use feedback from their instructors and peers for improving their learning. We discuss these ideas next in the coming subsections.

5.1. Seek Formative Assessment

> "*As soon as students get a grade, the learning stops. We may not like it, but the research [...] shows that this is a relatively stable feature of how human minds work*."—Dylan Wiliam

In formative assessment, in contrast to the commonly used summative assessment, the assessment's purpose is not to rank the students or to gauge their current learning per se; the explicit aim instead is to *facilitate* learning. Formative assessment, for this reason, is sometimes called assessment *for* learning (A4L) compared to summative assessment, which is called assessment *of* learning. In formative assessment, the current level of learning is assessed instrumentally so that pertinent feedback may be provided to *both* the student and the instructor so that they can take concrete steps to facilitate learning improvement. As an example, an instructor may dissect a student's response and highlight deficiencies and suggest avenues for improvement. Formative feedback is well suited to the OBE paradigm since it can be instrumental for the attainment of learning outcomes. It is well established in the literature [40,41] that formative assessments have a powerful effect on student learning (particularly for weaker students). John Hattie noted in his book Visible Learning [42], based on a synthesis of more than 800 meta-analyses related to learning achievement, that "*the most powerful single influence enhancing achievement is feedback*". We have previously seen the key role growth mindset is key for enhancing learning performance. Armed with a growth mindset, a learner can benefit greatly by becoming more coachable [43]—by which we mean that learners develop the mindset and openness to seek, accept, and act on to (potentially critical) feedback, which provides the learner valuable perspective on how to improve. With this, the learner also imbibes a passion for self-improvement sowing the seeds for lifelong learning (the pivotal Step 7 of our framework).

5.2. Learn to Think Like an Assessor

> "*When students become their own teachers they exhibit the self-regulatory attributes that seem most desirable for learners (self-monitoring, self-evaluation, self-assessment, self- teaching)*"—John Hattie.

Wiggins encourages students to think like an assessor and notes that this thinking eventually boils down to thinking about the following question: "*what kinds of evidence do we need to find hallmarks of our goals, including that of understanding?*" To align one's thinking with the overall assessment system being deployed, it helps if the learner can look critically through the assessment criteria and rubrics to see what kinds of evidence the instructor is seeking for the sought-after understanding. If the assessment criteria are unclear, the learner should immediately consult and discuss with the instructor for more clarity. This will allow the learner to plan activities and allocate time accordingly.

5.3. Develop Self-Assessment Skills

> "*When students become their own teachers they exhibit the self-regulatory attributes that seem most desirable for learners (self-monitoring, self-evaluation, self-assessment, self- teaching)*"—John Hattie.

The use of formative assessment can substantially transform students' performance by equipping them with the empowering skills of "*self-assessment*" (through which students acquire the skill of judging and monitoring their levels of learning) and "*self-directedness*" (through which they become capable of deciding what they should do next to improve their learning and setting learning goals for oneself). Reflection on one's performance is a vital component of a learner's self-assessment skills. There are various reflection-oriented self-assessment drills that a learner can try for any subject and level. For example, a learner can reflect on his or her academic strengths, motivation, interests, learning preferences. A learner may train himself or herself on dispassionately assessing an assignment and evaluating it for its strength and weaknesses. This can be done both before and after the learning activity or assignment (pre- and post-reflection). Performing a pre-mortem on a project submission, or a post-mortem on a failed test, provide a great learning opportunity that can facilitate significant learning improvement [44].

6. Step 5: Take Ownership of Learning

> "*Learning results from what the student does and thinks and only from what the student does and thinks. The teacher can advance learning only by influencing what the student does to learn*."—Herbert A. Simon.

The importance of active learning is established in the research literature and it is shown that a more active outlook is correlated with better student performance. The imperative for students to take ownership of their learning has become stronger in the face of the disruption caused by the COVID-19 pandemic since teacher's oversight has been naturally limited by the pandemic. Nonetheless, despite school closures, a wealth of educational opportunities still exists, and students can use this as an opportunity to learn to become more active. This will help the student during and beyond COVID-19. We discuss some related issues in the coming subsections.

6.1. Active Learning

> "*Converging results from diverse fields suggest that a passive organism learns little or nothing. Efficient learning means refusing passivity, engaging, exploring, and actively generating hypotheses and testing them on the outside world*."—Stanislas Dehaene.

Stanislas Dehaene identifies four pillars of learning in his book "*How We Learn*": the first two of which—"*Attention*" and "*Active Engangement*"—relate to Active Learning. The first pillar, attention, describes how by paying attention one locks on the human perception system on to a thing of interest allowing neural circuits to select, amplify, and propagate the signals we perceive as relevant increasing our learning efficiency multifold. The second pillar, active engagement, refers to mental activity and engagement and describes that to learn we need motivation, curiosity, and an active generation of hypothesis and refinement of our mental models through engagement with the real world (the error feedback one receives in this process is extremely important and represents Dehaene's third pillar of learning). This means in the immediate online-learning-focused COVID-19 environment, it is important to not only listen to lectures but to periodically test oneself to recall ideas from our minds and to relate them to previously learned concepts to strengthen our learning.

6.2. Leverage What Can Be Leveraged

> "*Entrepreneurship is a mindset, an outlook that shapes the way you see the world and the possibilities that it holds*."—Jim Plummer.

It is important for the 21st century engineer to be resourceful and entrepreneurial [45]. One manifestation of being resourceful is to realize that in life one does not have the luxury of changing everything on-demand—one ultimately can only play with the cards they are dealt with. However, it is up to the learner to devise the best strategy for fully benefiting from the opportunities available locally or globally. In the current era of globalization and open educational resources/courses, help is never far. One should leverage all the available resources. Various universities (such as MIT (https://covid19.mit.edu/undergraduate-students-student-success-coaching-program)) have programs available for student success coaching. Students should fully use these formal as well as informal opportunities where available and request such facilities from their university administrators and instructors where there are no such formal arrangements.

There are also various high-quality learning massive open online courses (MOOCs) offerings from various global and regional MOOC providers (e.g., Coursera, EdX, France Université Numérique, Edraak, FutureLearn) in different languages such as English, French, Spanish, German, Arabic, Chinese, etc. [46]. Apart from these riches, students should not hesitate to ask for help from the human resources and experts accessible within their community (city, university, country). The late Apple founder Steve Jobs described how he leveraged the remarkable power of asking for help by calling Bill Hewett (the co-founder of Hewlett-Packard) for some smart parts to build a project that he was doing by looking up Hewett's number in the public phone directory (https://tinyurl.com/JobsPowerOfAsking-Inc-com). Steve Jobs not only got the parts but also a summer job at the company. Steve Jobs recalling this story remarked that "*You gotta act. In addition, you've gotta be willing to fail, ... if you're afraid of failing, you won't get very far*". Students will do well to use the same idea by not hesitating in reaching out to faculty members, seniors, experts, and entrepreneurs, for help that can take them forward in their learning. The weaker students, in particular, stand to benefit significantly from gaining the courage to ask for help and to reach out to the various resources that they can access but paradoxically these students rarely ask for help, a fact that further exacerbates the divide between the top students and the lagging ones.

6.3. Collaboration and Teamwork

> "*Critical thinking and problem solving, communication and collaboration, and creativity and innovation are three top-drawer skill sets in our toolbox for learning, work, and life in the 21st century*."—Trilling and Fadel [47].

The benefits of collaborative learning are well established in the literature through numerous studies with students learning in small-groups achieving higher grades, retaining information better, and acquiring great communication and teamwork skills [48]. Such skills have become especially important in the 21st century [1,47]. These benefits are not automatic though and optimally leveraging collaborative learning requires attention to techniques scientifically shown to be conductive for effective team learning from the instructor and the learners [48]. With numerous software available for group interaction (such as Google Meet, Microsoft Teams, Slack, etc.), there are plenty of technical solutions that can be used to aid facilitation among team members even in COVID-19 lockdown situations. The need for learning the ability to work with multidisciplinary teams is particularly important and is a mandatory student outcome required by various Washington Accord-linked accreditation boards (e.g., ABET lists obtaining "*an ability to function on multidisciplinary teams*" as a mandatory student outcome).

7. Step 6: Focus on Developing Authentic Skills

> "*The most important method of education ... always has consisted of that in which the pupil was urged to actual performance*."—Albert Einstein.

In the 21st century, learners are expected to grapple and engage with complex open-ended problems that may defy simple solutions. It is no longer sufficient for learners to simply memorize information. Learners should be able to demonstrate learning and performance on authentic tasks (i.e., tasks that simulate realistic environments and problems that the learner would face in the real world). According to Wiggins [49], a performance task, problem, or project, can be said to be 'authentic' if it: (1) is realistic; (2) requires judgment and innovation; (3) engages the learner in "doing" the subject; (4) replicates or simulates real-world contexts; (5) assesses a learner's ability to deal with an open-ended complex task by using a repertoire of knowledge and skills effectively; (6) does not put artificial constraints on opportunities to practice, consult resources, obtain feedback, and refine performance. The ability to work on actual real-life problems, particularly in groups, is a much valued skill that has motivated the development of pedagogical approaches such as Problem Based Learning (PBL) used in various universities (e.g., Aalborg university, Denmark [50]). The attainment of expertise during engineering education depends in large part on practice on open-ended authentic tasks and engagement in authentic projects similar in complexity to those observed in the real world [51].

7.1. Develop an "Understanding" of the "Big Ideas"

> "*What we are claiming, based on both common sense and the research in cognition, is that no skill can be integrated into a powerful repertoire unless the learner understands the big ideas related to using the skill wisely*."—Wiggins and McTighe [12].

Wiggins and McTighe in their best-selling "Understanding By Design" [12] distinguish the knowledge of experts from the knowledge of novices by noting that experts seek to develop an *understanding* of the problem in terms of the core concepts or the big ideas. Wiggins and McTighe describe an *understanding* as a transferable abstract big idea of enduring value going beyond a specific topic—mastering such an understanding allows for robust learning that allows transfer and application. Such an understanding must be earned (i.e., it must be co-constructed by learners and developed inductively while "doing" the subject on authentic tasks in realistic settings). Wiggins and McTighe describe that learning big ideas economizes learning effort since these ideas are general and help organize many isolated bits of information coherently. In contrast, the knowledge of the novices is much more fragile since their knowledge is less likely to be organized around big ideas or interconnected. If an education only contains an unrelated collection of inert facts, it becomes, in the words of Alfred Whitehead, "*not only useless*" but "*harmful*." Due to this, experts can transfer their knowledge from one setting to another while novices find this very hard. In the words of John Dewey, "*To grasp the meaning of a thing, an event, or a situation is to see it in its relations to other things: to see how it operates or functions, what consequences follow from it, what causes it, what uses it can be put to*" [52].

7.2. Transfer of Learning

> "*Transfer must be the aim of all teaching in school—it is not an option— because when we teach, we can address only a relatively small sample of the entire subject matter*."—Wiggins and McTighe.

For 21st century skills, instead of teaching and testing for memorization of facts and information, we need to aim for *transfer*, where transfer implies a capability of deep comprehension and application in novel settings [28]. The body of knowledge has become so vast these days that it is impractical for a university education to attempt to cover even in narrow specializations all the related knowledge. Instead the overarching aim should be to understand ideas and concepts of broad applicability deeply and then have the capability of applying these ideas in new settings. Transfer is the essence of what Bloom and his colleagues referred to as *Application* in their taxonomy of learning objectives. Unfortunately, as Eric Mazur points out much of the current assessment practices focus on and encourages *Remembering*, which per Bloom's taxonomy is the lowest level of thinking skills [53].

7.3. Uncoverage Rather Than Coverage

> "*Teaching [and learning] specific topics or skills without making clear their context in the broader fundamental structure of a field of knowledge is uneconomical*." —Jerome Bruner

Without transfer learning, learning is fragile and students are incapable of generalizing concepts and in understanding their relationships. Without the development of transfer skills, students will not be able to understand a topic or subject and be able to use (or "apply", in Bloom's sense) knowledge and skill effectively. Wiggins recommends that learners should not only focus on "*covering*" topics as coverage can result in students being lost and alienated when they are unable to see the relationship of the covered topics but focus on "*uncovering*" the real issues lurking below the surface, and keep returning to them, as they consolidate and further their learning [12]. The conventional coverage of topics, according to the educator Jerome Bruner, is uneconomical since with coverage seeing the whole requires more and more effort as the topics begin to increase. A better approach would, in the words of the English philosopher Alfred Whitehead, be "*let the main ideas which are introduced be few and important, and let them be thrown into every combination possible*". In this way, the uncovering of the big ideas returns impressive results with frugal investment since the ideas learned are few in number but broadly applicable.

8. Step 7: Become a Lifelong Learner

> *"Give a man a fish, and you feed him for a day. Teach a man to fish, and you feed him for a lifetime."*—English Proverb.

It is estimated that presently engineering knowledge has a doubling time, and information half-life (i.e., when half of the engineering information becomes obsolete), of roughly 5–10 years (https://spectrum.ieee.org/view-from-the-valley/at-work/education/the-engineers-of-the-future-will-not-resemble-the-engineers-of-the-past). When we also consider the increased longevity of lifetimes, it becomes clear to see why it is critical to teach to engineers the ability and instrumental knowledge and engender a mindset for continuous lifelong learning.

8.1. Develop a Mindset for Continuous Lifelong Learning

> *"Most of what our students need to know hasn't been discovered or invented yet. 'Learning how to learn' used to be an optional extra in education; today, it's a survival skill."*—Dylan Wiliam

Duderstadt in his proposal "Engineering for a Changing World" [54] proposed that the engineering profession should also "*develop a structured approach to lifelong learning for practicing engineers similar to those in medicine and law. This will require not only a significant commitment by educators, employers, and professional societies but possibly also additional licensing requirements in some fields*." Harvard and some other universities are even formalizing the so-called 60-year curriculum to chart a plan for a lifetime of learning [55]. In such an environment, it becomes important to develop a mastery mindset that is not satisfied with sitting on past laurels and knowledge but is well-tuned with a mindset that values and cherishes continuous new learning.

8.2. Master the Instrumental Knowledge for Lifelong Learning

> "*They know enough who know how to learn*."—Henry Adams.

The ability to develop the capabilities of indistractablity or deep focus is very valuable in the 21st century—especially in the context of COVID-19 online learning environments. Tackling procrastination and practicing self-discipline in such environments is harder but very helpful. Like other skills, one can better at focusing and concentrating periodically [56–58]. In a similar vein, when students acquire meta-skills such as learning how to learn, read, write, they bring this skill to every course and reap its exponential benefits—this effect is sometimes called the "Matthew Effect" [59] or the rich get richer and the poor get poorer effect. One should be committed therefore to investing time in developing oneself regularly.

8.3. Develop by Practice the Skills for Lifelong Learning

"*Life is like riding a bicycle. To keep your balance you must keep moving*."—Albert Einstein.

Moving into the third decade of the 21st century, the 2020s, the unprecedented rate of increase in knowledge, and the demands of being a 21st century engineer [1,37], requires us to keep moving. Although it is true that the basics of engineering do not change overnight, the half-life of engineering knowledge is rapidly receding and now the unchanging basics must be regularly complemented with new ideas and knowledge. This places a premium on the meta-skill of lifelong learning and therefore it becomes important to acquire this skill and get better at this through practice. This practice should begin early and should be exercised vigorously during the engineering degree so that the student is well placed to contribute and thrive in a dynamic future world.

9. Putting These Ideas in Practice

As we noted in the introduction (Section 1), effective engineering education during and beyond COVID-19 depends on various factors including state policies, pedagogical methods used by the instructors, and the wide availability of digital technologies, which are all important topics to explore: however, the scope of this paper is limited to what the student/learner can do. In the remainder of this section, we discuss the issues involved in applying these ideas in practice.

9.1. About Labs and Practical Work

One of the biggest challenges facing engineering education and learning is to figure out an effective way of completing lab work in a virtual space through remote access. The use of virtual laboratories is not new in science, technology, and engineering and a detailed review of the tools available can be seen in [60–63]. Although virtual labs and simulations are not a replacement of hands-on experience with real-life devices and tools [62], they can serve the pedagogical ends quite well in the times of disruption where health concerns prohibit physical presence of learners in physical laboratories. Various companies such as MATLAB and National Instruments (NI) offer part of their services through web-based cloud services (e.g., MathWorks Cloud (https://www.mathworks.com/solutions/cloud.html); NI LabVIEW WebVI (https://www.webvi.io/)).

9.2. About Digital Divides

As we adjust to the new normal of online education to respond to the COVID-19 pandemic, we run the risk of producing a new form of social divide. This social divide emerges from the digital divide (some people have access to advanced digital technologies but others do not) due to which digital poverty also translates into an *online penalty* for some learners. Researchers have shown that this online penalty is minimal for high-achieving and affluent learners who will do well anywhere but quite severe for struggling, underprivileged, and vulnerable students (e.g., younger students, ethnic and racial minorities, and students with low prior achievement). The shift to online education can potentially accentuate the social divide as students from less-privileged backgrounds could be left behind as students are physically removed from campuses and resources such as libraries and labs. It is important to note that the home environment (is there a quiet space available in the house where the learner can participate in online learning with concentration?) intimately affects the learner's performance apart from computer and network connectivity. Other factors such as the need to take care of siblings can also contribute to an increased online penalty for the less-privileged classes or particular denominations of the population [64]. This can result in a vicious cycle resulting in further impeding the progress of students who are already disadvantaged and behind [65,66]. The students, particularly those who are disadvantaged in any way, are recommended in such settings to adopt actions described in our paper (such as taking ownership of learning and reaching out for help and support as discussed in §VI) to avoid the unfortunate situation where the students most in need for support are least likely to reach out for it [67,68]

9.3. Role of Educators

Although our focus in this student primer is to train students on what they can do to thrive in education during and beyond COVID-19, students require support from other stakeholders as well. In this subsection, we discuss the various core issues related to improving the education systems during and beyond COVID-19 that relate to educators, educational leaders, policy makers, and which students have limited control over. In particular, when using online teaching, educators must adhere to the triple imperatives we introduced in our related work written for educators [10]: namely (1) the *equity imperative*, which seeks to mitigate actions that intentionally or unintentionally creates or widens inequality; (2) the *inclusion imperative*, which seeks to include all learners actively into the education process; and finally (3) the *effectiveness imperative*, which seeks to ensure that the quality and coverage of learning is not compromised in online learning as much as is possible. Similarly, federal and regional state authorities have a role to play in guiding the online teaching processes [66].

We have discussed earlier in the paper how students should become more coachable. Conversely, educators should also think of themselves apart from teachers of content material as coaches, mentors, and guides of students. In particular, educators should focus on enhancing the metacognitive skills of students. As a specific example, while we have attempted to write this paper in an accessible fashion for students, many junior level students (undergraduate students and school/college students) who stand to gain by reading this paper are not yet well-attuned to reading research papers and may require support and guidance from their teachers. Additionally, educators can play their role by clarifying student queries particularly those that relate to the application of these ideas in their respective courses.

10. Conclusions

In this paper, we provide a primer for students on how to thrive in volatile, uncertain, complex, and ambiguous (VUCA) times such as the one resulting from the COVID-19 global pandemic. Thriving in engineering education settings during and beyond COVID-19 requires not only awareness of the Outcome-Based Education (OBE) paradigm underlying modern engineering programs but also significant metacognitive and learning proficiency. In this paper, we have highlighted seven steps that students can adopt to succeed in these times. These seven recommendations, listed pointwise, are that students should: *(1) begin with and always keep the end in mind; (2) work on upgrading their metacognitive skills; (3) aim for holistic well-rounded learning; (4) become coachable and develop the skills of self-assessment; (5) take ownership of their learning; (6) focus on developing 'authentic' real-world skills; and (7) develop proficiency of being a lifelong learner*. Although these tips are aimed at engineering students, we believe that this will also be helpful more generally for students of other disciplines.

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Article

COVID-19 Outbreak: Insights about Teaching Tasks in a Chemical Engineering Laboratory

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Abstract: Apart from the evident tragedy that the COVID-19 outbreak has meant regarding both personal and economic costs, the normal functioning of the academic year has been drastically altered at all educational levels. Regarding Spain, the state of alert implemented by the government from mid-March to June has affected traditional face-to-face sessions at universities, as they were forbidden and replaced by online lessons. The aim of this work was to explain our own experience during the COVID-19 outbreak in a chemical engineering laboratory at the University of Extremadura, concerning the university teaching and the final degree project follow-up, whose method of teaching was active and participatory, based on constructivism and focused on the student as the center of the learning process. Thus, the confinement affected both the teachers and students differently, depending on the degree of completion of their main tasks and their previous skills with computing and virtual tools, among other factors. The existence of an operating virtual campus and an online library has made the transition to total e-learning and telework easier for teachers and students.

Keywords: graduate education/research; chemical engineering; bioenergetics; biotechnology; student/career counseling

1. Introduction

The so-called COVID-19 disease derived from the SARS-CoV-2 virus has caused the infection and death of thousands of people around the world. The uncertainty about the wide range of symptoms associated to this virus, the high risk of infection and the lack of a specific treatment up to now [1] have brought up a situation where most countries were not prepared and could not anticipate the consequences associated with the sudden cut of any professional practices. Consequently, during the spread of the virus in 2020 and until an effective treatment or vaccine is found, the main ways to avoid or reduce its effect are by complying with hygiene standards and social distancing measures [2,3]. These measures have strongly affected any interpersonal activity, including education at all levels, as students and teachers in many cases have avoided face-to-face sessions during this period [4,5]. Nevertheless, and due to the vital role of education in society, education has not stopped and has had to adapt to these changes, mainly resorting to e-learning when possible. In this sense, e-learning can be considered as a way of learning conducted via electronic media, mainly on the internet, used by both teachers and students. In the case of universities, there are some recent studies where the authors pointed out the increase in e-learning activities in Italy, which was especially affected by the COVID-19 outbreak [6]. The context of the University of Extremadura (concerning the implementation of e-learning and the interdiction of attending classes), in Spain, could have been similar, possibly observing the same trend (as discussed in the following section). Studies carried out by other authors point out the quick adaptation to e-learning by university lecturers and administrators in Germany contributed to the possible implementation of highly digitalized hybrid campuses [7]. Nevertheless, this adaptation or transition should take into account many aspects. For instance, the digital skills of both teachers and students (in order to adapt the didactic contents to these new challenges), the design of e-learning courses, and their workload and interactivity, among others need to be considered [8–10]. Consequently, there are some signs that facing this difficult situation in the right way could imply the definitive implementation of telework and e-learning, at least at different levels. By telework (or teleworking) we mean the practice of working from home by using mainly information and communication technologies. In this work, this term and "e-learning can be used interchangeably when it comes to teacher tasks carried out at home, except for global work processes (including administrative tasks, for instance), where telework is preferred. In the case of students, the term e-learning will be exclusively used in this paper.

Although there are convincing reasons (such as family reconciliation, money or energy saving and mitigation of pollution) for the implementation of e-learning and telework, this implementation had been a slow transitional process, until their use was necessary due to the COVID-19 spread [11]. The effort to shift to this way of managing teaching staff, from preparing materials to designing suitable evaluation strategies, passing through the development of skills in using particular software, has to imply a permanent implementation of e-learning, not only to solve a temporary problem during a confinement. It can help traditional face to face teaching at the same time that it helps students in complex situations like this one; the benefits to the earth are too much to just ignore them.

The aim of this work was to expose our own experience during the coronavirus outbreak in the Chemical Engineering and Physical-Chemistry department of the University of Extremadura, in Spain, from the beginning of the state of alert established by the government to the subsequent stages for a return to a relative normality, as explained in Figure 1.

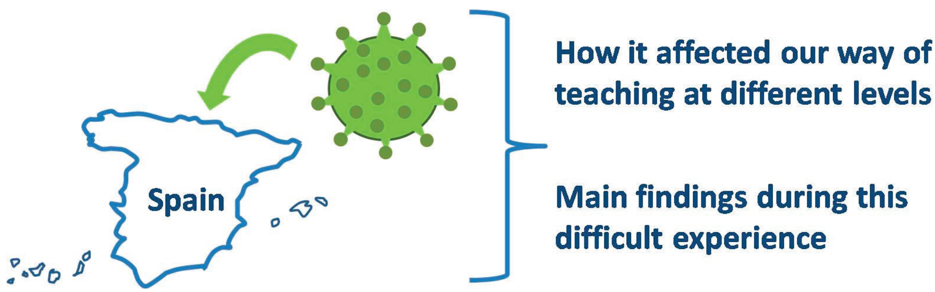

Figure 1. A graphical abstract of this work.

We believe that the lessons learned can serve to improve both teachers and students' achievements in the future.

Consequently, the following questions will be answered:

- How did the steps taken at national and regional level affect the normal functioning of our laboratory?
- What steps could we take in our laboratory to dampen the impact of the coronavirus outbreak on our staff and students?
- How were the final degree projects (FDP) carried out during this crisis?
- What were the main findings related to e-learning, FDP and communication between teachers and students derived from this crisis?

2. Context

In order to understand and have a general idea about the situation that took place in our university and the subsequent development of the events, some general data are provided in this section to assess the reaction of the different entities implied (more or less directly) in the normal functioning of our laboratory.

Thus, after its spread through many countries, starting with China, South Korea, Japan, Iran and Italy, among others, the coronavirus outbreak in Spain took place at the end of winter. The main events that took place during this period are summarized in Figure 2.

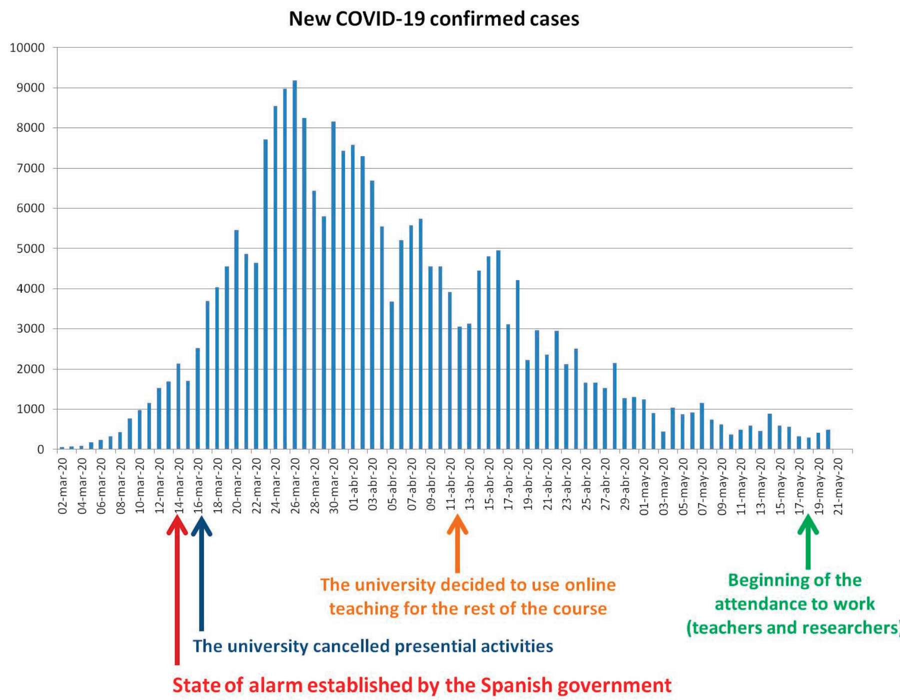

Figure 2. Main events during the COVID-19 outbreak affecting the functioning of University of Extremadura.

According to the data provided by the Spanish government [12], we can locate the beginning of the coronavirus outbreak in Spain in early March 2020, establishing the state of alarm (which implied restrictions in movements, and the normal development in commercial or professional activities, among other steps) in mid-March [13]. From then on, most companies, agencies and public administrations reacted immediately to this event, adapting their normal functioning to these circumstances. Thus, the main steps taken by the University of Extremadura were the following [14]:

- To cancel in-class activities, replacing it by e-learning, for the rest of the 2019–2020 course.
- To provide further training to teachers and students for e-learning adaptation.
- To postpone the exam periods of the second semester.
- To prepare and adapt workplaces for on-site work for teachers and researchers.

In order to avoid massive infections, the university cancelled in-class activities and on-site work (except for exceptional cases) immediately after the establishment of the state of alert. This way, the use of e-learning was promoted, at least provisionally (depending on the evolution of the outbreak). Finally, and according to the infection data (see Figure 2), the university decided to continue with e-learning until the end of the course. The tools available under these circumstances for teachers and students can be seen in Table 1.

Table 1. Main tools provided to teachers and students during the e-learning period.

Tool	Description	Reference
Virtual campus	Access to some online courses, notes, academic record, etc.	Virtual campus, University of Extremadura [15]
Online library	Access to main scientific journals	Library service [16]
Guides for teachers and students	Videos and tutorials about the use of virtual campus and online library	Webpage, University of Extremadura [17,18]

As a consequence, there was a considerable increase in the number of visitors to the virtual campus website [15] since the total transition to e-learning was carried out in mid-March. A way to assess this increase in the virtual campus activity was by checking the evolution of the Alexa Rank of its webpage, which is an index of the popularity of a webpage according to several parameters, such as the number of visitors. Consequently, as can be seen in Figure 3, the Alexa Rank [19] of this website improved up to 29,380 in July 2020, which was the period with the highest activity because of the exam periods (see Figure 4). It should be noted how the Alexa Rank was significantly worse in the same period last year (July 2019, with an Alexa Rank at around 45,000), which proved that the coronavirus outbreak and the subsequent state of alert provoked an increase in the use of this website. As expected, the same behavior was observed by other authors in Italy under similar circumstances [6].

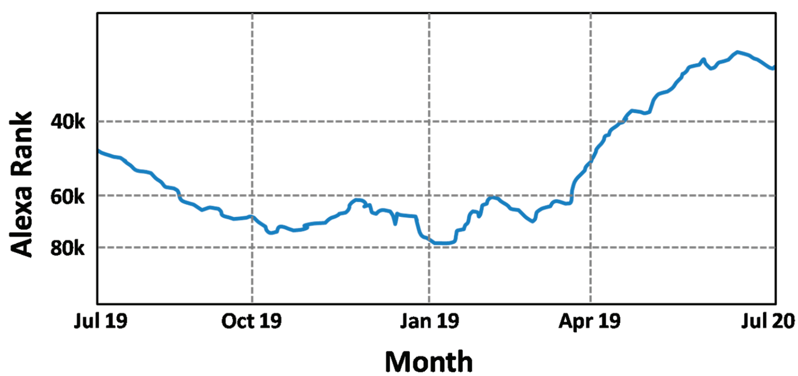

Figure 3. Alexa Rank evolution in the last year for the virtual campus site of University of Extremadura.

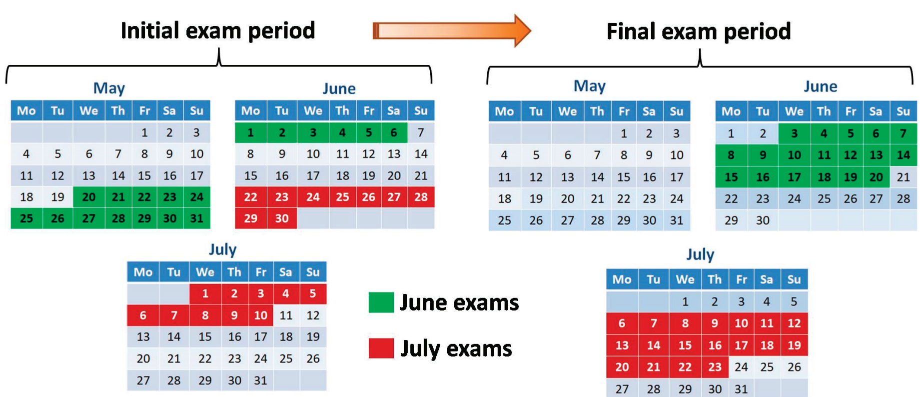

Figure 4. Main academic calendar changes for the second semester.

Some of these tools were already available, such as the virtual campus and the online library, which made the transition to total e-learning easier and less traumatic. However, and due to the recent and massive use of them, some guides were provided in order to make the adaptation to e-learning easier. Gradually, the university provided licenses on specific software (such as Zoom, Webex, Skype or Teams) to facilitate the management of online sessions, group meetings, etc. by teachers and researchers. Although this initiative was very convenient, many teachers did not have suitable computers at home to implement these tools and could not use them or had to buy the equipment.

Moreover, teachers were suggested to increase the number of continuous evaluation activities, in view of the uncertainty about the possibility of making the exam at the centers, and in consequence, they had to redistribute the weight of each evaluation activity on the final mark in the agendas. In order to promote the adaptation to these tools, there was a delay in the exam periods, as shown in Figure 4. Thus, in order to finish the course and to avoid an overlap with the following activities, these periods were delayed for only two weeks. We have to point out that the final degree project (FDP) defense is mainly included in the July exam period. Consequently, and taking into account that the main steps taken at a national level started in mid-March, there was not enough time to delay these periods if they wanted the following course to start normally (in September).

Concerning other issues such as quality control during this period, similar tests followed in the virtual campus were applied for the different subjects taught, and there were meetings with worker unions for health promotion during the confinement and the return to work.

Finally, from the 18th of May, the teaching and research staff could start the on-site work (especially for research and administrative tasks, not for teaching) with some restrictions and promoting telework as much as possible, after a previous disinfection of all facilities and the provision of some personal protective equipment such as masks. However, student attendance (except for some administrative or exceptional tasks) was forbidden for the rest of the course, and therefore our own experience about teaching from the coronavirus outbreak was through e-learning. Obviously, these measures did not only affect the time schedules but also the way of planning the public exposition of the work.

This was especially detrimental for teachers with low experience with ICT (information and communication technologies), who had to face a situation in which they felt insecure; this, in turn, brought up frustration in some cases. All teachers did their duty according to their previous training and motivation to learn, and a diverse range of options was found.

For the development of this study, the main results obtained in this study were based on anonymous surveys, specifically designed for teachers of our department and students, including the main data observed in the figures and tables (see the following section).

3. Our Own Experience

3.1. Methods of Teaching, Educational Tasks and Teaching Staff

The method of teaching used in our laboratory (both for theoretical and practical activities, including the final degree project) is active and participatory, where the student is the heart of the learning process, whereas the teacher provides educational guidance to the students. Thus, constructivism was applied in these cases, with the student carrying out tasks in order to "build" new knowledge that is based in familiar information (obtained in previous courses, mainly). Finally, in order to check the evolution of the student, at least three partial exams (which reduced the content of the final exam, if the student passes them) were carried out, including theoretical and practical exercises.

The main educational tasks carried out in the laboratory of biofuels in the Chemical Engineering and Physical-Chemistry Department are related to chemical and technical engineering for university students at all levels, including final degree projects (FDPs) as the final stage of advanced students before obtaining the university degree. Moreover, there is a special focus on scientific dissemination for all audiences (from pupils to professionals), explaining the foundations of biofuels, as explained elsewhere [20].

Table 2 shows the main characteristics of the subjects covered. Regarding the subjects, they were taught in two quarters at most, with two to three weekly lessons (taking 50 min each), including laboratory lessons in most cases.

Table 2. Kind of education provided to students.

Kind of Education	Field	Students
Subject	Chemical and technical engineering	All levels
Final degree project	Biofuel and bio-compound production	Advanced students
Scientific dissemination	Biofuel foundations	All audiences

Concerning e-learning, the method of teaching used was based on the following key points:

- Implementation of e-learning, including training for teachers and students when necessary.
- The learning process was based on constructivism, an educational culture where learning implies a reconstruction process of information, and new information is related to the previous knowledge of the student.
- The role of the teacher was to support the learning process of the student, with the latter having the ultimate responsibility in this process.
- In this case, apart from other resources such as books, presentations or notes, the internet was the main source of information, based mainly on the virtual campus and the digital library.
- Online courses were created and published, implying the collaboration of teachers and a multidisciplinary team including designers, programmers and educational experts, among others.
- The main tool used was the virtual campus, where e-learning and mentoring were integrated, implying an interactive and flexible environment.
- On this website, carrying out individual and group works was possible for students, and the implementation of courses was suitable for both teachers and students.
- On the virtual campus there were other useful tools, such as a "notice board" for main events of the course (including the exam period), teaching materials (easily printable) and a discussion forum in order to facilitate the communication between students and teachers.
- The duration and structure of contents (including partial exams) of the subjects implemented in the virtual campus did not significantly change compared to the original courses.

The general and main concern for teachers and students about the complete implementation of e-learning was the sudden development of the events (at all levels, from national regulations to the subsequent steps taken by the university) and the little room for maneuver, especially regarding exam and presentation preparation. Nevertheless, the adaptation to e-learning was not the same for teachers and students, mainly depending on their own circumstances. Moreover, the communication between teachers and students had pros and cons.

Concerning teachers, we could classify them in three main levels (Table 3).

Table 3. Main characteristics of the teaching staff in our department.

Teaching Profile	Age	Level	Characteristics
A	Around 30	Assistant university teacher	Novel teachers (Skilled at the use of online teaching software, edition of videos, etc.).
B	40–60	Full university teacher	Used to the management of the virtual campus, including launching activities.
C	Over 60	Professors	Before COVID-19 outbreak, used the virtual campus mainly to upload documents.

Thus, two main factors affected the performance of teaching: the degree of completion of the subject and the familiarity with e-learning techniques.

This way, for the degree of completion of the subject, there were teachers who only gave lessons in the first semester, and only had to face exams in the case some students did not pass their corresponding tests. On the other hand, within the second semester, there were also teachers who had enough time to give their lessons, with the completion of the exam left. However, these represented a small minority of cases. Most teachers had to re-adapt their lessons to e-learning, as they were giving classes when the coronavirus outbreak took place.

For familiarity with e-learning, professors (Table 3, profile C) were clearly affected by this drastic change, as they were used to face-to-face lessons, whereas assistant and full university teachers (A and B, respectively) carried out this transition more easily. Indeed, the latter had already used, more or less frequently, the e-learning platform before this new situation. Consequently, professors tended to create short presentations (like those used in face-to-face lessons) with an explanatory text, whereas the other teachers could use other methods, like videoconferences combined with presentations. Nevertheless, all subjects were successfully completed, although sometimes teachers and students had to use their own resources to solve some computer problems. Regarding the exams, these were completed online. For this purpose, most teachers used the virtual campus site, where they asked the students to submit some theoretical and practical exercises. The most interesting and distinguishing characteristics (compared to in-person examinations) were the following:

- The online identification of the student was required to make sure that they were doing the exam.
- Teachers preferred to weigh logic instead of memory. Thus, practical exercises had an important role in final examinations, in order to avoid "copy and paste" solutions for the students.
- Instead of using a global test time, each exercise (or set of exercises) had a specific time for its completion. Moreover, the times were specifically chosen for each exercise, in order to avoid extra-time that could be used by the student to resort to ITC (information and communication technologies) to solve the tests.

3.2. Final Degree Project Mentoring

Concerning our experience as mentors of final degree project (FDP) students, we took some steps two weeks in advance, regarding a possible confinement by the government and according to the events taking place in neighboring countries such as Italy, including the following:

- We increased the working pace, in order to carry out as many experiments as possible.
- When, in some cases, we realized that all the planned experiments could not be carried out properly, we modified and reduced the experimental work as much as possible, so that our FDP students could have enough data to prepare their FDP defense at home.
- We encouraged our students to install the computer software required to carry out their FDP comfortably.
- We established an online communication with all our FDP students, to continue online mentoring.

The drastic steps carried out had a clear explanation: the low oxidative stability of biodiesel and biolubricant samples. As explained in previous works, the main raw material used in our laboratory is vegetable oil, whose fatty acid profile determines the quality and characteristics of the biofuels and bioproducts obtained from it. As a consequence, the content of oleic acid and linoleic acid makes the subsequent compounds generated by transesterification (that is, methyl oleate and linoleate, among other more complex esters) unstable during storage. This could be explained by the molecular structure of these compounds (Figure 5), whose double bounds are "weak points" to generate free radicals if they react with oxygen, changing some properties of the bioproducts, such as viscosity and flash point [21–23].

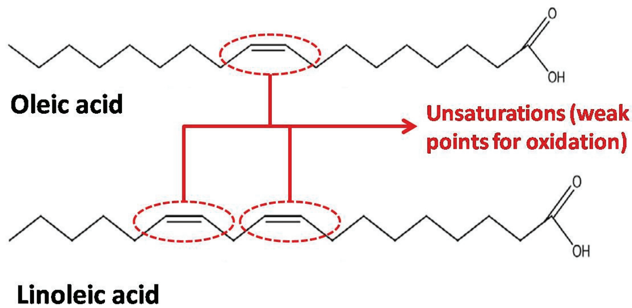

Figure 5. Simplified molecular structure of some fatty acids found in the vegetable oils usually utilized in our laboratory.

As a conclusion, every department should take into account the particularities of the final degree projects carried out, paying special attention to the nature of their experimental design (in this case, the instability of the samples treated) and including the availability of mentors and students, in order to interrupt in a proper way the experimental process of the FDP due to difficult situations like a state of alert.

According to our reasoning, it is important to try to classify the students into different groups, to understand the main trends observed, depending on their degree of completion of the project and paying attention to the experimental development. Figure 6 shows the main steps to be carried out during the FDP process in our laboratory.

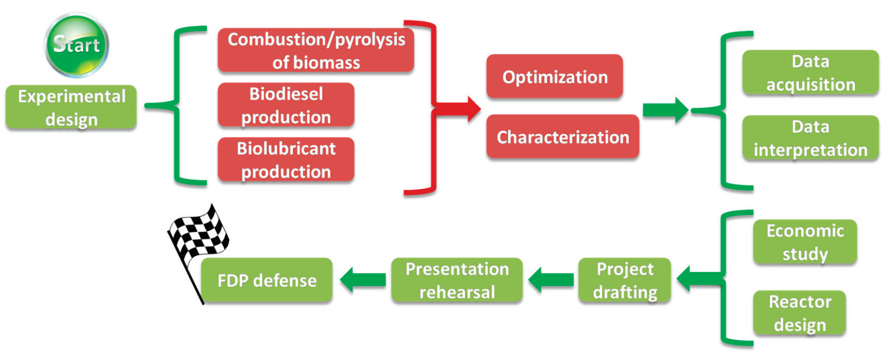

Figure 6. Main steps for the completion of a final degree project in our department. Steps that are mandatory to be done in the laboratory are shown in red. Steps that can be done by e-learning are shown in green.

Thus, the specific tasks carried out in our laboratory are included in Table 4. Most of these tasks were considerably influenced by the state of oxidation of the sample (that is, the vegetable oil). That was the reason why all these tasks needed to be done before the confinement. Otherwise, the results after this absence in the laboratory would have been completely different, as the properties of the vegetable oil would have changed (for the worse).

Table 4. Specific tasks carried out in person in the biofuel laboratory.

Step	Task
Combustion/pyrolysis of biomass	Combustion/pyrolysis in a fluidized bed reactor
Biodiesel and biolubricant production	Production through transesterification (see Figure 6)
Optimization	Optimization of the main parameters of the chemical reaction (temperature, catalyst, time, vacuum, etc.) in order to obtain the highest yield of a bioproduct
Characterization	Gas chromatography, IR, mass spectroscopy, UV/visible spectrum, viscosity, density, cold filter plugging point, flash and combustion points, surface analysis, etc.

In the same way, if the nature of the vegetable oil changed during storage (as it would have happened during the confinement), the chemical reaction to produce biodiesel or biolubricants (that is, transesterification, as it can be seen in Figure 7), and the subsequent production of the main bioproducts that are studied in our final degree projects would be altered, showing unacceptable results.

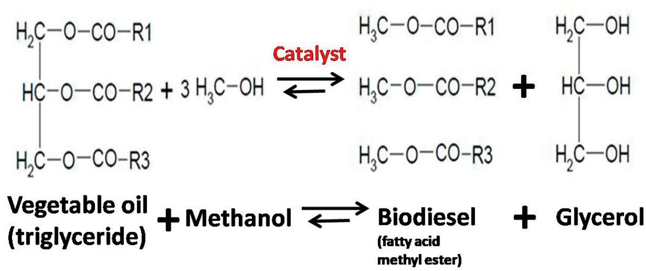

Figure 7. Transesterification reaction to produce biodiesel (fatty acid methyl esters).

As be seen in Figure 6, all the FDPs were focused on combustion or pyrolysis and biodiesel or biolubricant production, carrying out all the experimental procedure (Figure 6, in red) in our laboratories. Thus, according to Table 5, three different kinds of students were found, with their corresponding characteristics according to the degree of completion of their tasks, just before the temporary closure of our university (and, consequently, our laboratory):

Table 5. Different final degree project (FDP) student profiles before the coronavirus outbreak in Spain.

Student Profile	Experimental (Percentage of Completion, %)	FDP (Percentage of Completion, %)	Pending Subjects	Number of Students
A	100	0–20	0–1	2
B	50	0	3–5	2
C	10	0	3–5	3

As a consequence, we had to face different scenarios, and the students had to accomplish the FDP with some pending subjects, depending on the capacity of the student (although it is always advisable to have as much free time as possible to focus on the FDP). According to the table, only the students with their experimental part completed (that is, A students) were capable of advancing their FDP report during the confinement. This was due to two main factors: first, they had all their experimental data available to work (carrying out all the pending tasks in green in Figure 5) and second, they did not have many pending subjects to study. Consequently, they could increase their percentage of completion up to 100% during the coronavirus outbreak, being able to defend their FDP in June. However, B and C students, mainly due to the considerable number of pending subjects and the subsequent lack of time (because they had to adapt to virtual lessons), and on account of the scarcity of experimental data, did not advance in their FDP, calling off their planned FDP defense in June. Spinning in a vicious circle, those students with more load of work due to pending subjects also left behind the FDP, because passing their exams was a priority, and tried to communicate with the teachers too late. On their side, teachers had less time to supervise their projects at the end of the period because of their teaching duties (mainly evaluation activities at the end) and had to make a big effort to refocus these works because of the lack of experimental contents. Moreover, and for the reasons already discussed, their defense will be delayed for months, as their raw material to carry out the experiments was oxidized, thus having to wait for fresh vegetable oils extracted from seeds that have to be collected.

3.3. Communication between Teachers and Students

Finally, we wanted to point out a particularity related to e-learning lessons and mentoring, that is, that the communication between teachers and students during this period has drastically changed.

The most preferred way of communication between teachers and students was the use of e-mails along with the campus virtual site. For an immediate and effective communication, a schedule (similar to the one established for personal meetings) was chosen, although it could be more flexible depending on the "emergency" of the student requirements taking into account these exceptional circumstances, even allowing for other ways of communications such as phone calls or instant messaging services.

Ironically enough for a period where most people were confined at home, a lack of communication was observed between teachers and students in their different modalities. Figure 8 shows the main reasons why this lack of communication took place, in our opinion.

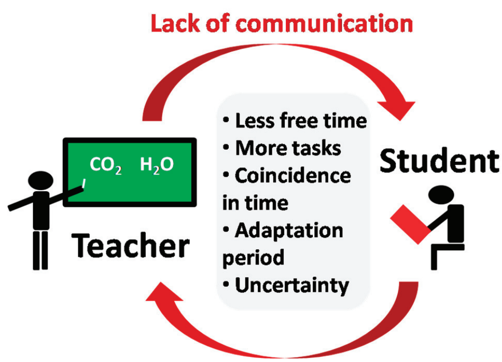

Figure 8. Main causes of lack of communication between teachers and students.

As explained in this figure, both teachers and students underwent (in greater or lesser degree) the following disadvantages:

- Less free time: Most teachers and students had family commitments, especially concerning children, which could not be solved at schools.
- More tasks: Many teachers are equally researchers, and during this period their tasks increased (for instance, there was an increase of peer-review activity, as many researchers used this period to submit pending research works).
- Coincidence in time: Due to the particularities of people (especially family commitments), they could work in the evening, at night, etc., not adapting to the schedule of other teachers/students who depended on their feedback.
- Adaptation period: Both teachers and students had to adapt to this new situation, by resorting to webinars or tutorials, in order to get used to the e-learning platforms.
- Uncertainty: Especially for students. Apart from the global uncertainty, which can cause cases of anxiety, depression and stress, as other authors have pointed out [24–26], the exam period extension could also cause demotivation.

Finally, during this period we were updating the prevention plan of the laboratory [27] for the following course, as we had not considered a pandemic outbreak. Thus, the main steps included were the following:

- A registration is required to enter the laboratory, in order to follow-up a possible viral rebound in our facilities.
- The use of mask is mandatory, in order to avoid a possible spread of the disease.
- Disinfectant gels and safety gloves are provided.
- Recommendation of notification if the worker has symptoms that are similar to those related to COVID-19 (especially cough, fever and shortness of breath).
- The promotion of telework as much as possible, by using software such as Zoom for online meetings, in order to avoid unnecessary face-to-face meetings.

To sum up, although it was a tough situation (personally, economically and professionally), coping with it has meant an enlightening experience, where we learned from the mistakes (and success) in order to improve the teaching experience. Even in these hard times there is room for learning and improvement, in this case for teachers and students. As the old saying goes:

"The man of little learning grows old like an ox; only his flesh grows but not his wisdom".

4. Conclusions

The main conclusions that we have reached about how the coronavirus outbreak has affected the development of our normal activities are the following:

- For teachers, researchers and tutors, there was a considerable impact because many of their activities are based on face-to-face lessons or meetings. Nevertheless, the existence of an operating virtual campus and an online library has made the transition to telework easier.
- The development of new tutorials for these new users, and for further skills, was required, mainly due to the massive use of these resources.
- For students, there has not been a great impact from a technological point of view, as they are generally used to new technologies. However, the uncertainty generated at all levels (including exam dates) might have caused some discouragement, and affected their study process.
- Depending on the degree of completion of their degrees (or courses), students could advance at different levels. The completion of a FDP was not advisable under these circumstances when the student had more than three pending subjects if they wanted to finish the course in the calendar year.
- Concerning the laboratory work, the main disadvantage found, apart from the obvious interruption, was the spoilage of the vegetable oils used as raw materials for biodiesel and biolubricant production. That was the reason why the conclusion of the ongoing experiments was so important. Otherwise, they should be repeated as the sample would have changed its properties due to auto-oxidation, requiring the collection of new vegetable seeds for oil production at the right season.
- The development of alternatives (and further implementing of telework) for this kind of situations, such as hypothetical new outbreaks, is necessary. The possible mistakes made during this experience can be a valuable lesson in order to improve the teaching process at all levels.
- Finally, this experience can be a starting point for the massive implementation of virtual classes. However, face-to-face lessons also present many advantages in the education process, suggesting that, as Buddha recommended to Sona in the parable of the lute, the middle way might be the best one, alternating (in a balanced way) both online and face-to-face lessons when possible.

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education sciences

Article

Exploring College Student's Perspectives on Global Mobility during the COVID-19 Pandemic Recovery

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Abstract: At the time of writing, more than 22 million cases of COVID-19 have been reported worldwide, and at least 770 thousand deaths. Under the pressure of the pandemic, promoting global mobility has become an emerging issue in higher education settings. Although various methods of enhancing student mobility have been implemented, little research has as yet confirmed the pandemic challenges for students. This study investigates the global mobility of Chinese college students and the factors influencing their travel decisions. A self-designed questionnaire, consisting of 15 critical indicators of mobile capabilities, intentions, and implementation decisions, was administered to collect data from 2226 participants. The Minitab and Amos software were used to conduct exploratory factor analysis (EFA) and to detect latent relationships among the data with structural equation modeling (SEM). The SEM and logistic regression model provide a clear picture of the relations among the variables, and show that international intention is the key indicator of global mobility implementation under pressure.

Keywords: COVID-19 pandemic; global mobility; higher education; internationalization; structural equation modeling (SEM); multi-group invariance analysis

1. Introduction

The term "global mobility" refers to border-crossing, which most often takes place for temporary purposes, such as a program of study, mid-career international experience, or employment [1]. In this paper, global mobility refers to non-permanent border crossings among college students for study and work. The student mobility figures rose from two million in 1999 to five million in 2016, with an average annual growth rate of 5.1% among countries belonging to the OECD (Organization for Economic Cooperation and Development) and 6.4% among non-OECD countries [2]. According to the 2018 OECD report, Asian students are more internationally mobile at the master's level, while European students tend to be more mobile at the bachelor's and doctoral levels. The report indicates that 89% of OECD citizens studying abroad do so in another OECD country, and about 70% of international students in OECD areas come from a country that is not an OECD member. International students in these countries originate mainly from Asia, which accounts for 87% of the international students in Australia, 77% in the United States, 61% in Canada, and 52% in the United Kingdom [2]. Studying abroad has become a key differentiating experience for students enrolled in tertiary education, and international student mobility has received increasing policy attention in recent years.

Various countries have initiated education policies to promote global mobility among students. For example, the Erasmus program encourages more than 4000 higher education institutions from more than 30 countries to work with them [3]; the New Colombo Plan is a signature initiative of the Australian Government, which aims to enhance knowledge of the Indo-Pacific region in Australia by providing incentives to Australian undergraduates to study and undertake internships in the region [4]; and Generation Study Abroad is a five-year initiative of the Institute of International Education to mobilize resources and commitments with the goal of doubling the number of U.S. students studying abroad by the end of the decade [5]. The importance of student global mobility is shown in related policy initiatives. Previous studies indicate that studying abroad can provide several advantages to students. These include an opportunity to access quality education, which may not be available in their home country, to acquire skills that may not be taught at home, to get closer to labor markets that offer higher returns on education [6,7], and to improve their intercultural sensitivity [8]. Studying abroad is also seen as a way to improve employability in increasingly globalized labor markets [9,10]. Other motivations include the desire to expand one's knowledge of other cultures and to improve one's foreign language skills, particularly English [2]. While arguments pertaining to all of these advantages have been presented, the extent to which the benefits are realized is unclear. Various methods of promoting global mobility among students have been implemented in different countries, although few studies have verified the effects through empirical testing, or the global mobility capabilities of students in Asia, where most international students originate. At time of writing, more than 22 million cases of COVID-19 had been reported worldwide, as well as at least 770 thousand deaths, according to Johns Hopkins University. Under the pressure of the pandemic, students' global mobility has become an emerging issue in higher education settings.

Given the limited utility of existing self-reporting instruments of student global mobility, this study aims to develop a comprehensive questionnaire that assesses the perceived global mobility capabilities of college students in China under the global pressure of the pandemic. Students from Asia have become the largest group of international students enrolled in OECD tertiary education programs at all levels, and among these students, over 860,000 come from China [2]. The present study examined Chinese students' perceptions of their global mobility capabilities, intentions, and the extent to which they have implemented global mobility under the pressure. Three specific research questions are posed:

a. What indicators can be used to assess student capabilities for global mobility?
b. To what extent do college students carry out their global mobility intentions?
c. What are the implications of this study for global mobility research?

The rest of this paper is organized as follows: Section 2 provides an overview of the literature on student global mobility. Sections 3–5 address the research design of the present study, the method of data collection, and the analytical tools used to interpret the data. Section 6 presents the results of the factor analysis and structural equation modeling, and Section 7 discusses the findings and their implications. Finally, Section 8 presents the conclusion and gives suggestions for future research.

2. Literature Review

Global mobility, which requires international cooperation, is driven by various interests. Among countries that participate in global mobility programs, these interests include academic and economic development, but also competition [11]. Among students, there are numerous factors contributing to international mobility, such as socio-economic status, academic achievement and abilities, social relationships, and former international experiences [12]. Other factors include the situation in a student's home country, such as the level of opportunity for higher education, the quality of national offers, and the relevance of international degrees with respect to the home-country's labor market [13]. This section focuses on the soft power theory and spatial theories as they relate to global mobility, and on studies that discuss the capabilities and intentions of students with respect to studying abroad.

2.1. The Impact of Global Mobility on Soft Power

Global student mobility for academic, economic, or political purposes has provided a new map in the world. Many countries view international academic mobility and educational exchanges as critical components for sharing knowledge, building intellectual capital, and remaining competitive in global settings. Studying abroad is a way to foster mutual understanding and cooperation, especially in a climate of increased political uncertainty and unrest [14]. Nye's theory of soft power provides a specific lens for examining the interdependency and complexity of internationalization in the context of higher education worldwide [15–17]. According to the soft power conversion model, higher education in the UK and US has a growing influence on worldwide economic, political, and social forces, which drive the global economy. Increasing international enrollment in higher education, both in the UK and US, is fundamental to governments and educational institutions that aim to provide a comprehensive internationalization agenda consistent with enhanced global capacity building and a globally competitive orientation [18]. From a student perspective, global mobility has the potential to enhance personal soft power with respect to career development. In sum, both personal and national purposes pertaining to global competition underlie enhanced global mobility.

The impact of global mobility on soft power is further underscored by the observation that technology, education, and economic growth are becoming more important in constructing soft power, whereas geography, population, and raw materials are becoming less important [18]. The notion of soft power has been converted into policies for outbound and inbound international education in different countries. To extend the concept of soft power, Knight [19] argued that higher education needs to take a lead in promoting the notion of knowledge diplomacy to avoid becoming mired in the soft power frame of reference that focuses only on self-interest and dominance, which might impact student decisions. Finally, Nagao [20] proposed a distinction between two types of soft power investments: (1) Those that involve direct payment from one government (or institution) to another, and (2) indirect investments among individuals and professionals for the purpose of scholarships, training, and nonmonetary cultural influences. The British Council of the United Kingdom, the Goethe Institute of Germany, and the Confucius Institute of China use indirect investments.

2.2. Interpretation of Spatial Theories

Larsen [21] proposed an analysis, using spatial, network, and mobility theories, to broaden the theoretical framework for analyzing internationalization in higher education. She argued that there are notable problems with the distinction between internationalization at home and abroad. Working within this binary framework means holding to the view that particular internationalization strategies are effective in a local setting and others are ineffective [21]. Mobility theories in particular combine social, spatial, and anthropological research, bringing together "some of the more purely 'social' concerns of sociology (inequality, power, hierarchies) with the 'spatial' concerns of geography (territory, borders, scale) and the 'cultural' concerns of anthropology and media studies (discourses, representations, schemas), while inflecting each with a relational ontology of the co-constitution of subjects, spaces and meanings" [22].

In brief, spatial theories are concerned with how space is constructed and changed by human activity within it, and how human activity is altered and shaped by spatial arrangements. The international scene is co-constructed within local universities, which in turn are co-constituted through the very international phenomena that influence and shape their identity [21]. With regard to network theories, Castells [23,24] argued that the space of places is based on the closely interrelated contiguity of practice, meaning, function, and locality, while the space of flows is comprised of the material arrangements that allow for the simultaneity of social practices without territorial contiguity. These spatial and network theories provide a window through which to view the complexity of the student global mobility issue, while broadening our understanding of this issue by presenting it from a wide and multi-faceted perspective.

2.3. Studies on Global Mobility Capabilities

Internationalization has been understood as a trend among policy makers to make border-crossing easier and facilitate knowledge transfer across international boundaries. With respect to global mobility among students, being familiar with the cultural expectations of people from other countries is important, considering the impact culture has on shaping the identities of students who choose to undertake the programs [25]. Therefore, developing an objective method to evaluate intercultural competencies has become paramount [26]. Various studies have shown that internationalization in higher education involves different activities, including foreign language learning and programs to increase global understanding, and they argue that the positive effects of internationalization extend from a more favorable view of other countries to a growing empathy with cultures other than one's own [27–29]. Previous studies focusing on the mobility capabilities of student address issues pertaining to communication, cultural awareness and adaptability, competencies, and skills.

2.3.1. Communication

Communication across borders via the Erasmus program has become a successful global mobility initiative. As Garrido [30] emphasized, volunteers in this program need to learn and use linguae francae (English and Spanish) to foster inter-cultural communication and solidarity. While communication skills are essential for all professionals, the requirement is even greater for those working with global mobility [31]. Foreign language proficiency, especially English, is considered crucial in the context of globalization and internationalization. While language requirements differ considerably among countries that participate in global mobility programs for students, it is not uncommon for countries to support the integration of international students by offering some level of English language instruction for free. On the other hand, the requirement of a certain level of competency in English can become a barrier to receiving grants or access to higher education institutions. In those cases, language is used as an exclusive regulation tool [13]. Foreign language skills include, at minimum, an ability to speak, understand, and read the language at the basic functional level required for carrying out everyday activities.

2.3.2. Cultural Awareness

Outbound-oriented mobility learning for economic or cultural reasons has been implemented in various countries, through international service-learning programs in which students can engage in cross-cultural dialogue and reflect upon their experiences [32]. Outbound mobility enhances opportunities for upward mobility, while also challenging the established cultural patterns of learning. Souto-Otero et al. [33] found that one of the differentiating factors between Erasmus and non-Erasmus students is their level of social and cross-cultural awareness, which tends to be higher among Erasmus students. Barriers to entry in the program include costs and socio-economic background. These observations highlight the importance of balancing the risks (credit recognition, costs, and benefits) of student mobility and managing personal anxieties (social factors).

2.3.3. Knowledge and Skills

Empirical studies evidence an association between mobility and quality of work at the individual, organizational, and national levels. Mobile researchers are on average more productive than non-mobile researchers [34,35]. Overall, there is a structural excess of labor supply among mobile researchers, and micro-level matching between an individual's competencies and job specifications is central to the hiring process [36]. Self-selection assessments pertaining to the skills of potential migrants are important to analyze, especially in the context of migration between rich countries [37]. Focusing on international study, Madge, Raghuram and Noxolo [38] assumed that both individual and collective phenomena impact student capabilities for mobile learning. With regard to push factors, it has been shown that an emphasis on theoretical knowledge in traditional teaching methods and curricula makes it difficult for higher education institutes to pursue educational goals that accelerate student mobility in Asian countries [39]. Moreover, various researchers propose that the value and nature of dynamic capabilities is context-dependent, meaning that different capabilities are required in different contexts [40–43]. For this reason, many students consider mobility as an opportunity to enhance their job-related competencies and skills, through an overseas internship, for example, or by acquiring an international license.

2.4. Factors Impacting Global Intention and Implementation

International student recruitment continues to gain prominence in the strategic priorities of higher education institutions. According to the American Council on Education's report [44], increasing students studying abroad and recruiting international students were identified, respectively, as the number one and number two priority activities for internationalization across all sectors of institutions [44]. Similar findings appear in other countries. At the same time, the past several years has seen barriers to global mobility that include increasing competition, tightened immigration policies, and the unwelcoming rhetoric of the Trump administration [45,46]. With respect to citizenship, the path is narrowing in both the United States and other countries, even for talented immigrants. If anti-immigrant and nationalistic rhetoric continues to be strong, it will negatively affect the perception of safety and post-graduate career opportunities for international students. Moreover, many institutions face the residual effects of the global financial recession, which make it difficult to grow their enrollment of international students.

Addressing sociopolitical, demographic, and economic shifts worldwide along with the global ambitions of universities, Choudaha and Van Rest [47] found a continued qualitative and quantitative growth of English-taught programs in Asia and Europe. The development of higher education in China is no exception. These programs may decrease the perceived need to study abroad, or they may heighten it, depending on student perceptions of foreign language learning and the value of being immersed in a foreign culture. There are many factors, both positive and negative, influencing the decision to study abroad, and these factors are not always easy to isolate or compartmentalize [48]. Traditional theories regarding international student mobility have been extensively dealt with in the transnational educational literature, while student choice remains an underrepresented topic [49]. Studies related to the international intentions of students and the decision to implement these intentions may be useful for constructing a new theoretical framework for understanding global student mobility under a specific global event.

2.5. The Challenge of Internationalization in Educational Settings during the COVID-19 Pandemic

Since the WHO declared the COVID-19 pandemic outbreak, the UN Educational, Scientific and Cultural Organization estimated that a sizeable population around the world—approximately 1.5 billion students and 63 million educators—have stayed away from their conventional education environments [50–52]. The scale and speed of school closures are unprecedented globally. It is unclear how long countries can maintain tight suppression measures before behavioral fatigue in the population occurs [53]. COVID-19 is an emerging contagious pathogen causing a high prevalence of pneumonia in infected individuals. Many studies report important effects on reducing transmission and the size of the pandemic. Yet, there is considerable heterogeneity in the impact on international student mobility depending on the students' characteristics and perspectives.

Education is one of the sectors most heavily affected by the negative consequences of the COVID-19 pandemic. As a response to this crisis and in order to mitigate the spread of the coronavirus and to save lives, governments in affected countries have imposed desperate measures of social distancing, widespread lockdowns, and restrictions on traveling, movements, and gatherings. A large number of schools and educational systems have had to face disruption to education and adopt internet-based methodologies to support their students via distance education solutions during the period of school closures [52,54–56]. Disparities in distance education have become more evident in the context of the COVID-19 pandemic. The COVID-19 lockdown has severely affected educational systems around the world, especially international student exchange. This study focused on college students' perspectives on identifying the incentives for global mobility.

3. Method

3.1. Measures of the Constructs

The related indicators adopted in this study have been reported in the previous literature. However, Bohmstedt [57] maintained that, to ensure content validity, measurement items need to characterize the concepts about which generalizations are to be made. Therefore, the proposed measurement indicators of global mobility in this study were taken from previous studies and then adapted to suit the present context. Figure 1 shows the theoretical framework for implementing global mobility. Within this framework, we assume that the capabilities of students will determine their mobility intentions and implementation decisions. The 15 indicators selected consist of five domains, namely communication, cultural awareness, knowledge and skills, intention, and implementing. Communication includes three indicators: Spoken_A, Reading_A, and Communication_A; cultural awareness includes three indicators, Cultural_A, Custom_A, and Global_A; knowledge and skills includes five indicators, Ethic_A, P_knowledge, P_skills, P_license, and P_internship; intention includes two indicators, Caring_intent and Working_intent; and implementing includes two indicators, Caring_ability and Working_ability. The details of the 15 indicators are listed in Table 1. All capabilities were presented using a 7-point Likert scale, ranging from 1—strongly disagree, to 7—strongly agree, indicating the level of importance students attached to each indicator. Levels of intention and implementation were determined by actual figures reported by students, for which the weighted levels ranged from very low (1) to extremely high (7).

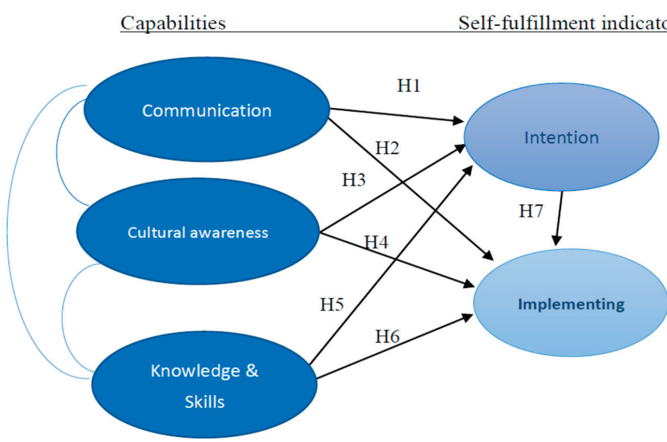

Figure 1. Theoretical framework for implementing global mobility.

Table 1. Global mobility capability requirements for college students.

Domains\Indicators	**Definitions**
Communication	
Spoken_A:	Ability to speak an international language
Reading_A:	Ability to read an international language
Communication_A:	Fluent communication in an international language
Cultural awareness	
Cultural_A:	Awareness of foreign cultures
Custom_A:	Respect for foreign customs
Global_A:	A global perspective
Knowledge & Skills	
Ethic_A:	Professional ethics in international job markets
P_knowledge:	International professional knowledge
P_skills:	International practice skills
P_license:	An international license
P_internship:	A completed international internship
Intention	
Caring_intent:	An international interest in caring
Working_intent:	An international working intention
Implementing	
Caring_ability:	Implementation of international caring
Working_ability:	Implementation of an international working intention

3.2. Hypotheses Development

This study developed seven hypotheses regarding college students' capabilities for global mobility that propose a link between, on the one hand, capabilities, including communication ability, cultural awareness, and knowledge and skills, and on the other hand, intentions and implementation decisions. The hypotheses are listed below:

Hypothesis 1 (H1). *Communication ability positively affects intentions of global mobility*.

Hypothesis 2 (H2). *Communication ability positively affects the implementation of global mobility*.

Hypothesis 3 (H3). *Cultural awareness positively affects intentions of global mobility*.

Hypothesis 4 (H4). *Cultural awareness positively affects the implementation of global mobility*.

Hypothesis 5 (H5). *Knowledge and skills positively affect intentions of global mobility*.

Hypothesis 6 (H6). *Knowledge and skills positively affect the implementation of global mobility*.

Hypothesis 7 (H7). *Intention positively affects the implementation of global mobility*.

4. Sample and Data Collection

Both an online survey (in China) and traditional questionnaire survey (in Taiwan) were conducted to collect data from the research targets. Ethical approval clearance and informed consent clearance were granted by the CHINAEM in China and by the Ministry of Science and Technology in Taiwan, due to the use of anonymous questionnaires. All the participants joined the survey on a voluntary basis. Data were collected from March 2019 to May 2019. The WHO declared the coronavirus disease 2019 (COVID-19) outbreak, caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), to be a pandemic on 12 March 2020 [52]. It is believed that there were no lockdown or other restrictions on global mobility before the pandemic in these areas. A total of 2250 questionnaires were collected.

Submitted questionnaires with incomplete answers were excluded, resulting in 2226 (25.5% male and 74.5% female; average age from 19.5 to 22.5) usable surveys. The target population included sophomore to senior students recruited from public colleges located in different regions of China, including 16.3% from northeast China (Heilongjiang and Jilin); 67.5% from east China (Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, and Shandong); 5.8% from north China (Beijing, Tianjin, Shanxi, Hebei, and Inner Mongolia); 2.3% from central China (Henan, Hubei, and Hunan)); 1.4% from south China (Guangdong, Guangxi, and Hainan); 4.1% from southwest China (Sichuan, Guizhou, Yunnan, and Chongqing); and 2.6% from northwest China (Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang). In addition, the target population included sophomore to senior students recruited from public (34.2%) and private (65.8%) colleges located in different regions of Taiwan, including 48.6% from northern Taiwan; 25.4% from central Taiwan; and 26.0% from southern Taiwan. In terms of socio-economic status, most of the students were classified as middle class. Among the total study sample, 39.17% had overseas experience, and 60.83% lacked this experience. The characteristics of the study sample are presented in Table 2.

Table 2. Characteristics of the sample.

Variables		Count	Percent
Gender	Male	567	25.5
	Female	1659	74.5
Social Economic Status (SES)	1 Poor	107	4.81
	2 Lower	294	13.21
	3 Middle	1534	68.91
	4 Upper	277	12.44
	5 Rich	14	0.63
Overseas experience	Yes	872	39.17
	No	1345	60.83
SES with overseas experience			
1 Poor	Yes	25	23.36
	No	82	76.64
2 Lower	Yes	102	34.69
	No	192	65.31
3 Middle	Yes	615	40.09
	No	919	59.91
4 Upper	Yes	120	43.32
	No	157	56.68
5 Rich	Yes	10	71.43
	No	4	28.57

5. Data Analysis

The data analysis procedure in this study involved exploratory factor analysis (EFA), reliability analysis, and structural equation modeling (SEM). The latter has been proved to be a flexible and powerful means of examining the relationships among constructs [58]. With respect to the EFA, items with factor loadings of less than 0.50 and with many cross loadings were omitted [59,60]. Varimax rotation was conducted, and the validity and reliability of the questionnaire were evaluated accordingly. The scales of each item were clarified by employing the related statistics in Minitab version 19. SPSS AMOS 19.0 was used to conduct the SEM analysis for exploring the structure of relationships between capabilities and implementation decisions, and for testing the measurement model. The overall model fit was assessed using seven common goodness-of-fit indices: The ratio of χ^2 to degrees of freedom (df), goodness of fit index (GFI), adjusted goodness of fit index (AGFI), comparative fit index (CFI), root mean square error of approximation (RMSEA), non-normalized fit index (NNFI), and incremental fit index (IFI) [61,62].

Logistic regression is the appropriate regression analysis to conduct when the dependent variable is dichotomous (binary). In this study, we examined the relationships between students' overseas experience and their weighting of the proposed capabilities. We further examined whether overseas experience was linked to future mobile intentions. Logistic regression was conducted by using the Minitab statistical package. A logit is a log of odds, and odds are a function of P, $logit(P) = a + \beta_1 X_1 + \ldots + \beta_n X_n$. The odds ratio (OR) was calculated to reflect the impact of students' responses. It was calculated according to the following formula [63,64]:

$$Odds = e^{\beta_0 + \beta_1 \chi_1 + \ldots + \beta_n \chi_n} \rightarrow \log(Odds) = \beta_0 + \beta_1 \chi_1 + \ldots + \beta_n \chi_n$$

$$Odds = \frac{P(y=1)}{P(y=0)} \frac{\text{The Odds will be} > 1 \text{ when there is a higher probability of predicting } y = 1}{\text{The Odds will be} < 1 \text{ when there is a higher probability of predicting } y = 0}$$

Finally, we employed the stepwise method used in more complicated logistic regression models. Adding independent variables to a logistic regression model will typically increase the amount of variance explained in the log odds. In this study, the variance is expressed as R^2.

6. Results

6.1. Factorial Structure

According to the related literature, theoretical global mobility can be estimated by using student capability with respect to communication, cultural awareness, knowledge and skills, global intention, and global implementation. In this study, the EFA results regarding capabilities for global mobility and implementation indicate that "capability" and "intention and implementing" constitute two dimensions in the global mobility survey. "Capability" refers to 11 related indicators, whereas "intention and implementing" consists of four indicators. In total, the proposed construct can explain 62.2% of the variance, as shown in Table 3. There were no indicators with a factor loading of less than 0.5. Thus, a total of 11 items or indicators were retained in the final version of "capabilities for global mobility," with that construct explaining 76.2% of the variance, as shown in Table 4.

Table 3. Factor loadings for two factors (capability and intention and implementing) in the global mobility scale.

15 Indicators	Factor1	Factor2	Communality
Capability domain			
P_knowlege	0.817	0.000	0.682
P_skills	0.803	0.000	0.662
Reading_A	0.796	0.000	0.634
Spoken_A	0.785	0.000	0.617
Communication_A	0.783	0.000	0.613
Global_A	0.775	0.000	0.619
Ethic_A	0.760	0.000	0.611
Culture_A	0.747	0.000	0.588
P_license	0.743	0.000	0.562
P_internship	0.739	0.000	0.566
Custom_A	0.679	0.000	0.472
Intention and implementing			
Caring_ability	0.000	0.848	0.729
Working_ability	0.000	0.833	0.695
Working_intent	0.000	0.816	0.678
Caring_intent	0.000	0.752	0.599
Variance	6.5286	2.7981	9.3267
% Variance	0.435	0.187	0.622

Table 4. Factor loadings for three factors comprising "capability" in the global mobility scale.

Indicators	Factor1	Factor2	Factor3	Communality
Knowledge and skills				
P_internship	0.862	0.000	0.000	0.810
P_license	0.805	0.000	0.000	0.745
Ethic_A	0.745	0.000	0.000	0.713
P_skills	0.695	0.000	0.000	0.713
P_knowledge	0.624	0.000	0.000	0.701
Communication				
Reading_A	0.000	0.834	0.000	0.851
Spoken_A	0.000	0.823	0.000	0.828
Communication_A	0.000	0.750	0.000	0.764
Cultural awareness				
Custom_A	0.000	0.000	0.860	0.820
Culture_A	0.000	0.000	0.704	0.712
Global_A	0.000	0.000	0.686	0.724
Variance	3.3536	2.6054	2.4211	8.3801
% Variance	0.305	0.237	0.220	0.762

Rotation method: Varimax with Kaiser normalization.

6.2. Results of Reliability Analysis

Reliability was estimated by evaluating the internal consistency of the instrument using Cronbach's α to represent each factor. In general, reliability analysis suggests that Cronbach's $\alpha > 0.6$ can be used as an index of convergent validity. In this study, the reliability analysis reveals that all of the indicators have high standardized factor loadings (see Table 5), reflecting convergent validity [65]. The Cronbach's α of the entire survey questionnaire is 0.899, which also exceeds the minimum standard of 0.70, as recommended by Hair et al. [66].

Table 5. Item statistics for Cronbach's alpha.

Indicators	Item-adj. Total Corr.	Squared Multiple Corr.	Cronbach's Alpha
Spoken_A	0.7836	0.6291	
Reading_A	0.8099	0.6608	0.884
Communication_A	0.7325	0.5392	
Culture_A	0.6802	0.4636	
Custom_A	0.6982	0.4876	0.828
Global_A	0.6805	0.4646	
Ethic_A	0.7476	0.5741	
P_knowlege	0.7385	0.5946	
P_skills	0.7658	0.6259	0.901
P_license	0.7454	0.5772	
P_internship	0.7837	0.6370	
Caring_intent	0.6152	0.4697	
Working_intent	0.6732	0.5056	0.652
Caring_ability	0.7204	0.5630	
Working_ability	0.6768	0.5296	0.744

Cronbach's alpha for all items = 0.899.

6.3. Results of SEM

The results of SEM, along with the recommended values for the common model fit, and the suggested saturated and independence models, are shown in Table 6. Most of the model-fit indices exceed their respective common acceptance levels suggested by previous research, thus demonstrating that the default measurement model exhibits a good fit with the data collected (GIF = 0.916, AGFI = 0.876, CFI = 0.934, RMSEA = 0.087, NNFI = 0.915, IFI = 0.934). According to the χ^2/df index, the $\chi^2 = 1458.239$ and $df = 81$, which is not a good fit. This result might have been caused by the large sample in this study. With respect to the scaled non-centrality parameter (SNCP) for large samples, the SNCP = (χ^2 – df)/n = 1377/2226 = 0.61, indicating a good fit (0.61 ≤ 3.00). The parsimony-adjusted measures indicate a parsimonious normed fit index (PNFI) and parsimonious goodness of fit index (PGFI) that exceed the recommended acceptance levels (≥ 0.5). This implies that the suggested model is a good fit.

Table 6. Fit indices for structural and independence models.

Fit Indices	Recommended	Default_m	Saturated_m	Independence_m
		Model fit summary		
χ^2/df	≤3.00	18.03	-	201.7
GIF	≥0.80	0.916	1.0	0.266
AGFI	≥0.80	0.876	-	0.161
CFI	≥0.90	0.934	1.0	0.000
RMSEA	≤0.1	0.087	-	0.300
NNFI	≥0.90	0.915	-	-
IFI	≥0.90	0.934	1.0	0.000
		Parsimony adjusted measures		
PNFI	≥0.5	0.718	0.0	0.000
PGFI	≥0.5	0.619	0.0	0.000
AIC (relative)	smaller	1536	240	21101

Properties of the causal paths, including the estimated standardized path coefficients and *p*-values for each equation in the hypothesized model, are presented in Table 7 and Figure 2. As expected, the results support H3, H5, and H7 ($\gamma = 0.416$, $p < 0.01$; $\gamma = 0.164$, $p < 0.006$; $\gamma = 1.156$, $p < 0.001$, respectively). The results reveal negative coefficients with respect to H1 and H4, indicating that the current survey target reflected specific and unexpected phenomena. H2 and H6 were not supported in this study, although both "Communication" and "Knowledge and Skills" exerted an impact on "Implementing" through "Intention" (H7) ($\gamma = 1.156$, $p < 0.01$). In the discussion section, we will expand on these results.

Table 7. Estimated standardized path coefficients and *p*-values.

Hypotheses			Estimated	Standardized	*p*
H1: Intention	<—	Communication	−0.193	−0.185	**
H2: Implementing	<—	Communication	−0.081	−0.066	0.136
H3: Intention	<—	Cultural awareness	0.425	0.416	**
H4: Implementing	<—	Cultural awareness	−0.238	−0.199	**
H5: Intention	<—	Knowledge and Skills	0.144	0.164	**
H6: Implementing	<—	Knowledge and Skills	0.062	0.061	0.194
H7: Implementing	<—	Intention	1.352	1.156	**

** $p < 0.01$.

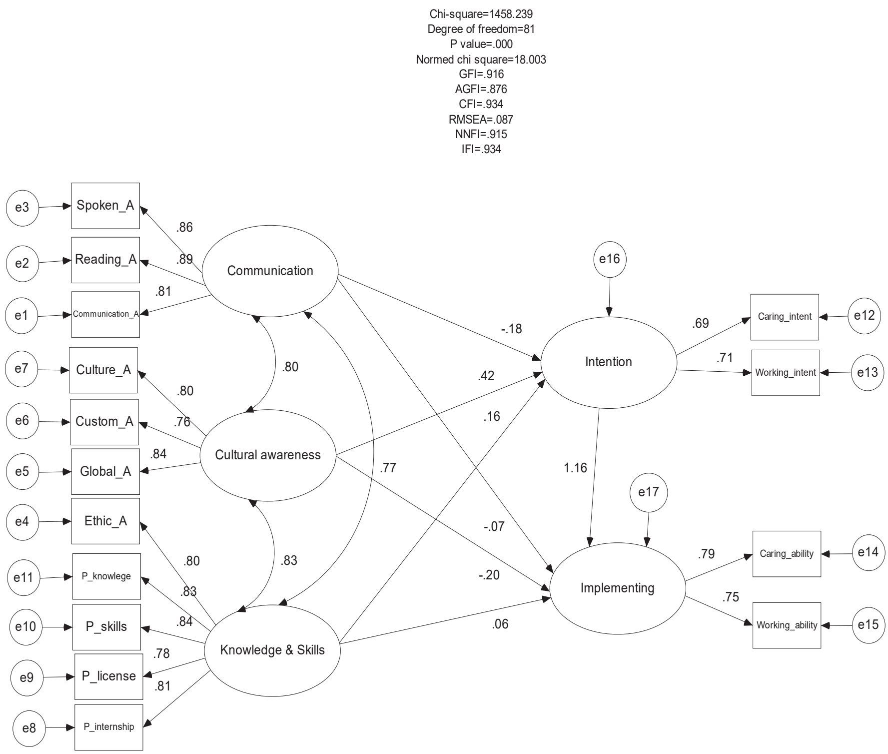

Figure 2. Paths taken toward the implementation of global mobility capabilities.

6.4. Results of Logistical Regression

The results of logistical regression reveal that "overseas experience" is significantly related to "cultural awareness" and "knowledge and skills." The deviance test displays the results of a Chi-square test used to indicate whether each of the individual terms in the regression was statistically significant after adjustment. The result reveals the adjusted R^2 = 0.22, and the AIC = 3082.15 with (df = 2224, χ^2 = 3078, p = 0.000). The result of logistical regression shows Y′ = 0.0554; the details are presented in Table 8. The calculated odds ratio for the perception of mobility among college students with overseas experience is p (1) = exp(Y′)/(1 + exp(Y′)). This result demonstrates that college students with overseas experience agreed with the importance of cultural awareness 1.057 times more often than others; the difference in the knowledge and skills of the two groups was less. Those with overseas experience were only 0.98 times as likely to have knowledge and skills than those without this experience.

Table 8. The results of logistical regression for mobility capabilities among students with overseas experience and those without this experience.

Capabilities	Coef	SE Coef	VIF	Odds Ratio	95% CI
Cultural awareness	0.0554	0.0200	1.91	1.0570	(1.0163, 1.0992)
Knowledge and skills	−0.0193	0.0105	1.91	0.9809	(0.9610, 1.0013)

The logistical regression equation for the implementation of mobility intentions shows that Y′ = 0.0622. Since the coefficient β_1 is 0.0662, the calculated odds ratio will be exp(β_1) = exp (0.0622)

= 1.064. This result reveals that college students with overseas experience had the opportunity to implement their global mobility intentions 1.064 times as often as those without overseas experience.

6.5. Results of the t-Test Analysis

The questionnaire administered in this study can determine the factors of global mobility that the students employed. The independent sample t test was used to analyze the differences between the respondents from Taiwan and China. The t-test results showed that there was significance in "Communication" ($t = -2.93$, $p = 0.003 < 0.01$), "Knowledge and Skills" ($t = -2.38$, $p = 0.017 < 0.05$), "Intention" ($t = -3.12$, $p = 0.002 < 0.01$), and "Implementing" ($t = -3.49$, $p = 0.000 < 0.001$) of the two groups, showing that significant difference was found between Taiwan and China for these four domains. In addition, there was no significance for "Cultural awareness" ($t = -1.44$, $p = 0.151 > 0.05$) of the two groups (shown as Table 9), showing that significant difference was not found between Taiwan and China in this domain.

Table 9. Summary of an independent sample t test on global mobility across China and Taiwan.

Domains	Area	N	Mean	S.D.	t-Value	p
Communication	Taiwan	1188	5.92	1.29	−2.93 **	0.003
	China	1038	6.06	0.83		
Cultural awareness	Taiwan	1188	5.85	1.11	−1.44	0.151
	China	1038	5.91	0.82		
Knowledge & Skills	Taiwan	1188	5.36	1.25	−2.38 *	0.017
	China	1038	5.48	0.95		
Intention	Taiwan	1188	4.18	1.34	−3.12 **	0.002
	China	1038	4.36	1.33		
Implementing	Taiwan	1188	4.77	1.03	−3.49 ***	0.000
	China	1038	4.92	0.91		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

6.6. Results of Multi-Group Invariance Analysis

Given that the structural equation models were replicable in each individual sample, we conducted a series multi-group structural equation model to identify any variation in the measurement parameters and pattern of structural relationships among the constructs in the proposed model across Taiwan and China. The results showed that this model demonstrated good fit with the data according to the multiple criteria adopted, $p < 0.001$, RMSEA > 0.60, NFI > 0.90, IFI > 0.91, GFI > 0.89, AGFI > 0.85, CFI > 0.91, ECVI > 0.82 (shown in Table 10). We subsequently estimated nested models that constrained the factor loadings to be invariant across the two groups. Table 11 shows that assuming model Unconstrained to be correct, the invariance across two groups for model Measurement weights was significant ($p < 0.001$); assuming model Measurement weights to be correct, the invariance across two groups for model Structural weights was significant ($p < 0.05$); assuming model Structural weights to be correct, the invariance across two groups for model Structural covariances was significant ($p < 0.001$); assuming model Structural covariances to be correct, the invariance across two groups for model Structural residuals was significant ($p < 0.05$); and assuming model Structural residuals to be correct, the invariance across two groups for model Measurement residuals was significant ($p < 0.001$). The results revealed that the model provided little support for the generalizability of the standardized measures of the constructs used here.

Table 10. Summary of model fit for two-group structural equation models.

	x^2	df	*p*	RMSEA	NFI	IFI	GFI	AGFI	CFI	ECVI
Unconstrained	1666.0 ***	160	0.000	0.065	0.921	0.928	0.904	0.856	0.928	0.821
Measurement weights	1769.1 ***	170	0.000	0.065	0.916	0.924	0.898	0.856	0.924	0.858
Structural weights	1786.2 ***	177	0.000	0.064	0.916	0.923	0.897	0.860	0.923	0.860
Structural covariances	2026.7 ***	183	0.000	0.067	0.904	0.912	0.886	0.851	0.912	0.963
Structural residuals	2033.8 ***	185	0.000	0.067	0.904	0.912	0.886	0.852	0.912	0.964
Measurement residuals	2151.6 ***	200	0.000	0.066	0.898	0.907	0.881	0.857	0.907	1.003

*** $p < 0.001$.

Table 11. Nested model comparisons for two-group structural equation models.

Model Comparison	x^2	df	*p*	NFI Delta-1	IFI Delta-2	RFI rho-1	TLI rho2
Measurement weights	103.143 ***	10	0.000	0.005	0.005	0.000	0.000
Structural weights	17.071 *	7	0.017	0.001	0.001	−0.003	−0.003
Structural covariances	240.514 ***	6	0.000	0.011	0.011	0.010	0.010
Structural residuals	7.084 *	2	0.029	0.000	0.000	−0.001	−0.001
Measurement residuals	117.777 ***	15	0.000	0.006	0.006	−0.002	−0.002

* $p < 0.05$, *** $p < 0.001$.

7. Discussion

Ever since internationalization has become mainstreamed at institutions of higher education, support for international activities has increased [1]. Near the beginning of this paper, we raised the question: What kind of indicators can be used to interpret the capabilities of global mobility? Previous literature provides various perspectives on global mobility capabilities, but there are few empirical findings especially pertaining to student perspectives on the issue [10,13,32,35,36]. In this study, we selected 15 indicators of global mobility to address the issue from a student perspective. The results of the EFA suggest that communication ability, cultural awareness, and knowledge and skills can be used to construct a reasonable framework of mobile capabilities with fitted validity and reliability. Furthermore, SEM demonstrates that these capabilities transfer to implementation by way of student intention under the pressure of the global pandemic.

This study further explored the extent to which college students implement their global mobility intentions. Because the target group in this study did not comprise students in OECD countries, the results provide a valuable window on the global mobility intentions and implementation activities of the largest segment of students worldwide who take part in global mobility programs. In this study, H1 (Communication ability positively affects intentions toward global mobility) had a negative coefficient in the SEM model, indicating that foreign language skills are negatively correlated with global mobility intentions. This might be explained by the perceived lack of need to study abroad among students who are proficient in a foreign language. Moreover, the global ambitions of universities are resulting in continued qualitative and quantitative growth of English-taught programs in Asia and Europe [47]. This phenomenon is also reflected in the Chinese higher educational setting, where many students are proficient in English. This study suggests that these students have a reduced intention to engage in global mobility. Similarly, H4 (cultural awareness positively affects the implementation of global mobility) had a negative coefficient in the SEM model. Again, when cultural awareness is not perceived as a problem for students, the implementation of global mobility is likely to be seen as unnecessary. H2 (communication ability positively affects the implementation of global mobility) and H6 (knowledge and skills positively affects the implementation of global mobility) were not supported in this study, although the influences of both "Communication" and "Knowledge and Skills" on "Implementing" were supported through the category of "Intention." Thus, intention is shown to be the crucial factor determining whether or not students will participate in a global mobility program.

What do the findings suggest with regard to global mobility research, including the impact of internationalization on knowledge and skills, and the opportunities for global mobility implementation? The results of the logistics regression indicate that students with overseas experience agreed with the importance of cultural awareness 1.057 times more often than those without this experience. The difference in knowledge and skills between students with overseas experience and those without this experience was less. Since these results are based on the perceptions of the participants, they might reflect China's ambition in global competition and soft power maneuvering and, more specifically, its present approach of using "outward-oriented" higher education internationalization strategies for status and image. Students who participate in higher education collaboration, such as the Confucius Institute program, international development aid in higher education, and international student recruitment [67], may view their knowledge and skills as comparatively high. This could negatively affect their interest in studying abroad.

The invariance of global mobility across Taiwan and China was examined by adopting a rigorous, hypothesis-testing approach using structural equation modeling to explore whether standardized measures put forward by the instrument we developed are generalizable across the two groups, and whether the pattern of influence of the hypothesized relationships among the constructs is consistent across these two areas. The result revealed that there were some variations; these were largely unsubstantial and did not compromise the model fit in the model comparisons, supporting the hypothesis of invariance. The findings provide evidence that the global mobility of 15 indicators and the five domains were not equivalent across Taiwan and China. However, Hagger et al. [68] suggested that evaluation and diagnostic instruments that provide equivalent measurement across areas or national cultures are particularly valuable to researchers who seek to develop an instrument with generalizability across samples from different cultural backgrounds. Due to the fact that the metric invariance requirement is usually difficult to satisfy, some researchers [69,70] have proposed that if the non-invariant items constitute only a small portion of the model, then cross-group comparisons can still be made because the non-invariant items will not affect the comparisons to any meaningful degree.

8. Conclusions

This study, which examined global mobility capabilities among college students in China, was based on student self-evaluations. The results indicate that intention of global mobility is the key factor determining global mobility implementation under the pressure of the pandemic. The study employed a rigorous procedure to develop and validate the proposed student mobility model; nevertheless, it has two main limitations that might be addressed in future research. First, the findings were based on survey results from a limited area within China. A random-stratified sampling technique was not adopted, which may impose limits on the generalizability of the results. Future research might examine other areas or other countries to establish the robustness of the current results. Second, the use of self-reported data to investigate research elements introduces the risk of common method bias, including the difficulty of interpretation without additional contextual information. Future research should include both objective and subjective measurements and consider their correlations. In conclusion, this study contributes to the literature and our understanding of college student's perspectives on global mobility. Global mobility in higher education is an important issue, especially when the educational settings worldwide are challenged by the COVID-19 pandemic.

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education sciences

Article

E-Learning Critical Success Factors during the COVID-19 Pandemic: A Comprehensive Analysis of E-Learning Managerial Perspectives

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Abstract: During the COVID-19 pandemic, educational institutions were shut down all over the world, which impacted over 60% of students and caused a massive disruption of the education system. The goal of this paper was to identify the critical success factors for E-learning during COVID-19 using the multi-criteria Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) techniques to enhance the educational process. Data were generated by interviewing 69 E-learning managers in educational institutions during COVID-19 based on defined evaluation criteria and E-learning approaches through several channels. We found that technology management, support from management, increased student awareness to use E-learning systems, and demanding a high level of information technology from instructors, students, and universities were the most influential factors for E-learning during COVID-19. Among the five learning systems, blended learning was the most suitable learning system to practice. These results demonstrated that, regardless of how extraordinary the technology is in an educational institution, the readiness of E-learning execution played a large role in boosting the educational process during the COVID-19 pandemic.

Keywords: e-learning; critical success factors; distance learning; COVID-19/Coronavirus pandemic; AHP-TOPSIS

1. Introduction

Prior to the COVID-19 pandemic, E-learning was growing approximately 15.4% yearly in educational institutions around the world without uncertainties or pressure on those institutions or on students [1]. However, as this research was conducted during COVID-19, the situation has changed dramatically. Educational institutions began providing most of their services online, including lecturers and different assessments via several platforms for over 60% of students around the world due to global restriction measures to minimize the spread of COVID-19 [2]. Referring to the data released by the World Health Organization (WHO), COVID-19 has been reported in over 216 countries, and there are areas with millions of confirmed cases [3]. Many countries have taken precautionary measures, including lockdowns of schools and universities, and switching to full E-learning mode during the spread of the Coronavirus, to avoid future expected waves [4]. This action was in response to social distance rules, which were strongly recommended by the WHO to prevent the spread of COVID-19 [5]. This lockdown began in the middle of the spring semester, which was unplanned for both instructors and students.

However, many studies have previously examined the critical success factors (CSFs) in the education sector from both the instructor's and students' perspectives for future improvement in the E-learning system. Organizations can determine the most valuable CSFs that should be achieved in order to boost a project mission. Thus far, these studies examined the CSFs of E-learning during typical times. Yet, the CSFs during the COVID-19 pandemic are expected to be different than the CSFs during typical times for many reasons. Firstly, during COVID-19, the switch to E-learning was for all educational institutions, which was unplanned. Not all institutions had the ability to switch smoothly as not all of them were previously implementing E-learning, unlike institutions that already offered E-leaning and were planning for and investing in the E-learning process. Secondly, during COVID-19, many factors other than educational ones, such as political and health factors, influence the process, which makes it an abnormal situation. For example, during typical times, students may visit the library, attend tutoring sessions, and even go to places with a good internet connection speed if they do not have a good internet connection at home, unlike during COVID-19 where students were in curfew situations. Thirdly, the course material of the classes that were taught through E-learning pre-COVID-19 were well-prepared, unlike during COVID-19 where courses were not planned to be taught through E-leaning.

The list could continue, not only for the CSFs but also for E-learning system approaches. These are just some of the main differences worth evaluating during the pandemic. In this paper, we discuss the essential success factors from the perspective of E-learning managers in various educational institutions using multi-criteria decision-making methods to ensure the continuity of educational objectives and students' prosperity in their education while fulfilling the World Health Organization (WHO) social distancing recommendations. This provides the perspective of E-learning managers, which allows us to understand the best practices during uncertain crises that could force educational institutions to switch to E-learning. This can help policy makers in educational institutions to better execute the educational process during a crisis through improving the most critical factors to prepare for.

2. Literature Review

2.1. E-learning

E-education, distance-learning, and online learning are all different terminologies of E-learning. The authors in [6] defined E-learning as "the wide set of applications and processes which use available electronic media and tools to deliver vocational education and training". Researchers [7] stated that E-learning is "the use of various technological tools that are web-based, web distributed, or web capable for education". E-learning has been growing year after year as there are many advantages, such as flexibility, internet accessibility, and cost-effectiveness [8]. These advantages could transform education into a lifelong learning process. According to [9], having access to lectures anytime, as many times as needed, allows students to better recall the information that is required for traditional education.

The flexibility of E-learning is a solution for people's commitments to their family or work, which may increase the number of people who enroll in this type of education. In fact, this goes beyond the learners; it gives flexibility also for the instructors. In addition, educational institutions are implementing E-learning technologies to improve the communication among learners and instructors for better knowledge exchange as well as to strengthen the learning community to accomplish personal objectives [10].

In 2005, the Kingdom of Saudi Arabia established the National Center of E-learning and Distance Learning (NCEDL), in which at least nine universities were involved [11]. This central role was aimed at enhancing the experience of E-learning in educational institutions by adapting and implementing the most effective practices of the E-learning system globally [12]. According to the National Center of E-learning and Distance Learning, the NCEDL has been involved in several E-learning system projects, such as the Learning Portal, which helps students to access the online learning material remotely as well as train teachers in the use of E-learning tools. Furthermore, the center has created an Award for Excellence of E-learning to encourage educational institutions to utilize E-learning, which involves around 42 institutions.

In 2011, the government of Saudi Arabia established the Saudi Electronic University (SEU), with tens of thousands of students enrolled in its different programs, including undergraduate and graduate studies. Since the occurrence of these events, King Abdulaziz University implemented many technological tools in order to enhance their practice in the E-learning system, such as the Learning Management System (LMS), which supports fresh and junior students by providing access to over 16,000 e-books as well as other academic resources online [12]. All these efforts for E-learning impacted the education transformation from on-campus to distance learning during the COVID-19 pandemic, which happened suddenly without enough time to plan.

2.2. TOPSIS and E-learning

In 1981, Hwang and Yoon developed the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method [13]. This method is commonly known for the Multiple Criteria Decision-Making practice to determine the best alternative among a set of alternatives [14]. This method essentially determines the distance of both the positive and the negative alternatives of the ideal solution [15]. The TOPSIS technique is widely used in many industries, including education; specifically, E-learning is becoming more popular and is growing over time.

For instance, researchers in [16] evaluated the criteria of five different approaches of E-learning, where each approach's performance was rated and computed using the TOPSIS method. They concluded that the Flipped Classroom, a student-centered approach with online material provided to student's prior to classes, was suggested as the most convenient E-learning approach, whereas 'strategic readiness for E-learning implementation' was ranked as essential criteria. Additionally, in [17], the authors evaluated and selected the learning objectives of e-content and educational material in web-based learning systems. They combined both the Analytic Hierarchy Process (AHP) and TOPSIS methods to ease the selection process. They suggested that the learning outcomes metadata is an effective procedure to produce e-content.

Eight criteria were evaluated using the Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) and the TOPSIS method to examine the E-learning readiness as well as to weight the criteria based on Simple Additive Weighting (SAW) and AHP to determine the weaknesses and improve the implementation of E-learning [18]. Indeed, TOPSIS has been commonly used to evaluate different criteria and factors in E-learning as well as different educational system approaches. Therefore, conducting this technique will help to find the most CSFs for E-learning during COVID-19.

2.3. Analytic Hierarchy Process (AHP) and E-learning

In 1980, Saaty [19] developed the Analytic Hierarchy Process (AHP). This is an effective decision-making process where quantitative and qualitative features are considered [16]. When the decision relies on several criteria, the AHP method is one of the most effective techniques to use [16]. Although the method has been criticized over its process, almost all fields, including resource allocation, management, and education, have used this technique for making important and responsible strategic decisions [20]. For example, Dweiri [20] researchers investigated and prioritized the critical factors of violations of academic integrity in Saudi Arabia within educational institutions. They stated that twelve essential factors of E-learning were prioritized using an analytic hierarchy process. They concluded that the most critical factor was the inappropriate guidelines provided to students, whereas a shortage of feedback was the least critical factor amongst all factors.

In [21], the authors evaluated the CSFs of E-learning from both the instructor and student perspectives at Sebelas Maret University. They stated that they used AHP and fuzzy techniques to determine the ranking of the CSFs from both perspectives. They concluded that the five CSFs from the instructor's point of view were fiscal policy, regulatory policy, course quality, relevant content, and technical support. Whereas course quality, relevant content, completeness of the content, attitudes toward students, and flexibility in taking courses were the five critical success factors from the students' perspective. However, the focus in this paper was on E-learning during the COVID-19 pandemic, which is an abnormal situation. Thus, we implemented the AHP method in order to calculate the weight of the different criteria.

2.4. Critical Success Factors and Type of E-Learning System

The critical success factors are referred to as ”characteristics, conditions, or variables that, when properly sustained, maintained, or managed, can have a significant impact on the success of a firm competing in a particular industry” [22]. By finding the CSFs, stakeholders can boost these factors for better outcomes. The types of E-learning systems are identified in Table 1, to determine the most appropriate type of system associated with AHP and the TOPSIS technique during COVID-19. The factors that were evaluated in this paper are identified and defined in Table 2. Figure 1 summarizes the critical success factor hierarchy problem discussed in this paper based on the multiple-criteria decision analysis problem representation. Those criteria and alternatives were identified from previous studies on E-leaning and were categorized to represent the majority of the criteria that were evaluated in other studies under different conditions.

Table 1. E-Learning system definition and prior research.

Type of E-Learning System	Prior Research	Definition
Blended Learning	[4,16,23]	Mix of traditional and online classes
Flipped Classroom	[16,23,24]	Student-centered approach with online material provided to students prior to classes
ICT Supported Face-to-Face Learning	[25–27]	Traditional learning supported by information and communication technology.
Synchronous Learning	[16,24,28]	A real-time interaction distance learning
Asynchronous Learning	[16,24,28]	Non-real time interaction distance learning

Table 2. E-Learning criteria, definition, and prior research.

Factors	Prior Research	Definition
Student Characteristics	[25,29–31]	This factor focuses on the student’s environment while learning. It includes the student’s pace of learning, commitment, attitude, motivation, knowledge of computer systems, and demographics.
Instructor Characteristics	[8,25,29–31]	This factor focuses on the instructor’s environments while teaching. It includes the instructor’s attitude, flexibility, knowledge of learning technology, teaching style, and efficacy in student motivation.
Learning Environment	[8,25,29,31]	This factor focuses on the learning environment and facilities that are provided for both students and instructors. It includes a learning management system, technical infrastructure, interactive learning, and access and navigation.
Instructional Design	[8,25,29,30]	This factor focuses on the instructional system to meet the objectives of the institution. It includes the content quality, objective clarity, learning strategies, and learning psychology.
Support	[8,25,29–31]	This factor focuses on supporting both the instructors and students to enhance their experience. It includes communication tools, help disk availability, and training.
Information Technology	[21,25,26,29,30,32]	This factor focuses on the information technology system to deliver learning materials and objectives. It includes ease of use, reliability, efficiency, privacy, and information.

Table 2. *Cont.*

Factors	Prior Research	Definition
Technology Knowledge	[8,25,29–31]	This factor focuses on the knowledge of using technology for both instructors and students. It includes the use of computers, the use of software, and communication interaction.
Course	[8,20,21,25,29,31]	This factor focuses on the course material and objectives. It includes course evaluation, assessments, content development, and learning evaluations.
Level of Collaboration	[8,21,30,31]	This factor focuses on the collaboration level between faculty members. It includes the lack of social interaction, project team supervision, and managerial support.
Knowledge Management	[8,21,30,31]	This factor focuses on the management knowledge within the educational institution for faculty members and administration. It includes the management team, managing delivery and maintenance, time management, thinking strategies, and implementation expertise.

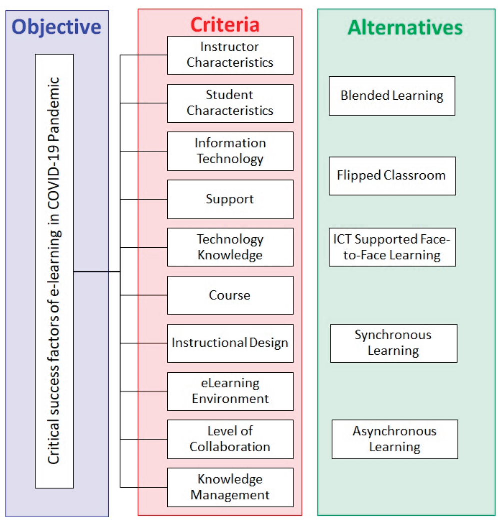

Figure 1. Critical success factors problem hierarchy.

3. Materials and Methods

The methodology in this research consists of three parts; a survey, the AHP method, and the TOPSIS method. Further details will be provided in the next subsections.

3.1. Data Collection

Firstly, the research team visited 69 educational institutions and planned several meetings with the distance learning managers to create an appropriate picture of the problem. Table 3 summarizes the E-learning management staff demographic data in terms of age, gender, nationality, academic degree, and job title. This shows that most participants (90%) had a PhD, and that, with respect to job title, the biggest group were Associate Professors (45%). Furthermore, the majority were Saudi nationals (71%). The managers evaluated the criteria associated with each E-learning system. During the first meeting, the discussion of the decision criteria were as follows: Instructor Characteristics, Student Characteristics, Information Technology, Support, Technology Knowledge, Course, Instructional

Design, E-Learning Environment, Level of Collaboration, and Knowledge Management. The decision alternatives were as follows: Blended Learning, Flipped Classroom, Information and Communication Technology (ICT) Supported, Face-to-Face Learning, Synchronous Learning, and Asynchronous Learning. The managers of E-learning rated each criterion associated with each e-learning system toward the CSFs of E-learning in the COVID-19 pandemic, as shown in Table 4.

Table 3. E-Learning management staff demographic data.

		Frequency	Percentage
Age	30–39 Years	17	25%
	40–49 Years	24	35%
	50–59 Years	28	41%
Gender	Male	57	83%
	Female	12	17%
Nationality	Saudi	49	71%
	Non-Saudi	20	29%
Academic Degree	Master's Degree	7	10%
	PhD	62	90%
Job Title	Lecturer	7	10%
	Assistant Professor	19	28%
	Associate Professor	31	45%
	Professor	12	17%
Discipline	Education	7	10%
	Science	9	13%
	Arts	4	6%
	Business	22	32%
	Medicine	2	3%
	Engineering	19	28%
	Political Science	6	9%

Table 4. E-Learning approaches and evaluation criteria.

No.	Alternatives	No.	Criteria
1	Blended Learning	1	Instructor Characteristics
2	Flipped Classroom	2	Student Characteristics
3	ICT Supported Face-to-Face Learning	3	Information Technology
4	Synchronous Learning	4	Support
5	Asynchronous Learning	5	Technology Knowledge
		6	Course
		7	Instructional Design
		8	E-Learning Environment
		9	Level of Collaboration
		10	Knowledge Management

3.2. The Analytic Hierarchy Process (AHP)

To apply the AHP method, the following steps were performed based on [19,33]

Step 1: Weight each criterion and decision alternatives. The ratings are given in Table 5.

For instant, if the E-learning managers determined that, in the E-learning process and based on the criteria and the rankings shown in Table 5, the Instructor Characteristics were very strongly preferable to the Student Characteristics (in other words, the E-learning Instructor Characteristics had a greater influence on the learning process compared with the Students Characteristics), they will give rank 7 to the Instructor Characteristics in the pair-wise comparison matrix when comparing the Instructor Characteristics versus Students Characteristics. On the other hand, the intermediate ratings (2, 4, 6, and 8) were also used. The reciprocal ratings (1/9, 1/8, etc.) were used in cases where a second alternative was chosen over the first, assigning a rating in the case of comparing an alternate with itself, as shown in Table 6. For example, Student Characteristics pair-wise compared to Instructor Characteristics at 1/7, which indicates that the Student Characteristics were seven times more preferable to Instructor Characteristics from the managerial perspective.

Step 2: Develop the pair-wise comparison matrix and rate the relative importance among every pair of decision alternatives, as shown in Table 6. The alternatives are listed in the matrix horizontally (first alternative) and vertically (second alternative) as associated with the numerical ratings.

Step 3: Set up the normalized matrix by dividing all numbers in the pair-wise comparison matrix column by the sum of its column, as shown in Table 7.

Step 4: Determine the average priority vector for all the rows in the normalized matrix. Then use these averages to create the priority vector of all alternative preferences associated with the criterion where the sum of this vector is 1, as shown in Table 8.

Step 5: Calculate the consistency ratio and use it to measure the subjective input. A ratio of less than 0.1 was considered good. For the ratios greater than 0.1, the subjective input was considered for re-evaluation.

Step 6: Develop the priority matrix to obtain the priority vectors for each criterion using the results of Step 4.

Step 7: Develop the criterion pair-wise development matrix following the one used to create the alternative pair-wise comparison matrices utilizing the ratings of Step 2, normalize the matrix following Step 3, and develop the priority vector criterion in Step 4.

Step 8: Develop the overall priority vector through multiplying the criteria priority vector in Step 7 with the priority matrix in Step 6.

Microsoft Excel was used to perform all these steps.

Table 5. Analytic Hierarchy Process (AHP) ratings.

Linguistic Rating	Numerical Rating
Extremely preferred	9
Very strongly preferred	7
Strongly preferred	5
Moderately preferred	3
Equally preferred	1

Table 6. Pair-wise comparison matrix.

	Instructor Characteristics	Student Characteristics	Information Technology	Support	Technology Knowledge	Course	Instructional Design	E-Learning Environment	Level of Collabor-Ation	Knowledge Management
Instructor Characteristics	1	1/7	1/7	1/9	1/8	5	1/5	1/3	1/3	1/9
Student Characteristics	7	1	1	1/3	5	5	3	5	3	1/7
Information Technology	7	1	1	1/5	3	5	3	7	3	1/7
Support	9	1/3	5	1	7	7	5	5	3	1/5
Technology Knowledge	8	1/5	1/3	1/7	1	5	1	3	3	1/7
Course	1/5	1/5	1/5	1/7	1/5	1	1/5	3	1/3	1/9
Instructional Design	5	1/3	1/3	1/5	1	5	1	7	3	1/5
E-Learning Environment	3	1/5	1/7	1/5	1/3	1/3	1/7	1	1/5	1/7
Level of Collaboration	3	1/3	1/3	1/3	1/3	3	1/3	5	1	1/5
Knowledge Management	9	7	7	5	7	9	5	7	5	1
Sum	52	11	15	8	25	45	19	43	22	2

Table 7. Normalized matrix.

	Instructor Characteristics	Student Characteristics	Information Technology	Support	Technology Knowledge	Course	Instructional Design	E-Learning Environment	Level of Collaboration
Instructor Characteristics	0.02	0.01	0.01	0.01	0.01	0.11	0.01	0.01	0.02
Student Characteristics	0.13	0.09	0.06	0.04	0.2	0.11	0.16	0.12	0.14
Information Technology	0.13	0.09	0.06	0.03	0.12	0.11	0.16	0.16	0.14
Support	0.17	0.03	0.32	0.13	0.28	0.15	0.26	0.12	0.14
Technology Knowledge	0.15	0.02	0.02	0.02	0.04	0.11	0.05	0.07	0.14
Course	0	0.02	0.01	0.02	0.01	0.02	0.01	0.07	0.02
Instructional Design	0.1	0.03	0.02	0.03	0.04	0.11	0.05	0.16	0.14
E-Learning Environment	0.06	0.02	0.01	0.03	0.01	0.01	0.01	0.02	0.01
Level of Collaboration	0.06	0.03	0.02	0.04	0.01	0.07	0.02	0.12	0.05
Knowledge Management	0.17	0.65	0.45	0.65	0.28	0.2	0.26	0.16	0.23
Sum	1	1	1	1	1	1	1	1	1

Table 8. Priority vectors.

Instructor Characteristics	Student Characteristics	Information Technology	Support	Technology Knowledge	Course	Instructional Design	E-Learning Environment	Level of Collaboration	Knowledge Management
0.025143	0.111681	0.106554	0.169233	0.068143	0.022556	0.076001	0.023157	0.049536	0.347996

3.3. The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

To apply the TOPSIS method, the following steps were performed, based on [32,34]

Step 1: Form the matrix expressed as follows:

$$D = \begin{bmatrix} A_1 & X_1 & X_2 & \cdots & \cdots & X_n \\ A_2 & X_{11} & X_{12} & \cdots & \cdots & X_{1n} \\ A_3 & X_{21} & X_{22} & \cdots & \cdots & X_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ A_m & X_{m1} & X_{m2} & \cdots & \cdots & X_{mn} \end{bmatrix} \quad (1)$$

where:

Ai = ith alternative project and Xij = the numerical outcome of the ith alternative project with respect to the jth criterion.

Table 9 shows the structure of the TOPSIS matrix.

Step 2: Normalize the decision matrix (D) by applying the following formula:

$$r_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{n} {X_{ij}}^2}} \quad (2)$$

Table 10 shows the TOPSIS normalize matrix.

Step 3: Construct the weighted normalized decision matrix that is shown in Table 11 by multiplying the normalized decision matrix by its relative weights. The following formula is used to calculate the weighted normalized value vij:

$$V_{ij} = W_{ij} R_{ij} \quad (3)$$

Step 4: Define both the positive and negative ideal solutions:

$$A^* = \left\{ \left(max\ v_{ij} \middle| jieJ \right), \left(min\ v_{ij} \middle| jieJ' \right) \right\} \forall\ J = 1,\ 2,\ 3,\ \ldots,\ n \quad (4)$$

$$A^- = \left\{ \left(min\ v_{ij} \middle| jieJ \right), \left(max\ v_{ij} \middle| jieJ' \right) \right\} \forall\ J' = 1,\ 2,\ 3,\ \ldots,\ n \quad (5)$$

where:

J is associated with the benefit criteria and J' is associated with the cost criteria.

Table 12 shows the TOPSIS positive and negative ideal solutions.

Step 5: Calculate the separation of all alternatives from the positive ideal as follows:

$$S_i^* = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V_j^* \right)^2} \ \forall\ \mathrm{i} = 1, 2, \ldots, \mathrm{m} \quad (6)$$

Step 6: Calculate the relative distance of Ai with respect to A^*, the ideal solution, which is defined as:

$$C_i^* = \frac{S_i^-}{(S_i^* + S_i^-)},\ 0 \le C^* \le 1\ \forall\ \mathrm{i} = 1, 2, \ldots, \mathrm{m} \quad (7)$$

where performance alternatives become better with larger values of Ci^*.

Step 7: Rank the order of preference.

All steps were performed using Microsoft Excel.

Table 9. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) matrix.

	Instructor Characteristics	Student Characteristics	Information Technology	Support	Technology Knowledge	Course	Instructional Design	E-Learning Environment	Level of Collaboration
Blended Learning	1.796	0.003	0.032	0.006	0.436	193.488	0.49	0.49	6.452
Flipped Classroom	2.103	0.017	0	0	0.194	112.148	0.04	4225	0.001
ICT Supported Face-to-Face Learning	0.823	0.004	0.125	1.328	0.16	2.465	0.686	0.656	23.329
Synchronous Learning	2.89	0.052	0.206	1.595	0.032	0.922	0.24	0.212	0.96
Asynchronous Learning	2.624	0	0.006	0.001	0.141	0.448	0.689	0.084	24.9
sum	10.235	0.076	0.37	2.931	0.962	309.47	2.145	4226.442	55.642
√(sum)	3.199	0.275	0.608	1.712	0.981	17.592	1.464	65.011	7.459

Table 10. Normalized matrix.

	Instructor Characteristics	Student Characteristics	Information Technology	Support	Technology Knowledge	Course	Instructional Design	E-Learning Environment	Level of Collaboration
Blended Learning	0.419	0.182	0.296	0.047	0.673	0.791	0.478	0.011	0.341
Flipped Classroom	0.453	0.473	0.033	0.006	0.449	0.602	0.137	1	0.004
ICT Supported Face-to-Face Learning	0.284	0.221	0.582	0.673	0.407	0.089	0.565	0.012	0.648
Synchronous Learning	0.531	−0.832	−0.747	−0.738	0.184	0.055	0.335	0.007	0.131
Asynchronous Learning	0.506	0.045	0.123	0.019	0.382	0.038	0.567	0.004	0.669
sum	2.193	0.088	0.288	0.007	2.095	1.575	2.081	1.035	1.792

Table 11. Weighted normalized decision matrix.

	Instructor Characteristics	Student Characteristics	Information Technology	Support	Technology Knowledge	Course	Instructional Design	E-Learning Environment	Level of Collaboration
Blended Learning	0.0105	0.0203	0.0315	0.0079	0.0459	0.0178	0.0363	0.0002	0.0169
Flipped Classroom	0.0114	0.0528	0.0035	0.001	0.0306	0.0136	0.0104	0.0232	0.0002
ICT Supported Face-to-Face Learning	0.0071	0.0247	0.062	0.1139	0.0278	0.002	0.043	0.0003	0.0321
Synchronous Learning	0.0134	−0.093	−0.0795	−0.1249	0.0125	0.0012	0.0254	0.0002	0.0065
Asynchronous Learning	0.0127	0.005	0.0131	0.0033	0.0261	0.0009	0.0431	0.0001	0.0331
A*	0.0134	0.0528	0.062	0.1139	0.0459	0.0178	0.0104	0.0001	0.0002
A-	0.0071	−0.093	−0.0795	−0.1249	0.0125	0.0009	0.0431	0.0232	0.0331

Table 12. Priority vector.

	Si*	Si-	Ci*	Rank
Blended Learning	0.1191	0.5108	0.8109	1
Flipped Classroom	0.3063	0.2859	0.4827	4
ICT Supported Face-to-Face Learning	0.2788	0.3586	0.5625	3
Synchronous Learning	0.562	0.0398	0.0662	5

4. Results and Discussion

The data were collected by interviewing 69 E-learning managers. The response rate for both the first and second rounds of interviews was 100%. Every factor's weight was calculated using AHP software and Microsoft Excel 2013. The inconsistency ratio was calculated to achieve consistent weights among all participants. Table 8 shows that Knowledge Management (0.347996), Support (0.169233), Student Characteristics (0.111681), and Information Technology (0.106554) were the most critical success factors that influenced the E-learning process during the COVID-19 pandemic.

The primary purpose of the TOPSIS technique is to discover the best alternative that should have the shortest distance, which is the Euclidean distance, from the ideal solution. The data for the E-learning system alternatives based on their criteria are provided in Table 9, which shows the calculation of the square root of the squared summation for the given criteria for each E-learning system. The value in every cell was divided by the root summation of the square value, which gives the normalized decision matrix, as shown in Table 10. Table 11 shows the weighted normalized decision matrix, along with the ideal best and the ideal worst values. Table 12 shows the Euclidean distance from the value of both the ideal best and worst along with the performance score for every alternative using the TOPSIS method.

The research team used Microsoft Excel 2013 software to analyze and employ both AHP and TOPSIS techniques. The demonstration of the steps and analysis was provided in Section 3. As the result of the analytic hierarchy process for the E-learning critical success factors during the COVID-19 pandemic, Table 12 shows that Blended Learning appeared to be the best decision alternative for educational institutions to consider when selecting an E-learning system during the COVID-19 pandemic, with a total weight of 0.811. This was followed by Asynchronous Learning, which was considered to be the second-best alternative, with a total weight of 0.564, and then by the ICT Supported Face-to-Face Learning with a total weight of 0.563. This was then followed by the Flipped Classroom with a total weight of 0.483 and, finally, Synchronous Learning with a total weight of 0.066.

The findings revealed that the course type and contents did not have such a great impact on learning outcomes as previous studies showed, because it is a managerial perspective and all the courses are quoted with the same weight/importance [35]. A focus on providing the users (students and instructors) with more training in knowledge management would be wise [36]. Educational institutional support is very important in the success of E-learning. This is compatible with [37], which stated that providing computer and training support to students positively impacted the students' use of the learning system. Our study found that student characteristics played a large role in educational systems during COVID-19.

The findings also indicated that students must understand their role during the social distancing measures, build their own attitude and commitment, and find ways to self-motivate in order to gain successful learning outcomes. The findings for student characteristics are consistent with a study from [26,38].

The primary objective of this paper was to identify and prioritize the critical success factors of E-learning system adoption during the COVID-19 pandemic. We employed AHP and TOPSIS, and this study may assist educational institutions in gaining a better understanding of the critical success factors for E-learning adoption during the COVID-19 pandemic. Focusing on crises, such as the COVID-19 pandemic, the current study is relevant as no previous research has discussed issues where the entire educational system worldwide was affected with many interruptions. Many educational institutions shifted from in-class education toward E-learning. E-learning system adoption is not an easy process, nor can one system fit all different types of disciplines and institutions around the globe. This research tackles the different possible systems and their critical attainment factors.

5. Limitations

This research tackled the different possible systems and their critical attainment factors. There are many studies regarding general education and E-learning; however, there was a lack of literature that included the effect of pandemics that would reflect the same situation that the world is facing during COVID-19. One of the drawbacks of the multi-criteria decision analysis tools is that they are very sensitive to the perspective the study is focused on. Therefore, the same applied tools would provide different results and findings based on whether the issue was tackled from the student perspective or the instructor perspective. Finally, this study took place in Saudi Arabia, and might not apply to other countries due to differences in perspective and regulations.

6. Conclusions

The educational process worldwide has been interrupted due to the COVID-19 pandemic. E-learning is becoming much more necessary, and is very important in education. Educational institutions during COVID-19 face the unique challenges of smoothly maintaining the process of learning while ensuring that it is still beneficial. Therefore, these institutions must understand what drives instructors and learners toward the E-learning system. The main focus of this study was to classify and prioritize E-learning systems during the COVID-19 pandemic as well as to recognize practical implications.

This study prioritized different systems of E-learning using multi-criteria approaches. We discovered that the most significant factors influencing E-learning success during the COVID-19 pandemic were related to technology knowledge management, support from management, increased student awareness of utilizing E-learning systems, and demanding a high level of information technology from the instructors, students, and universities. This finding should be seriously considered as no matter how great the technology is, readiness for E-learning implementation still plays the leading role in improving the educational process. Blended Learning was the most preferred E-learning system out of the five methods discussed in this study. The results of this study provide useful information to the E-learning managers of universities in their process of implementing modern technologies in education.

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education sciences

Article

Tutorials for Integrating 3D Printing in Engineering Curricula

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Abstract: Three-dimensional (3D) printing can revolutionize the way products have been designed and manufactured. This necessitates engineering graduates equipped with the knowledge and skills of 3D printing. As a result, the educational aspects of 3D printing have earned a great deal of attention. Nevertheless, to teach 3D printing in an undergraduate engineering degree program, an outcomes-oriented approach integrating engineering design, object visualization/digitization, and 3D printing domains can be used. Accordingly, this study presents a tutorial development method to teach undergraduate engineering students the knowledge and skills of 3D printing. The method integrates the abovementioned domains maintaining a hierarchy among the seven ABET-prescribed outcomes. The hierarchy organizes the outcomes into three levels (primary, secondary, and tertiary). The presented method is implemented by introducing a tutorial where a spur gear-pinion pair is designed, visualized, digitized, and 3D printed systematically. E-learning tools can be developed to deliver the tutorial online.

Keywords: 3D printing; CAD/CAM; engineering education; tutorial; educational outcomes

1. Introduction

Additive manufacturing (AM) [1–3], popularly known as three-dimensional (3D) printing [4,5], has the potential to revolutionize the way products have been designed and manufactured. 3D printing adds materials layer by layer to fabricate an object, unlike subtractive manufacturing (e.g., Computer Numerical Control (CNC) machining) or formative manufacturing (e.g., casting). The material addition processes are classified as binder jetting, directed energy deposition, material extrusion, material jetting, powder bed fusion, sheet lamination, and vat photopolymerization [6]. The benefits of 3D printing are the freedom to design highly customized products, the realization of complex geometry, the fabrication of multi-material objects, and the rapid prototyping [1,7,8]. As a result, 3D printing has earned much attention from different sectors including the automotive industry [9], aerospace industry [10], biomedical industry [11], fashion industry [12–14], food industry [15], construction industry [16], and cultural heritage preservation [17,18]. This list grows.

A typical workflow of 3D printing is schematically illustrated in Figure 1. As shown in Figure 1, 3D printing is carried out by the following six steps [19]:

(1) Formulate a concept of the object to be fabricated.
(2) Convert the concept into a solid model (virtual model) using off-the-shelf Computer-Aided Design (CAD) packages or other means.
(3) Convert the solid CAD model into a triangulation model (known as STL dataset) that can be read by the relevant 3D printing system.

(4) Convert the STL dataset into a set of machine instructions (e.g., G-code) for the layer by layer movements of the printer head(s) for adding materials using the relevant 3D printing system.
(5) Export the machine instructions to a 3D printer and execute the printing process.
(6) Carry out finishing operations (e.g., removing support, polishing, painting, and the like) of the 3D printed object.

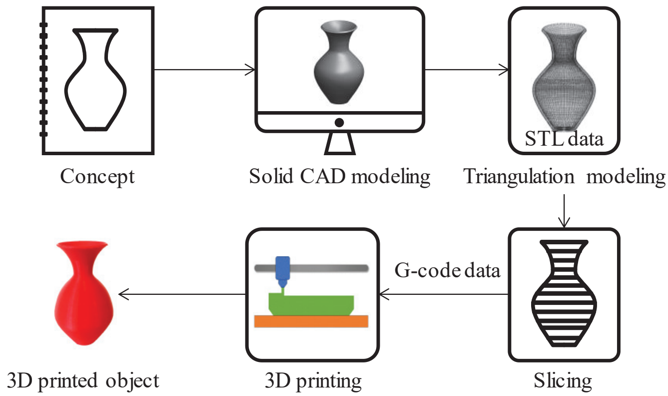

Figure 1. A typical workflow of 3D printing.

As mentioned before, 3D printing can revolutionize the way products have been designed and manufactured [1–18]. This necessitates individuals equipped with the knowledge and skills of 3D printing. Particularly, some engineering students must have the knowledge and skills to implement and improve the workflow regarding 3D printing, as shown in Figure 1. As a result, 3D printing has earned much attention from educators worldwide [20]. An account of the educational aspects of 3D printing is presented in Section 2, showing the educational opportunities and challenges of 3D printing in engineering and other fields (e.g., medicine). However, as far as the quality of engineering education is concerned, a set of prescribed outcomes must be considered while developing course contents, delivering them, assessing students, and reporting the quality of education [21]. (Section 3 deals with outcome-oriented educational activities.) As such, the educational activities of 3D printing must follow an outcome-oriented approach (see Section 3) as explicitly as possible for engineering students. At the same time, the approach must integrate engineering design domain, object visualization/digitization domain, and 3D printing domain. (These domains are described in Section 3). As a result, a tutorial that integrates the abovementioned domains with the aid of some predefined educational outcomes can seamlessly integrate 3D printing in engineering curricula. Accordingly, this article's objective is to develop an outcome-oriented approach that can educate students with the knowledge and skills of 3D printing, integrating engineering design, object visualization/digitization, and 3D printing domain. The structure of this article is as follows. Section 2 describes the relevant research work available in the literature regarding the educational aspects of 3D printing. Section 3 presents a method to develop outcomes-oriented tutorials for incorporating 3D printing in engineering curricula. Section 4 presents a case study showing one of the tutorials developed based on the proposed method. Section 5 concludes this article.

2. Related Work

As mentioned before, 3D printing has earned much attention from educators worldwide [20]. Many authors have reported 3D printing's contributions in education, including its effectiveness, advantages, limitations, and avenues for improvement [22]. For the sake of better understanding, this section briefly describes some of the related work as follows.

Many authors have studied the general aspects of 3D printing in education. For example, Chekurov et al. [23] reported 3D printing's effectiveness in enhancing engineering students' creativity. This numerical study also showed that the contents relevant to design for 3D printing help students enhance their creativity if the contents are offered in multiple years. Diriba et al. [24] studied the maturity timeline of 3D printing technology and elucidated its social, ethical, and legal challenges. In particular, the authors showed that 3D printing is useful in achieving "educate to innovate." Furthermore, the authors emphasized that higher education institutes should take the lead regarding the 3D printing-based collaborations using university–industry–government relationships. This necessitates 3D printing-related education at all levels. Despeisse and Minshall [25] used a literature review and evidence collected from workshops to identify the key educational themes by which the current skill gap and barriers in implementing 3D printing can be addressed.

Many authors have studied the educational aspects of 3D printing targeted at high school and undergraduate students and instructors. For example, Kirchheim et al. [26] described tutorials to teach 3D printing to undergraduate students and lifelong learners from product development and other relevant issues (e.g., quality control). They showed that knowledge and skills of realizing relatively complex parts using 3D printing enhance learners' open-ended problem-solving capability. Urbanic [27] presented some 3D-printing-based undergraduate design projects to impart the knowledge and skills of the real-life design process to the students. The author showed that the students could successfully fulfill the desired engineering requirements without using highly technical knowledge. Fidan et al. [28] reported the effectiveness of Additive Manufacturing Studios in engineering education. The target is the K-12 and community college teachers and students where several institutes and a larger number of instructors collaborate. Through the Additive Manufacturing Studios, the instructors grasp the meaning of student outcomes prescribed by ABET, in addition to the current trend of these technologies.

Many authors have studied the educational aspects of 3D printing in science, technology, engineering, and mathematics (STEM). For example, Ali and Khine [29] compiled twelve selected articles dealing with the current trends and theoretical and practical aspects of 3D printing in teaching and learning of STEM. For another example, consider the article by Alhamad et al. [30]. In this article, the authors reported that 3D printed objects (e.g., car, truck, aero-foils, and wings) help engage students more intensely in learning advanced engineering topics (e.g., fluid mechanics, mechanics of materials, and alike). Asiabanpour [31] showed the effectiveness of additive manufacturing in engineering education. The author designed a stand-alone additive manufacturing course and discussed various examples wherein AM had been utilized as a service and outreach tool to recruit K–16 students into STEM programs. Lin et al. [32] studied the effects of 3D printing on the development of high school students' knowledge structures toward the engineering design process. This quasi-empirical study showed that 3D printing, coupled with modeling principles, could help students elaborate on modeling and feasibility analysis concepts. Whether or not 3D printing can help when the students are exposed to multiple modeling tasks is still a research question [32].

Many authors have studied the educational aspects of 3D printing targeted at eLearning, CAD/CAM (CAM stands for Computer-Aided Manufacturing), and product development. For example, Loy [33] studied 3D printing to empower eLearning. The author showed examples of how the students integrated the virtual and real worlds from the context of eMarking. Galina and Na [34] showed that making 3D printing facilities available to a library space helps many students transform theory into a physical reality, and, thereby, learn the relevant subject matter more effectively. Other studies (e.g., [35]) also support similar findings. Verner and Merksamer [36] implemented the learning concept called conceive–design–implement–operate, integrating 3D printing facility with parametric CAD package and equation editor. As reported by the authors, a wide range of engineering students could enhance their engineering competencies through this 3D-printing-based learning approach. Liu and Jin [37] developed a detailed digital manufacturing course framework for senior aircraft manufacturing engineering undergraduates. According to this framework, 3D-printing-related content, along with traditional CAD–CAM–CAE (CAE stands for Computer-Aided Engineering)and digital-metrology-related content, must be incorporated to educate individuals who want to pursue a career in the aircraft manufacturing industry.

Medical students often learn about human structures and apply the relevant knowledge in clinical contexts throughout their study periods. They need to communicate what they have learned regarding human structures and clinical/surgical diagnosis to the stakeholders (their peers, educators, and patients). 3D printing nowadays plays a vital role in the abovementioned educational and learning aspects. Many authors have studied the implementation of 3D printing in medical education. For example, Ransikabum et al. [38] reported a feasibility study on the fabrication of a 3D medical model aiming to enhance medical students' learning. The study reported a six-step process of additive manufacturing that links additive manufacturing to medical imaging for understanding. This kind of education can be delivered effectively if 3D printing is integrated with medical education, as reported by many authors [39–44]. Apart from 3D printing's contributions to mainstream STEM and medical education, as mentioned above, it is equally beneficial to educating individuals with special needs [45].

3. Tutorial Development Method

This section presents a general method to develop tutorials for educating undergraduate engineering students with the knowledge and skills of 3D printing. Before introducing the method, some salient points are described below, which are complementary to the educational issues described in the previous section.

3.1. Outcome-Oriented Depth–Breadth-Based Engineering Education

The objective of engineering education is to produce "T-shaped" engineers equipped with a breadth of knowledge and depth of expertise [46]. Engineering design is one way to nurture the students' breadth of knowledge and depth of expertise. In engineering design courses, students apply the knowledge gained to design and build systems/devices; the designed systems/devices must meet the predefined standards and multiple constraints [47]. However, there are many proximal stakeholders in the ecosystem of engineering education: students, instructors, institutes, professional societies, employers, and accreditation bodies [46]. An outcome-oriented approach makes a curriculum transparent and accountable to the stakeholders [47,48], requiring some learning outcomes, as mentioned before. The set of outcomes has been evolving [47]. Currently, seven outcomes as listed in Table 1 are followed by ABET-accredited engineering programs [47,48].

Table 1. ABET Educational Outcomes for Undergraduate Engineering Programs [47,48].

Outcomes	Descriptions
1	Students can apply engineering, science, and mathematics knowledge to identify, formulate, and solve problems
2	Students can produce solutions executing the processes of engineering design to meet specified needs relevant to public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3	Students can communicate effectively with a wide range of audiences using oral, written, and digital means
4	Students can make informed judgment considering the impact of engineering solutions in global, economic, environmental, and societal contexts as a response to their ethical and professional responsibilities
5	Students can establish goals, plan tasks, and meet objectives being members of a collaborative and inclusive team with shared leadership
6	Students can develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to conclude
7	Students can acquire and apply new knowledge as needed, using appropriate learning strategies

The first outcome ensures that the students can apply engineering, science, and mathematics knowledge to identify, formulate, and solve problems. The second outcome ensures that the students can produce solutions executing the processes of engineering design to meet specified needs relevant to public health, safety, welfare, as well as global, cultural, social, environmental, and economic factors. The third outcome ensures that the students can communicate effectively with a wide range of audiences using oral, written, and digital means. The fourth outcome ensures that the students can make informed judgment considering the impact of engineering solutions in global, economic, environmental, and societal contexts as a response to their ethical and professional responsibilities. The fifth outcome ensures that the students can establish goals, plan tasks, and meet objectives being members of a collaborative and inclusive team with shared leadership. The sixth outcome ensures that the students can develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to conclude. The last outcome ensures that the students can acquire and apply new knowledge as needed, using appropriate learning strategies.

3.2. Method

Thus, how to uphold the abovementioned seven outcomes while educating students with engineering design is an important aspect of engineering education. In this respect, a 3D printer can play a vital role. Based on this consideration, a tutorial development method is proposed, as schematically illustrated in Figure 2. The proposed method integrates the abovementioned seven educational outcomes and the following three domains: (1) engineering domain, (2) object visualizing and digitization domain, and (3) 3D printing domain. The tasks performed in the engineering domain ensure that the object (to be) realized is modeled so that the results can be handled in the next domain. The tasks performed in the object visualizing and digitization domain help visualize the object for the sake of human understanding and digitize it for 3D printing. The tasks performed in the last domain ensure that the object is printed using an available 3D printer. In the proposed method, any set of outcomes out of the seven can be associated with the domain-specific tasks. This results in many different tutorials (Tutorial 1, . . . , Tutorial *i*, . . .), as schematically illustrated in Figure 2. This implies that in the tutorial domains an instructor chooses some of the outcomes while developing a tutorial. Moreover, there is a hierarchy that must be maintained among the outcomes and domains. This leads to a task–outcome hierarchy diagram. One of the possible hierarchies is shown in Figure 3. As seen in Figure 3, some of the outcomes are directly related to the task domains. These are defined as primary outcomes. Some of the outcomes are directly related to the primary outcomes. These are defined as secondary outcomes. Lastly, some of the outcomes are related to all task domains, as well as to the primary and secondary outcomes in a concurrent manner. These outcomes are defined as tertiary outcomes. On the other hand, in the task domains, there are six processes, denoted as A, B, C, D, E, and F. The processes A, C, and E are the outcomes of the activities associated with the engineering, object visualizing and digitization, and 3D printing domains, respectively. The processes B, D, and F are the outcomes of the activities that link the respective domains. The activities in processes B and F link the engineering domain to the other two domains, respectively, whereas process D links the object visualizing and digitization domain to the 3D printing domain.

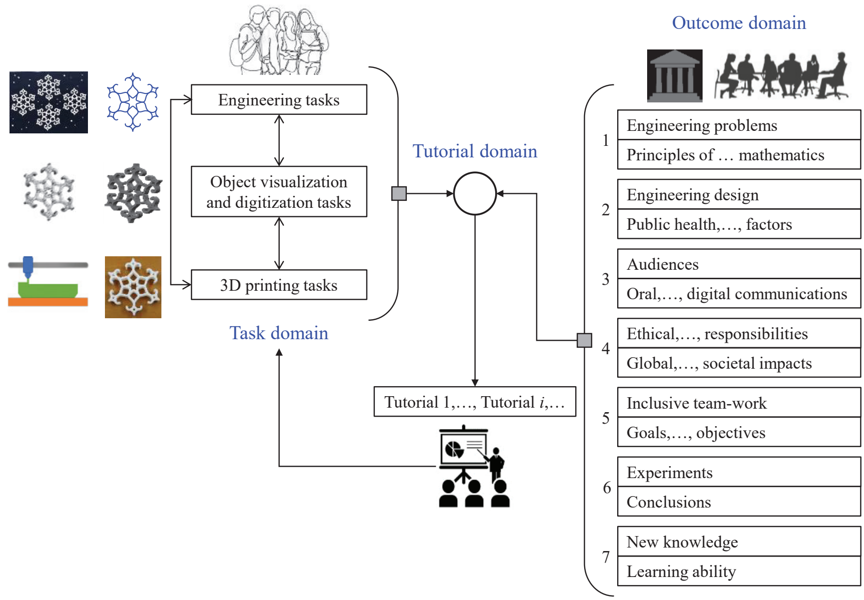

Figure 2. Tutorial development method.

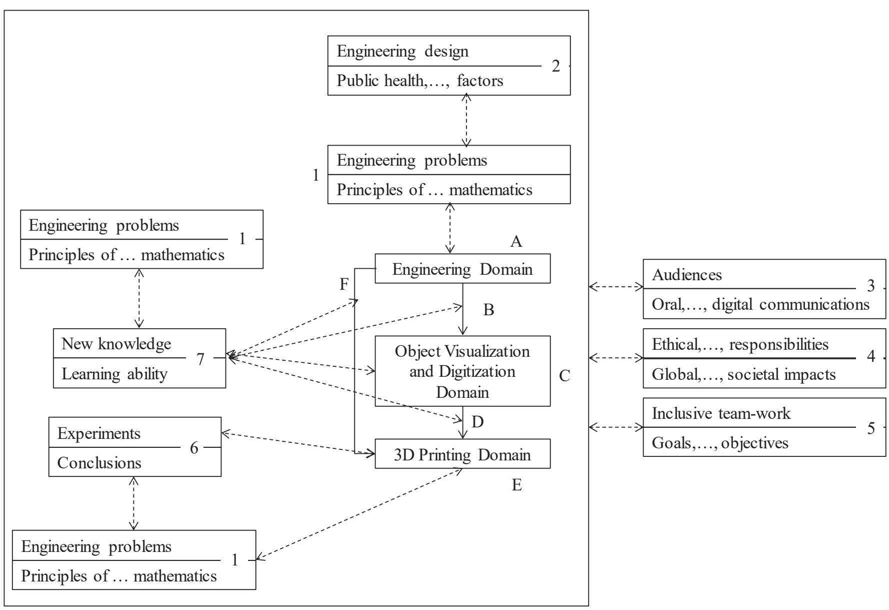

Figure 3. A hierarchy among outcomes and task domains.

As seen in Figure 3, the process denoted as A is directly linked to Outcome 1, and Outcome 1 is directly linked to Outcome 2. Thus, the activities associated with A mean that the students apply the knowledge of engineering, science, and mathematics to identify, formulate, and solve a given problem. Subsequently, the students consider some real-life constraints and coordinate the tasks associated with Outcome 1 to formulate a design process. As such, Outcome 2 becomes a secondary outcome of A.

For example, if the given problem is to materialize an aerofoil, the students apply a set of governing equations in determining its shape. Subsequently, the students define the aerofoil design process considering some real-life constraints (e.g., aerofoil for a small aircraft). Now, B is directly linked to Outcome 7 and makes A meaningful to the next domain (object visualizing and digitization domain). Thus, the students acquire and apply knowledge to create the shape information of aerofoil in such a way so that the information can be handled in C. Acquiring new knowledge is again linked to Outcome 1; that is, the students must apply some other pieces of mathematical, engineering, and scientific knowledge other than the governing equations of the aerofoil. C is also directly linked to Outcome 7 and indirectly linked to Outcome 1. As a result, in this case, students acquire knowledge to create a 3D solid model of the object (aerofoil) using the information acquired from the process B. In this case, a default choice is to use an off-the-shelf CAD package. As such, the students learn from other sources (that goes beyond the course where this tutorial is integrated) how to transfer the aerofoil's shape information to CAD software. Once the activities associated with C are done, it is time to perform the activities associated with D. Since most of the 3D printing systems can work on the triangulated dataset of the objective to be fabricated (STL dataset [49]), D entails the activities that ensure that the triangulated dataset of the object is prepared based on a predefined standard. This can be done using the functions offered by the CAD software. However, a full understanding requires the knowledge of an entity called a facet. A facet captures the information of a triangle in the triangulated model of an object. The information is as follows: (1) the three vertices of a triangle, (2) the order of the vertices, and (3) one of the normal vectors of the tringle showing its orientation (outward of the object to be fabricated).

Thus, D associates Outcome 7 (the ability of self-learning from reference materials of given CAD software), and, at the same time, Outcome 7 associates Outcome 1 (triangulation related vector algebra). Alternatively, if the students produce the necessary triangulation dataset directly in the engineering domain by developing a dedicated program or some other means, it can be transferred to the 3D printing domain for performing the tasks related to E. These alternative paths related activities constitute F. Thus, F is also directly related to Outcome 7. In addition, Outcome 7 is associated with Outcome 1, similar to D. Since E refers to all activities associated with 3D printing in the 3D printing domain, it can be oriented toward achieving Outcome 6 and Outcome 1. When Objective 6 is emphasized, the students are supposed to carry out an experiment, analyze and interpret data, and draw conclusions. In the case of 3D printing, the students can fabricate the object several times varying the printing conditions (layer thickness, feed rate, filling rate, and alike) and printing methods (e.g., stereolithography, fused deposition, and alike) and measure the accuracy of the fabricated object. The students may use data analysis knowledge and optimize the printing process using some realistic criteria (minimize energy and material consumptions, maximize accuracy, and like). Thus, Outcome 6 is concurrently related to Outcome 1. On the other hand, students may be assigned to develop an analytical or empirical model of the 3D printing process. If it is done, then the 3D printing domain directly relates Outcome 1, as schematically illustrated in Figure 3. When the students achieve the primary and secondary outcomes (Outcomes 1, 6, and 7), as schematically illustrated in Figure 3, the tertiary outcomes can simultaneously be achieved. For example, if the students can articulate the ethical issues (e.g., positive social changes that they can bring about using the competency they have gained through performing the tasks associated with A, . . . , F), then the tertiary outcome, Outcome 4, is covered. If the students form a team with shared responsibilities and perform accordingly, then the tertiary outcome, Outcome 5, is covered. If the students prepare a detailed report on how they have conducted A, . . . , F being, at the same time, aware of the outcomes (Outcomes 1, . . . , 7), then the tertiary outcome, Outcome 3, is covered. Now, it may not be easy to articulate the new knowledge gained (Outcome 7). In this respect, the knowledge taxonomies [50,51] can be used.

4. Implementation

The previous section presents a general method to develop tutorials for educating undergraduate engineering students with the knowledge and skills of 3D printing. This section implements the method by eliciting a tutorial. In particular, the tutorial deals with 3D printing of a spur gear. Thus, it is suitable for senior-level undergraduate students enrolled in mechanical, industrial, and manufacturing degree programs. The descriptions of the tutorial are as follows.

4.1. Outline of the Proposed Tutorial

Most of the students enrolled in the undergraduate mechanical, industrial, and manufacturing degree programs learn about machine elements (gear, pulley, shaft, bolts, and alike). They are familiar with the governing equations of the elements and their usages in electromechanical systems. They might be familiar with building a solid model of a spur gear using an off-the-shelf CAD package. Based on this consideration, Figure 4 schematically illustrates the structure of the tutorial.

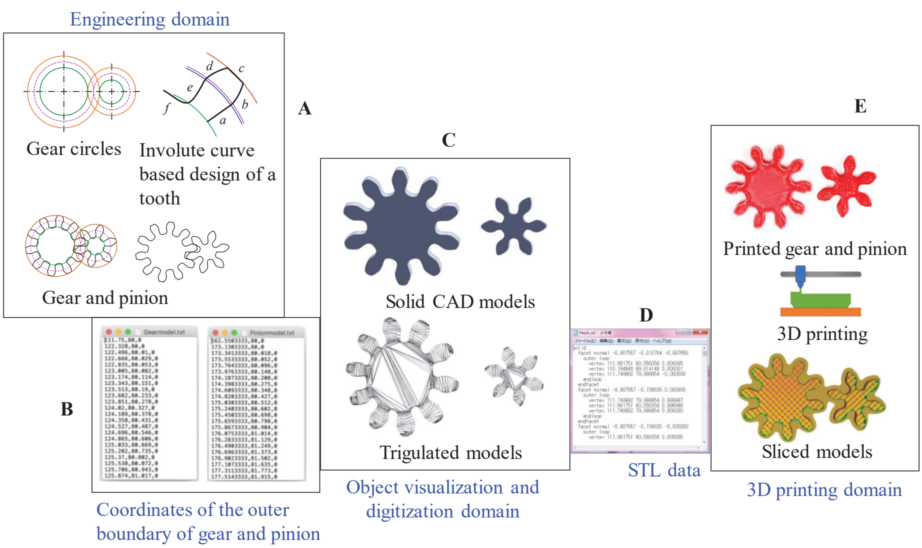

Figure 4. A tutorial for 3D printing in education.

As seen in Figure 4, the tutorial consists of processes denoted as A, . . . , E; F is not included in this tutorial. A (engineering domain) deals with how to design a spur gear. B deals with the dataset consisting of the coordinates of the outer boundary of the designed gear–pinion pair. C (object visualization and digitization domain) deals with solid modeling of spur gear–pinion pair with the aid of off-the-shelf CAD software. B's input is the set of coordinates of the outer boundary of the designed gear/pinion. D deals with STL data [49] preparation from the triangulated model of the gear/pinion. E (3D printing domain) deals with 3D printing of the gear–pinion pair using an ordinary 3D printer.

4.2. Administering the Tutorial

To administer A, the instructor can assign students to determine the governing equations of a tooth of a spur gear. The instructor can assign students to formulate a tooth model consisting of six segments ($a, \ldots, f$ as shown in Figure 4) within the realm of the four circles known as pitch, base, outer, and root circles. Out of these segments, the segments b and d are the involute curves [52]. Others are the lines connecting b and d to the abovementioned circles. If the students can perform the above assignment, they fulfill the primary outcome (Outcome 1).

Afterward, the students can consider the engineering design aspect, which refers to a secondary outcome (Outcome 2). As such, the students can apply a system approach—input processing–output approach. In the input module, the students can ask a gear designer to input the values of velocity ratio, number of teeth of the gear, number of teeth of the pinion, pressure angle, and diametric pitch. In the processing module, all sorts of calculations can be performed to determine the distance between the centers of gear and pinion; dimensions of the addendum and dedendum; values of clearance and contact ratio; dimensions of the pitch, base, outer, and root circles of gear/pinion; values of working depth; tooth thickness; and rotation angle of gear/pinion [52]. In the output module, the designed gear–pinion pair can be visualized.

Figure 5 shows the screen-print of a spreadsheet-based gear design tool. If the students can build a similar design tool, they fulfill both primary and secondary outcomes (Outcomes 1 and 2). Therefore, the instructor can evaluate students based on whether they can build a design tool similar to the one shown in Figure 5.

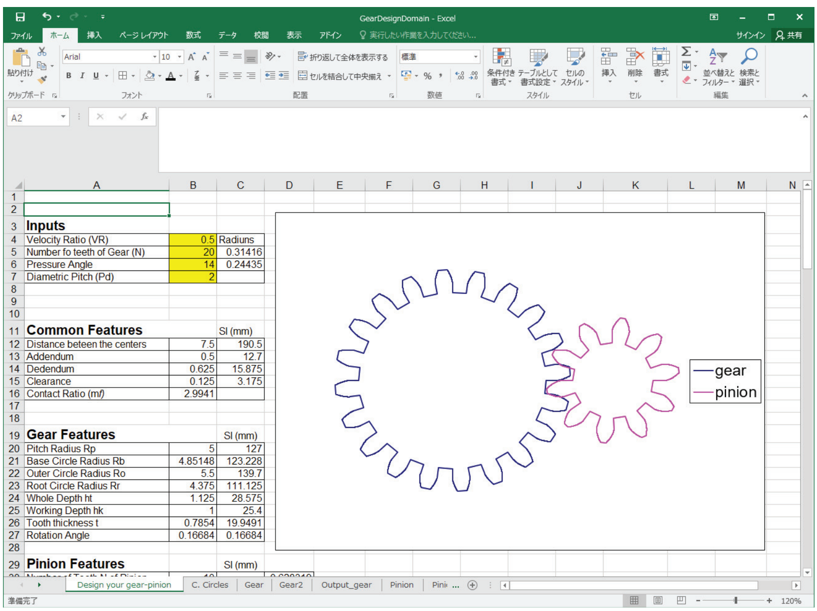

Figure 5. A tool for designing spur gear.

In B, the instructor can assign students to extract the design information of gear/pinion in terms of some points because most of the off-the-shelf CAD packages nowadays have a function to input coordinates of points collected from an external source. Thus, the students must go through the manual of the given CAD package and make sure of the underlying data format. This means that the students' self-learn how the coordinate data input function works for the given CAD package. As a result, Outcome 7 becomes the primary outcome of B. On the other hand, Outcome 1 becomes the secondary outcome because the students must apply the knowledge of parametric curves to parameterize the equations of gear/pinion segments ($a, \ldots, f$) for representing the segments using some points. At the same time, the students must apply basic geometric modeling techniques (e.g., rotation of point/curve centering a point/axis). Therefore, the instructor monitors and evaluates the students' performance based on Outcome 7 (primary outcome) and Outcome 1 (secondary outcome). If successful, the students produce documentation similar to the one shown in Figure 6. As seen in Figure 6, the students plot the coordinates of the gear and pinion's outer boundaries and store them in text files (ASCII) so that the information becomes meaningful to the tasks underlying C.

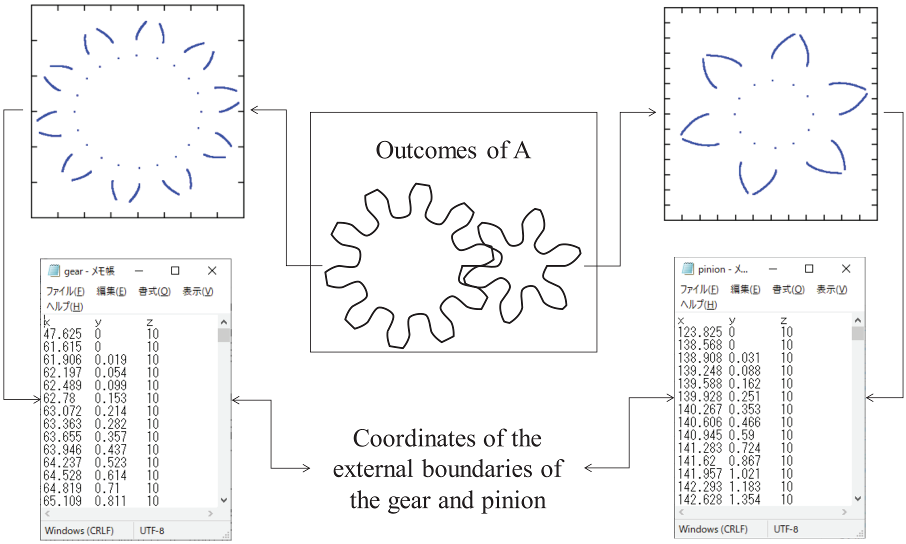

Figure 6. Outcomes of B with respect to those of A.

In C (object visualization and digitization domain), the gear/pinion coordinate information generated in B (the text files are shown in Figure 6) is used to create a solid model of gear/pinion. In this respect, the students need to know how a set of points stored in an ASCII text file can be input into the given CAD package. The students also find out the required operations to perform constructive solid modeling [53]. The students self-learn how the CAD package converts points to a curve, and then a solid model. Therefore, Outcome 7 becomes the primary outcome of C. At the same time, the students must apply the knowledge of geometric modeling to triangulate all faces in the solid model of the gear/pinion. The triangulation process stores the gear/pinion in terms of facets where a facet means three vertices of a triangle and a normal vector defining the orientation of the triangle. Thus, Outcome 1 becomes a secondary outcome of C. If successful, the students produce documentation similar to the one shown in Figure 7. As seen in Figure 7, the students produce the solid models and triangulate models of the gear and pinion, respectively using the output of B. Thus, the instructor assesses the students' performance based on the contents shown in Figure 7, keeping in mind that Outcomes 7 and 1 are the primary and secondary outcomes, respectively.

In D (STL data domain), the students are required to create the STL [49] datasets of gear and pinion. Most of the off-the-shelf CAD packages have the function to generate STL data from a solid model. Thus, the students need to know how to create an ASCII text file that stores the STL data using a given CAD package. This means that the students self-learn how the CAD package converts a triangulated model into STL data format. Therefore, Outcome 7 becomes the primary outcome of D. At the same time, the students must know the construction of an STL data block. An STL data block consists of three vertices and a normal vector, and the information of these four elements must be stored in a specific format [49]. This requires the knowledge of calculating the normal vector from three vertices of a triangle [54]. Thus, Outcome 1 becomes a secondary outcome of D. If successful, the students produce documentation similar to the one shown in Figure 8. As seen in Figure 8, the students produce two text files (ASCII format) storing the STL datasets of the designed gear and pinion. Thus, the instructor assesses the students' performance based on the contents shown in Figure 8 (only the segment marked D), keeping in mind that Outcomes 7 and 1 are the primary and secondary outcomes, respectively.

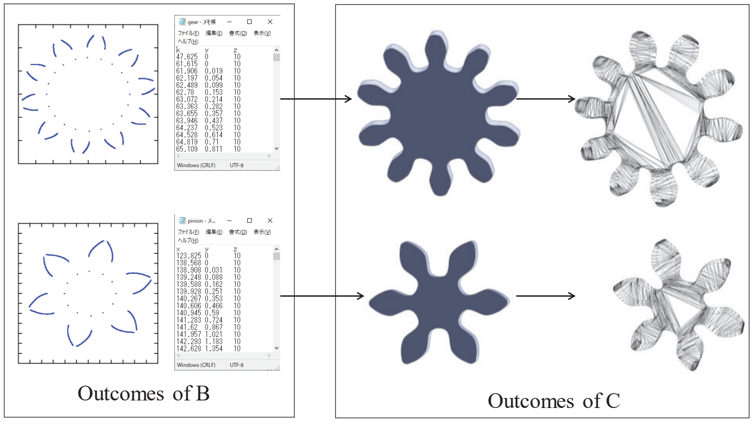

Figure 7. Outcomes of C with respect to those of B.

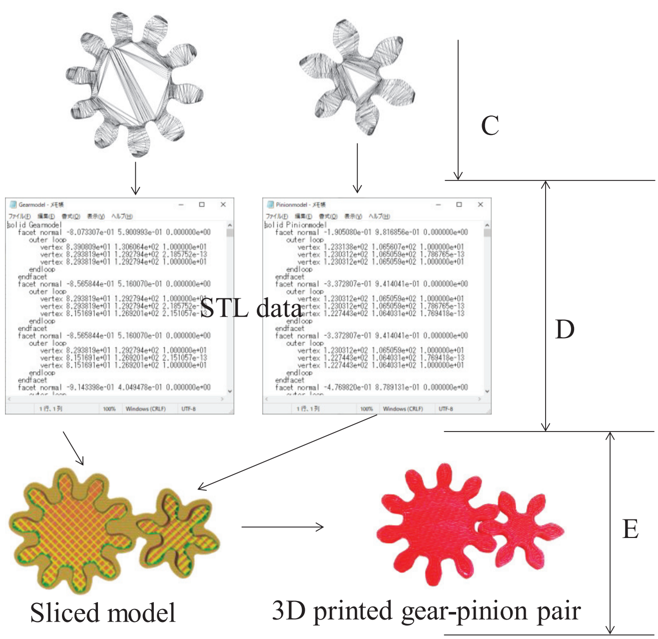

Figure 8. Outcomes of D and E with respect to C.

In E (3D printing domain), the students are required to print the gear and pinion using a given (most likely a commercially available) 3D printer. Thus, the instructor assesses the students' performance based on the contents shown in Figure 8 (only the segment marked E). In this case, the instructor uses Outcome 6 as the primary outcome and Outcome 1 as the secondary outcome. As a result, the instructor must instruct the students to print the same object (in this case, a gear–pinion pair) several times by changing the printing conditions (filling rate, printing head feed rate, layer thickness, and alike) and to measure the printing performance (e.g., printing time, the material used, energy consumption, accuracy/precision of the gear and pinion, shape error, surface roughness, and alike). The students can interpret in terms of quality, sustainability [55], and alike using relevant analytical knowledge

(Outcome 1). Figure 9 shows some of the examples of gear and pinion pairs that the students printed. Based on the students' preferences, the size and shapes of the gears and pinions are different. A group of students has taken a video clip demonstrating that the gear–pinion pair has been printed according to the design because they rotate very smoothly. Refer to the Supplementary materials to run the video clip.

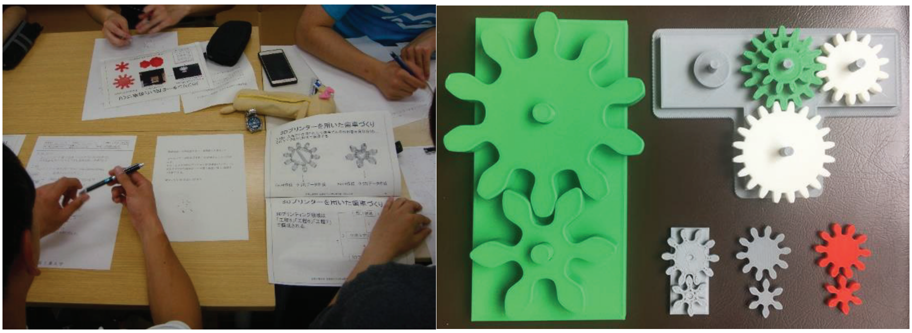

Figure 9. Pictures of students' activities and outcomes.

The students can form teams to perform the tasks underlying Figures 5–9 and keep the teamwork and leadership documentation. Finally, the students can present their work and submit a term-report, as elaborately as possible. This way, the students demonstrate their ability regarding the tertiary outcomes, that is, Outcomes 3, . . . , 5.

It is worth mentioning that while offering the tutorial, it can be divided into two parts. In the first part, the students are exposed to the tutorial. In this case, the course materials (Figures 5–8) can be distributed using a course content management system. The student can participate in the first half, either being at home or visiting a laboratory facility equipped with 3D printers and other relevant facilities. A report showing that they have understood the underlying processes and have built an attitude toward engineering design can be used to evaluate individual student performance. The picture shown on the left-hand side in Figure 9 shows students' activities in the first half. In the last half, the students can form teams and choose shapes (may not necessarily be a gear) and print the selected shapes following the instructions they received in the first half. A detailed presentation of the work done can be used for evaluating the performance of the teams. The picture shown on the right-hand side in Figure 9 shows some of the results of students' activities in the last half.

4.3. Effectiveness of the Tutorial

Apart from the outcomes assessments based on the outcomes shown in Table 1, the tutorial's effectiveness can be evaluated by studying the comments and the reports and presentation documents submitted by the students who took part in the first half and second half, respectively. Appendix A presents Table A1 listing the comments of fifteen students (from seventy-six students) who took part in the first half of the tutorial this year.

As seen in Table A1, regarding the first half of the tutorial, the students discuss various aspects of the tutorials, their expectations, and what they have learned, what they could not learn, positive aspects about 3D printing, negative aspects of 3D printing, and alike. The authors briefly describe fifteen randomly selected comments from the seventy-six students who took part in the tutorial this year. In particular, the students understood the processes underlying engineering design, CAD modeling, and 3D printing. They appreciated the role of 3D printing in materializing different shapes very quickly. They also became aware of the limitations of 3D printing (e.g., printing time, accuracy, and metallic part making). The students also extended their learning process regarding manufacturing through the tutorial. For example, some students wanted to apply 3D printing in other areas such as reverse engineering (rebuilding of broken objects), the materialization of natural objects (leaf-shape), and alike. They also grasped the contents they learned in other courses through the tutorial more effectively.

Regarding the second half of the tutorial, the students formed small teams and applied the knowledge they learned in the first half and performed the tasks underlying the five processes (A, . . . , E). Each group produced a detailed presentation, including video clips and other necessary evidence showcasing their learning performances. For example, one of the gear trains shown in the picture on the right-hand side in Figure 9 was 3D printed by the students, where they used different gear-profiling equations. The students then assembled the gears and tested the backlash of the train, as prescribed in https://www.nmri.go.jp/oldpages/eng/khirata/design/ch06/ch06_02.html. This way, the students showed the accuracy of the 3D printed gears and their enhanced understanding of precision mechanisms. This kind of self-motivated learning attitude of the students can prepare them for the agile job market more effectively.

5. Concluding Remarks

3D-printing-relevant tutorials can prepare engineering students more effectively for their studies and careers. The contents described in this article shed light on how to educate undergraduate engineering students on the knowledge and skills of 3D printing using an outcome-oriented tutorial.

The presented tutorial development method and its implementation (3D printing of spur gears) are strictly focused on the seven ABET-prescribed outcomes. It is found that a hierarchy among the outcomes exists. Though the tutorial organizes the outcomes in three levels (primary, secondary, and tertiary), other hierarchical strategies can be considered based on the needs of an engineering program.

The tasks to be performed in the three main domains (engineering design domain, object visualization/digitization domain, and 3D printing domain) and two connecting domains (object–coordinate point cloud domain and STL data creation domain) are presented as elaborately as possible. The descriptions of the tasks help both instructors and students administer the tutorial systematically.

Based on this study's findings, an e-learning tool can be developed, ensuring online delivery.

Supplementary Materials: The following are available online at http://www.mdpi.com/2227-7102/10/8/194/s1, The supplementary material consists of a video clip showing the movements of a 3D printed gear–pinion pair.

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Appendix A. Students' Comments

This appendix presents Table A1 listing the comments of fifteen students (from seventy-six students) who took part in the first half of the tutorial this year.

Table A1. Students' Comments Regarding the First Half of the Tutorial.

Students	Comments
1	It turns out that the gears used in many mechanical products such as cars are made through a more complicated process than I expected. I thought that if there were time when 3D printers were cheap and available, it would be possible to self-repair cars and motorcycles with this knowledge, especially old motorcycles. There may be cases where parts are no longer available but can be made easily by ourselves using the information of the broken part.
2	This tutorial enhanced my interest in 3D printers. I had seen 3D printer only once on TV but could not grasp the technical detail until I learned from this tutorial. It turned out that various parts can be made by using a 3D printer, and complex ones can be made by assembling them. I think there will be more places where 3D printers will be used, so I would like to pay attention to it.
3	Though I could not use a 3D printer this time, I learned about it with great detail. I was able to learn how to handle the data of an object for 3D printer. Next time, I want to use 3D printer and do by myself up to the last step to materialize a complex shape.
4	In this lecture, I learned how to make gears by using a 3D printer. I used a 3D printer before, and I find it very convenient. However, this printer has the drawback of not being able to make too small parts accurately and trying to make a large one taking a great deal of time. Although there are such drawbacks, it is still convenient, so I would like to continue to pay attention to 3D printers.
5	I found that designing with a 3D printer can be done with simpler procedures than I had thought. I was strongly interested in the field of 3D printers that can shape what I imagined while reducing the cost of prototypes.
6	I learned about making gears using a 3D printer. I realized that there are many processes just to make gear parts and it takes time. I look forward to using 3D printer to produce a part by myself using the knowledge gained in the tutorials.
7	I know about 3D printing and its utility. From this tutorial, for the first time, I could grasp the processes involved in 3D printing. It would be great if I could work on a research topic related to 3D printing.
8	By learning the process of gear making using a 3D printer, I deepened my understanding and interest in manufacturing using a 3D printer. I want to use the 3D printer myself. I am currently learning the usage and basics through CAD and CAE lectures, but I was able to learn concretely how to make use of that knowledge, and my motivation to learn further increased.
9	This time, I could not actually experience making gears using a 3D printer due to coronavirus's influence, but I was able to understand the details of the 3D printer working processes, and I felt that it was of sufficient value. I actually wanted to use a 3D printer to print natural and complicated shapes (e.g., autumn leaves).
10	In this lesson, I learned how to make a 3D model using CAD and became more interested in CAD. I have not used it yet, but since I have a 3D printer and I knew the manufacturing process, I wanted to make something more complicated than gears by myself.
11	3D printing is an exciting field. There are many types of 3D printers, and I think it's exciting that you can create various three-dimensional objects to suit our purposes. If we create data with CAD, we can make it by the subtractive manufacturing process. In this case, it takes high skills to create the program. Nevertheless, 3D printing does not need such programming skills and makes things simple and easy.

Table A1. *Cont.*

Students	Comments
12	I learned that designing mechanical parts requires a set of formulas. I knew about 3D printers from video clips posted on the Internet, but this tutorial taught me the processes involved in 3D printing. Now I know the conditions and setting needed to make things using 3D printing. I think that 3D printers are handy for creating small objects, but I think that it will be costly for large objects as large objects will require a 3D printer larger than the objects. If 3D printers can use metal as a material and can perform complex printing, its usages will expand in industrial production.
13	This time I took the course online. Next time, I want to use 3D printer by myself. Also, it was nice to know that the 3D printer not only has the convenience of part making directly from 3D CAD data but also can suffer disadvantages (long printing time).
14	3D printer will suffer limited use due to long printing time. Simultaneously, detailed knowledge of using the computing facility is needed to use a 3D printer appropriately.
15	It was interesting that I could get a detailed understanding of making gears using a 3D printer. I enjoyed learning about the usage of CAD modeling and 3D printing in an integrated manner.

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Studying During the COVID-19 Pandemic: A Qualitative Inductive Content Analysis of Nursing Students' Perceptions and Experiences

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Abstract: Coronavirus disease 2019 (COVID-19) is the latest pandemic with a high rate of morbidity and mortality worldwide. Crises like these can harm the academic functioning and psychophysical health of nursing students. With this qualitative study, we aim to explore how students perceive the COVID-19 crisis and what their personal experiences were while studying during the global pandemic. In the study, data saturation was achieved after analyzing the reports of 33 undergraduate nursing students, using the inductive thematic saturation method. Data were collected using an online form, which students filled out, describing their perceptions and experiences. Qualitative inductive content analysis of students' reports resulted in 29 codes, indicating different student perceptions of the efficiency of state institutions in crises. All students described the spread of misinformation on social networks and the risky behavior of the population. Most are afraid of infection and worried about the well-being of their family, so they constantly apply protective measures. Students recognize their responsibility to the community and the importance and risks of the nursing profession. They also describe negative experiences with public transportation and residence in the student dorm. The fear of possible infection in the classroom is not significant, however, students are afraid of the clinical settings. Thirteen students reported difficulty in concentrating and learning, while all students praised teacher support and faculty work in this crisis.

Keywords: COVID-19; coronavirus infections; pandemics; qualitative research; nursing students; student experiences; student perceptions; student safety

1. Introduction

Coronavirus disease 2019 (COVID-19) is the latest infectious disease to develop rapidly worldwide [1], to the extent of a severe global pandemic [2]. The etiologic agent of COVID-19 is the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which emerged in Wuhan, China [1,2]. According to the World Health Organization (WHO), from December 2019 to mid-April 2020, more than 2 million COVID-19 cases and more than 100.000 deaths have been confirmed worldwide, including more than 200 countries [3]. In Europe alone, more than 1 million people were infected during this period. In Croatia (CRO), the first case of COVID-19 was identified on February 25th, 2020, after which the number of confirmed cases increased steadily.

There is still a lack of experience about COVID-19 in the world and there are many ongoing scientific studies [4]. SARS-CoV-2 is known to possess potent pathogenicity and transmissibility [4]. Patients with severe COVID-19 tend to have a high viral load and a long virus-shedding period [5]. However, the transmission of infection is also possible from asymptomatic patients [6]. The risk of transmitting a disease to healthcare professionals is unavoidable in these situations [4,7,8], which is also a serious threat to nursing students [9], who are very quickly becoming aware of their risk of infection [10,11]. For example, in Italy, more than 15,000 health workers were infected with SARS-CoV-2 by mid-April, and more than 19,000 were tested positive in Spain [12]. Nursing students are a direct link between hospitals and universities, with the capacity to act as a conduit of pathogens to large, susceptible populations [9]. These facts are very stressful for students, with possible negative implications for their studies and their psychophysical health [11]. Therefore, universities need to respond promptly and appropriately to protect their students by preventing the spread of this infectious disease into the university community during an epidemic [9]. Due to the COVID-19 pandemic, on 16 March 2020, regular university classroom teaching, as well as student training in the clinical settings were discontinued in Croatia. The project of live distance lectures delivered to students at home was started by creating online virtual classrooms. Thus, the possibility of direct contact of nursing students with patients, students and faculty members is blocked, which is a very effective method of protecting students and the entire community [13].

Given that COVID-19 is a new pandemic, a review of the related literature has found no currently available relevant study that describes the perceptions and experiences of nursing students during the COVID-19 pandemic. Existing, mostly quantitative studies have described the insights, perceptions, and experiences of nursing students concerning an earlier Middle East respiratory syndrome coronavirus (MERS-CoV) epidemic that occurred in Saudi Arabia in 2012 [14]. Thus, students from Al-Ghad International College for Applied Medical Sciences from Saudi Arabia considered coronavirus to be a very deadly virus, dangerous for humanity, and that preventive measures of isolation are necessary [15]. Additionally, they hold that MERS-CoV is a fatal disease, and that healthcare professionals are at high risk for infection. Students from two other Arab studies came to the same conclusions [10,16]. Qassim University students believe that transmission of the disease can be prevented following universal precautions given by WHO [17]. However, nursing students often find that the population is unaware of the transmission of the viral infection and the severity of the situation, and does not act on the recommendations of state institutions [8,15,17]. The results of a Korean study suggest a positive correlation between nursing students' attitudes towards infection prevention measures and the frequency of their use [18]. Furthermore, several relevant studies describe sources and ways of informing students during the epidemic and possible arising difficulties [8,9,11,15,17]. Thus, students most often use the Internet, TV, and radio for information purposes [15,17], social networks such as Twitter [8,9], or they obtain information from college sources, official health authority statements [11], or from friends and family [9]. According to WHO, the world is currently affected by massive "infodemic" (info[rmation] + [epi]demic), an over-abundance of information, which involves the excessive dissemination of false information associated with COVID-19 [19]. Students are often exposed to a lot of misinformation in these situations, which can cause psychological distress [9,11]. Al-Rabiaah et al. [11], in their recent quantitative study, described the perceptions and determinants of psychological distress of students from different health professions, during the MERS-CoV epidemic. Their results indicated a high level of stress in all students, which had negative consequences on students' learning and academic achievement, as well as on their overall psychological health [11].

The previously mentioned studies indicate the importance of examining the perceptions, feelings, and attitudes of nursing students during major epidemic crises, to provide adequate measures of student protection and support promptly. Unfortunately, the available literature still does not offer enough in-depth analyses of nursing students' experiences during pandemics (especially not for COVID-19), which could significantly affect the level of global understanding of the seriousness of nursing students' needs, problems, and difficulties in extreme crisis situations. Therefore, the purpose of our study is to fill this gap by providing the results of a qualitative inductive analysis of the free-form (undisturbed) nursing students' descriptions of their own perceptions, emotions, expectations, and behaviors, while studying during the COVID-19 pandemic. Thus, we expand the existing global knowledge about the psychological and behavioral aspects of nursing students' functioning in crisis situations.

Thus, our study sought to explore the perceptions and experiences of Croatian BSc nursing students regarding the new COVID-19 global pandemic, three days before the Croatian Government decided to temporarily close all educational institutions in the country and implement remote learning. Thus, by inductive qualitative analysis of students' experiences, we are seeking to gain a better and deeper understanding of the possible impact of the pandemic on their study process. In particular, the study focused on providing answers to the following questions: (1) how students perceive the COVID-19 crisis; and (2) what their personal experiences were while studying during the global COVID-19 pandemic.

2. Materials and Methods

2.1. Design and Theoretical Framework of the Study

This qualitative study was conducted in Osijek on March 13th, 2020, seventeen days after the first identified case of COVID-19 in CRO, and three days before the temporary cancellation of regular university teaching. According to WHO [20], on the day the study was conducted, sixteen COVID-19 cases were identified in CRO, with no fatalities, and 132,758 COVID-19 cases and 4955 deaths were confirmed worldwide. The study is designed to accurately describe the phenomenon of students' experiences, using a generally accepted method of conventional inductive content analysis [21]. This type of design is usually appropriate when there are only few previous studies and grounded theories describing the phenomenon in question, or when the phenomenon itself is fragmented [21,22]. Therefore, this study does not have one strict theoretical starting point. However, given the aim of the study and the subsequently identified relations between categories and subcategories [21], certain results can be considered in terms of cognitive theories of emotions [23], fear, and stress [24]. Other results can be interpreted from the perspective of humanistic nursing theories and theories of professional identity in nursing, such as Erickson's psychosocial theory [25] and personality type theory [26,27]. Thus, using a conventional approach to content analysis, relevant concepts and theories are addressed in the discussion section of the study [21].

2.2. Participants

The participants in the study were 33 BSc nursing students, from the Faculty of Dental Medicine and Health in Osijek, Croatia. There was 29 female (88%) and 4 male (12%) students, with a mean age of 21 years. Purposive sampling, based on intended research outcomes, was performed according to the defined criteria [28]. The sample size was further determined based on informational needs and using a model of inductive thematic saturation, as a criterion for discontinuing data analysis [29,30]. The inductive thematic saturation applied in this study focused on the identification of new codes or themes. In such an approach, saturation appears confined to the level of analysis and its implication for data collection is at best implicit [30]. The saturated number of 33 respondents in this study is consistent with other similar relevant studies and descriptions, which suggests that, to obtain a detailed insight into the phenomenon studied in such studies, the data should be based on about 1 to 30 participants [21,22,28–32]. Smallest acceptable sample size of interviews in all qualitative research is elsewhere determined at around fifteen, but not exceeding fifty respondents [32].

The inclusion criteria for participation in the study were: (1) enrollment in a BSc Nursing Studies program; (2) voluntary student participation in the study; and (3) written student reports, following the two major research questions and the researcher's instructions. Of the 37 received student reports, four were excluded from further analysis, because they were not substantively completed.

2.3. Data Collection

Data were collected using the online form, which included details of the study, additional guidelines, and two major research questions. It was sent via e-mail from the students' office to all eligible participants. Online data collection has been applied to minimize any potential risks, and to maintain a higher degree of confidentiality [33]. Due to the anonymity of participants, the form included an encrypted ID code (a combination of letters and numbers). In order to minimize the biases of researchers and participants, and to maintain neutrality, researchers were not otherwise directly involved in working with participants, and any suggestions from researchers were avoided. The questions are formulated considering potential biases, and in a manner that allows the participant to feel accepted, no matter what the answer is. Following Bengtsson [29], non-suggestible, open-ended written questions were used to further encourage students to express their thoughts. Writing time and amount of text were not limited. Open-ended written questions provide students with freedom of writing, a secure flow of thoughts, and a detailed description of their perceptions and experiences, which cannot be achieved using structured questionnaires with preconceived questions and provided answers [29]. Additionally, students stated that the written form of expression is more appropriate than oral, because it does not cause anxiety and gives them more time to think and respond, which further reduces the possibility of wrong answers.

Thus, students were asked to describe (1) their perceptions of the COVID-19 crisis and (2) their experiences while studying at the time of the global COVID-19 pandemic. All students received the final coded data for additional verification of responses [22].

2.4. Data Analysis

In this qualitative study, an inductive approach was applied, using a conventional content analysis of students' written reports [29]. Conventional content analysis is a research method for the subjective interpretation of the text data content through the systematic classification process of coding and identifying themes or patterns. Content analysis can be used as a method on all types of written texts, regardless of the way research data is collected [21,22]. Additionally, this type of analysis contributes significantly to a deeper understanding of human perceptions and experiences [21,22].

The open-ended written questions method of analysis directly influenced the depth of analysis and determined the manifest approach in this study [34].

The open coding procedures in the study were performed by three researchers (the authors of this article with experience in qualitative data processing). Thus, following the steps of Elo and Kyngäs [22], researchers independently and inductively created codes, sub-categories, generic categories, and main categories. This form of triangulation has been applied to minimize the effect when multiple researchers draw different conclusions based on different data [29]. According to Elo and Kyngäs [22], at least two people need to analyze and encode data independently and separately from each other. After completing individual data analyses, the next step is to jointly achieve a definitive organization of data, so a common consensus could be ultimately reached [34]. In accordance with the research questions and analytic framework, we applied a model of inductive thematic saturation of the data with a focus on the identification of codes/themes [30].

2.5. Ethical Considerations

All participants were informed about the details of the study. Participation in the study was voluntary, and students could withdraw from the study without any consequences. The anonymity of participants was guaranteed. To ensure confidentiality, participants were provided with an encrypted code. Only researchers had access to research data. The study was conducted following the Declaration of Helsinki. Ethical Committee of the Faculty of Dental Medicine and Health in Osijek approved this study (IRB approval number: 2158/97-97-07-20-06).

3. Results

The final organization of the data defines a total of 29 codes, 11 sub-categories (SC), and four generic categories (GC) within the two main categories (MC): (1) students' perceptions of the COVID-19 crisis, and (2) students' experiences while studying during the global COVID-19 pandemic (Table 1).

3.1. Students' Perceptions of the COVID-19 Crisis

Participants described in their reports the current crisis in the country, based on their perceptions of the efficiency of the state institutions, the plausibility of information systems and modes of behavior of the population during the COVID-19 crisis (GC: "state institutions and population in the COVID-19 crisis") (Table 1). Thus, 21 participants believe that state institutions are implementing effective infection control measures (SC: "actions of state institutions"). For example, the students affirmed:

> "Our national government is successfully protecting its population. They properly regulate and control isolation measures"
>
> (P. 7).

> "Institutions provide useful guidance on how to suppress COVID-19"
>
> (P. 2).

However, 12 participants felt that interventions of government institutions were delayed and insufficient, e.g.,

> "More rigorous measures should be taken immediately, state borders closed and quarantine declared. Now, it is too late"
>
> (P. 9).

> "There are long rows of people in front of pharmacies which lack medications, face masks, or medical gloves. We are not well-prepared for this crisis".
>
> (P. 21).

Twenty-three participants hold that state institutions are effectively informing the general population about the crisis (SC: "population information"), e.g.,

> "Praise to the Coronavirus Crisis Management Team for frequent and proper public informing on TV networks"
>
> (P. 3).

However, 9 participants doubt the accuracy of the information provided, e.g.,

> "I don't think the population is getting accurate data on the actual numbers of infected and deceased. It may be a panic prevention measure"
>
> (P. 31)

Table 1. The process of data abstraction contained in the students' reports.

MC	Generic Categories	Sub-Categories	Codes (Frequency of Statements)
Students'perceptions of the global COVID-19 pandemic	State institutions and the population in the COVID-19 crisis	Actions of state institutions	- Effective population protection measures (21) - Delayed and insufficient population protection measures (12) - Shortages of protective equipment and medication in pharmacies (12)
		Informing the public	- An efficient system of informing the public (23) - Doubtful veracity of the information provided by state institutions (9) - Spread of misinformation through media and social networks (33)
		Population behavior	- The gravity of the situation is not taken seriously (21) - Inappropriate and risky behavior of the population (21)
	Students in the COVID-19 crisis	Emotions and opinions of students	- Fear of the COVID-19 infection (19) - Concerns for the senior members of the family (33) - Influence of human factors and technology on the spread of disease (5)
		The behavior of students and their sources of information	- Applying prevention procedures to control the infection (30) - Using only reliable sources of information (32)
		Students' value systems and beliefs	- Awareness of the responsibility towards the community (23) - Recognizing the benefits of the human communion (23) - Recognizing the importance and risks of the nursing profession (23)

Table 1. *Cont.*

MC	Generic Categories	Sub-Categories	Codes (Frequency of Statements)
Students'experiences while studying during the global COVID-19 pandemic	Experiences with student life activities	Public transportation services	- Avoid using public transportation (14) - Non-compliance of passengers with prescribed protection measures (14)
		Residence in a student dormitory	- Restriction of socializing and learning with friends (3) - Feeling uneasy about social distancing of students (3)
		Teaching and learning process	- Mild fear of becoming infected in the classroom (5) - Severe fear of becoming infected in the clinical setting (15) - Learning difficulties (13) - Professionalism, courage and humanity of the teachers (33)
	Experiences with the organization of work at the faculty	Teaching activities of the faculty	- Supporting the suspension of the classroom and clinical activities (33) - Satisfaction with distance learning (33)
		Preventative measures	- The important role of the faculty in preventing the spread of infection (30) - Effective protective measures imposed by the faculty (30)

MC = Main categories.

All participants believe that there is a massive spread of fake news and misinformation, e.g.,

> "Some media, and especially social networks, are responsible for millions of fake news and misinformation, and that must be severely sanctioned"
>
> (P. 24).
>
> "Incredible nonsense is spreading through social networks"
>
> (P. 12).

As many as 21 participants (SC: "population behavior") think that the population does not understand the gravity of the situation and does not follow the instructions of the Coronavirus Crisis Management Team, e.g.,

> "People do not follow the instructions of the Coronavirus Crisis Team. They do not maintain a proper 2-m distance indoors, they gather and shake hands. It is self-destructive behavior"
>
> (P. 25).

In the reports, participants also focused on their functioning in a crisis situation (GC: "students in COVID-19 crisis") (Table 1). Thus, all participants indicate a sense of concern for older members of their family (SC: "student emotions and opinions"), e.g.,

> "I know that the elderly are the most vulnerable group and I worry greatly about my grandparents"
>
> (P. 22).

Nineteen participants are truly afraid of COVID-19 infection, e.g.,

> "I admit, I'm very scared of the infection"
>
> (P. 33).
>
> "My fear of COVID-19 is growing more intense every day, this is terrible, I can't wait for it to end"
>
> (P. 19).

That the human factor, globalization, and modern technologies increased the spread of COVID-19 is considered by five participants, e.g.,

> "It may be ironic, but 'thanks' to people and technology, especially to planes and our cellphones that we do not disinfect, the virus has spread worldwide in just a few months"
>
> (P. 1).

As many as 30 participants describe in their reports how they constantly apply prevention procedures to control the infection (SC: "student behavior"), e.g.,

> "I don't shake hands with people and I keep recommended social distance of two meters. This is how I protect myself, but also my family and friends"
>
> (P. 14).
>
> "I almost always wash my hands according to the protocol, because this is the most important measure of protection"
>
> (P. 27).

> "I always wear a face mask in the supermarket"
>
> (P. 3.)

Twenty-three participants are trying to gather information only from relevant sources, e.g.,

> "I only get information via the Internet or TV when the Coronavirus Crisis Team makes official statements"
>
> (P. 3).

> "I avoid unverified information circulating on social networks"
>
> (P. 7).

> "I follow TV news programme and official web sites of the Croatian Institute of Public Health and our university"
>
> (P. 2).

Furthermore, 23 participants claim to be aware of their responsibility to the community, so they actively participate in volunteer activities (SC: "student values and beliefs"), e.g.,

> "I want to help people because it makes me happy"
>
> (P. 8).

> "Helping people is now necessary"
>
> (P. 17).

Additionally, the same participants claim that they recognize the importance of human communion, e.g.,

> "I now see the power and importance of people uniting. Unfortunately, we need a tragedy to understand the significance and strength of community"
>
> (P. 23).

As many as 23 participants report that during the COVID-19 crisis they recognized the true importance, responsibilities, and risks of the nursing profession, e.g.,

> "I am now aware of the significance, the responsibility and the dangers of our profession. The nurses are at extreme risk at work because of the COVID-19"
>
> (P. 17).

> "The COVID-19 crisis confirms the risks of our future profession"
>
> (P. 8).

3.2. Students' Experiences while Studying During the Global COVID-19 Pandemic

Participants based their reports on experiences with public transportation services, residence in a dormitory, and teaching activities (GC: "experiences with student life activities") (Table 1). Thus, 14 participants stated that they were afraid to use public transport services (SC: "public transport services"), e.g.,

> "I no longer take the bus to college because people are undisciplined and do not wear face masks"
>
> (P. 5).

> "Now my parents drive to college because it is a risk to travel by tram"
>
> (P. 26).

Three participants report unpleasant experiences in the student dorm (SC: "student dormitory"), e.g.,

> "In the dorm, we no longer hang out with our colleagues, we eat and study separately"
>
> (P. 15).

> "I feel tense and nervous in the dormitory"
>
> (P. 18).

Five participants reported fear of attending college classes (SC: "teaching process"), e.g.,

> "It is true that only 16 cases of COVID-19 have been reported in Croatia so far, but still I am little afraid of contact with students at the faculty"
>
> (P. 30).

> "I feel a little nervous during the lectures because some students work in the hospital and are in physical contact with patients"
>
> (P. 16).

Additionally, 15 participants reported fear of future visits to the clinical setting even after the pandemic had ceased, but they also understand the importance of clinical education, e.g.,

> "I am very much afraid of future clinical training in the hospital, even after the end of the epidemic"
>
> (P. 10).

> "Hospitals sometimes do not have protective equipment for us"
>
> (P. 7).

> "I am afraid of the clinical environment, but it is a very important part of our study and I cannot wait to work with patients again"
>
> (P. 12).

> "I am afraid of becoming infected in the hospital, however, our profession is based on real clinical conditions and direct contact with patients"
>
> (P. 3).

Significant problems with learning at home, such as lack of motivation, impaired concentration and impaired memory, have been reported in as many as 13 student reports, e.g.,

> "I'm afraid of COVID-19 and I just cannot learn"
>
> (P. 4).

> "Because of this crisis I cannot concentrate, and when I study I cannot remember anything"
>
> (P. 13).

> "It is hard to learn when the lives of me and my family are at stake"
>
> (P. 28).

All participants praise the professionalism, courage and humanity of teachers in this crisis, e.g.,

> "Our teachers are doing well, supporting and encouraging us, even though they are at risk of infection"
>
> (P. 11).
>
> "Teachers fully understand our fears"
>
> (P. 12).

Furthermore, all participants are satisfied with the organization of work at the faculty during the pandemic (GC: "experience with the organization of work at the faculty") (Table 1) and support the planned temporary suspension of regular teaching activities (SC: "faculty teaching activities"), e.g.,

> "The faculty is functioning great in this COVID-19 crisis"
>
> (P. 8).
>
> "I support the official decision to suspend classroom teaching soon and to start distance education"
>
> (P. 12).
>
> "Online teaching during the COVID-19 crisis is a lifesaver for us"
>
> (P. 1).

As many as 30 students think that the faculty has an important preventive role and successfully implements the COVID-19 prevention measures (SC: "infection prevention measures"), e.g.,

> "The faculty really cares about our safety. We have a lot of hand disinfectants and protective equipment here"
>
> (P. 6).
>
> "The faculty is important in controlling the spread of viral infection because it carries out continuous education on prevention measures, and suspension of classroom teaching and clinical training is a strong and effective preventive measure"
>
> (P. 17).

4. Discussion

According to research questions, our aims were the following: (1) to describe students' perceptions of the COVID-19 pandemic, and (2) to describe students' experiences while studying during the COVID-19 pandemic.

4.1. Students' Perceptions of the COVID-19 Crisis

Participants focused their perceptions largely on the topics of the efficiency of state institutions and the behavior of the population during the COVID-19 crisis (GC: "state institutions and the behavior of the population during the COVID-19 crisis"). Thus, according to reports submitted by 21 participants, state institutions are implementing effective measures to control infections and protect the population. This conclusion is supported by the results of other studies [10,15], in which the majority of students agree that the authorities undertake the necessary measures for disease control, and their health education campaigns help reduce MERS-CoV transmission. In contrast, 12 participants in our study feel that the interventions of state institutions were delayed and insufficient, and that more rigorous measures should be taken, such as closing state borders and declaring quarantine. Additionally, the same 12 participants say that people were unnecessarily waiting in long rows in front of pharmacies that did not have enough face masks, disinfectants and medications on stock, and that a better supply of population was needed. These results indicate that participants take the situation very seriously, proposing more effective prevention of the spread of the coronavirus.

Twenty-three participants are claiming that institutions effectively inform the population about the crisis, which is consistent with the results presented in other studies [8,10,11,15,17]. However, 9 participants in our study believe that state institutions are hiding real data, to prevent the spread of panic amidst the population. All 33 participants report the widespread occurrence of false information (so-called "infodemia"), most commonly delivered by social media and social networks [19]. In modern times, social media can be valuable [35], but also a very risky way of informing [11].

Most participants believe that citizens are not taking the situation seriously enough and, therefore, not behaving by the recommendations of state institutions, which indicates a serious and critical approach of the nursing students involved in our study. This result is supported by Tork [17], who concluded that people are not fully aware of how the infection is transmitted. Thus, each individual's informed knowledge, attitude and behavior in crisis situation have a serious impact on the spread of infection and the safety of the entire community [36].

As many as 19 participants are suffering from an intense fear of infection, with great concern for older members of their families (GC: "students in COVID-19 crisis"). These results are supported by studies confirming that most students find coronaviruses highly contagious and fatal [10,16,37]. During epidemics, nursing students often experience fear and high levels of psychological distress [11,38,39]. Otherwise, fear is a positive psychological, physiological, and behavioral condition that facilitates students coping with an adverse or unexpected situation, in this case, a global pandemic [40]. So, in these extreme situations, fear is an expected and justified emotion and reflects the seriousness of participants' approach to a global problem. However, from the aspect of Aldwin's theory of stress, such crisis situations caused by natural or technological disasters, also called focal stressful events, occur suddenly and significantly threaten the mental and/or physical integrity of people [24]. Personal control over such situations is very weak.

Interestingly, five participants claim that the human factor and advanced technology contribute to the spread of COVID-19, especially the million miles of daily air passenger traffic and the frequent use of cell phones that people rarely disinfect. Participants base their interpretations on the fact that SARS-CoV-2 is highly transmissible. Thus, new scientific studies describe that SARS-CoV-2 has stability in aerosols for three hours at room temperature [2], on glass surfaces for up to two days [41], and plastic and stainless steel and up to four days [41]. Researchers conclude that SARS-CoV-2 can be highly stable in a favored environment [2], but it is also susceptible to standard disinfection methods [41].

Almost all participants adhere to the prescribed protective measures and wear face masks at indoor public spaces. This serious and professional approach of students dealing with the crisis is supported by the results of several studies [8,15]. Students are currently exposed to a variety of public and official views on the effectiveness and proper use of face masks to suppress COVID-19 transmission [42]. WHO [43] states in its published guidelines: *"If you are healthy, you only need to wear a face mask if you are taking care of a person with suspected SARS-CoV-2 infection"*? For example, a new study by Leung et al. [44] indicates that surgical face masks could prevent the transmission of human coronaviruses and influenza viruses from symptomatic individuals. It is striking that SARS-CoV-2 remains stable and infectious for as long as 7 days on the outer layer and 4 days on the inner layer of the surgical mask, as suggested by a new relevant study [41].

Most participants claim that they gather information only from relevant sources, via the Internet and TV. Their primary sources of information are reports from the Coronavirus Crisis Management Team, the Croatian Institute of Public Health and their home university, which is supported by other studies which state that students are informed via the Internet, TV and radio [11,15,17], or they obtain information from the faculty [11]. Additionally, participants say they ignore unverified information widely spread across social networks, which suggests their ability of critical reflection and developed media literacy. In this case, it should be considered that these are personal beliefs of students in an extremely stressful situation that directly threatens their lives, when there is a possibility that participants are not able to objectively assess the level of truthfulness of certain information [24]. However, earlier reports suggested that students often gather information through current social networks in crises [8,9] and find it difficult to distinguish rumors from facts [45]. According to Al-Rabiaah [11], false information can also cause severe forms of psychological tension for students.

As many as 23 participants recognize the importance of bringing people together in a crisis, they feel responsible to the community and participate in various volunteer work. Thus, participants implement a holistic approach, as primordial nursing theory, in a support context, together with their knowledge and skills [46]. Additionally, through the experience of crisis, participants recognize the true value and importance of nursing, but also the reality of high risks of the nursing profession. It is important to point out that none of the participants mentioned the possibility of quitting their studies or leaving the nursing profession in their reports. There is considerable evidence that students who experience a disparity between expectations and actual experiences are at risk of withdrawing from their studies [34]. Thus, regardless of the extreme crisis, psychological tension, fear of contagion, and the daily increase in numbers of infected and deceased healthcare professionals, participants still believe they made a good choice of their future profession. This is also supported by the students claiming that they hope to return to work with patients soon, regardless of their fear of the COVID-19. Additionally, students are aware that nurses must be competent and well prepared for these and similar crises. Therefore, nurses in these extremely crisis situations must have a unique knowledge base, abilities, and skills that are needed to respond appropriately to health care and human service needs [47]. Such students' views can be considered and elaborated using the theoretical concept of professional identity and from the aspect of humanistic nursing theories, whose philosophical deep roots are grounded in humanism, existentialism, and phenomenology [48] Thus, the identity of nurses develops throughout their professional lives, from entering into the educational system, growing during the years of their study and clinical experience, and continuing to develop throughout their careers. It is precisely the period of their higher education that is crucial, because nursing students acquire the knowledge and skills that make them a special kind of health care professionals [27].

4.2. Students' Experiences while Studying During the Global COVID-19 Pandemic

Participants described their experiences in the context of using public transportation services, residence in a dormitory, and regular teaching process at the university (GC: "experiences with student life activities"). Thus, 14 participants avoided using public transportation to and from faculty, as people on buses and trams did not adhere to the recommended safeguard measures. Such undisciplined behavior of people in crises is not uncommon [17], and threatens the health of the entire population [36]. Ten days after conducting this study, all public transport lines were temporarily suspended by decision of the Coronavirus Crisis Management Team.

Three participants described feeling uneasy or anxious about the measures of social distancing in the dormitory [35]. It is known that rigorous public health measures of isolation can have adverse psychological effects, such as nervousness, anger, fear, sadness, confusion, insomnia, depression, stress, etc. [49]. In contrast, Wang and associates [50], in their study, conducted on a sample of 444 students, and described how the quarantine measures prescribed to prevent the spread of H1N1 flu had no psychological effects on the students. To prevent the negative psychological impact of isolation measures, it is important to inform the population clearly and accurately, to explain the reasons and expected duration of individual events, and to secure the smooth operation of basic work activities and sufficient supplies (food, water, medications, etc.) [49].

Only five participants felt a mild fear of infection during classroom lectures, while 15 participants described high levels of fear caused by the expectation of impending departure to the clinical setting, even after the end of the pandemic. These results are supported by studies, in which most students claimed that they avoid going to the clinical setting because they are scared of contagion [8,16]. Such results are not surprising, as they indicate students' awareness of the pathogenicity and transmissibility of SARS-CoV-2 [4] and the high risk of infection in the clinical settings [4,10,11]. Additionally, participants are confronted with the fact that healthcare professionals around the world are becoming ill or even die because of the COVID-19. However, participants, at the same time, understand the importance of clinical education, and hope to work with patients as soon as possible. Clinical faculties in the clinical environment facilitate the student's acquisition of professional knowledge: technical, psychomotor, interpersonal, and communication skills; attitudes; professional responsibility; self-confidence; and autonomy in the clinical setting [51]. Furthermore, several participants reported occasional problems with lack of protective masks and medical gloves for nursing interns in the hospital, which is confirmed by other studies [52,53]. By exposing themselves to risks, especially in the clinical setting, nursing students can be victims of infection, and also potential transmitters of the disease to the wider population. Therefore, higher education and health care institutions around the world need to educate students on the most effective crisis management measures and continuously protect their students by providing high quality and safe clinical learning environment [9].

Due to the COVID-19 crisis, 13 participants described lack of motivation, impaired concentration and impaired memory, which made learning difficult for them. According to Al-Rabiaah [11], during epidemics, students in the health professions often suffer from decreased psychomotor concentration and learning disabilities and avoid learning activities, which can have negative implications for their academic achievement [11].

All participants in our study praise the professionalism, courage, and overall humanity of teachers in this crisis, which is very important, because it mirrors support for the students and delivers useful feedback to their teachers and higher education institutions [7]. Participants state that teachers work in accordance with the new situation, carefully adapting the curriculum, the exam literature, methods of teaching, learning outcomes, elements and evaluation criteria, helping students greatly in this crisis.

The organization of work at the faculty during the pandemic is supported by all participants (GC: "experiences with the organization of work at the faculty"). Prompt interventions of cancelling students' departures to the clinical setting, suspending classroom teaching, and initiating distance learning, are found to be proper and reasonable by the participants. Participants believe that the faculty has an important preventative role and successfully implements epidemic prevention measures, which is consistent with students' reports analyzed in other studies [16].

The results of this study, despite the application of the inductive approach, are not too surprising. The relations between the formed subcategories and categories point to the fact that students' perceptions and experiences were significantly conditioned by their physiological reactions, emotions, and fears, which further confirms the dominant influence of cognitive theories of emotions, fear, and stress underlying this study.

4.3. Limitations of the Study

In this qualitative study, participants included nursing students from only one Croatian university. Additionally, because the COVID-19 infection is a newly emerging pandemic, there is a lack of references to similar studies, especially regarding the experiences of nursing students, and the potential influence of the COVID-19 crisis on their study process. Therefore, the results were analyzed and discussed in comparison with relevant studies describing nursing students' experiences during an earlier MERS-CoV epidemic. Additionally, the results of the study are a reflection of the perceptions and experiences of a saturated group of respondents and cannot be generalized to include other nursing students, and especially not the students of other professions. One should certainly take into account the very specific professional identity of nursing students and the aspects of humanistic nursing theories that have led most of them to choose their profession.

4.4. Usefulness and Applicability of Study Results

The results of this study provide a deeper insight into the perceptions, feelings, opinions, and experiences of nursing students during the COVID-19 pandemic. The data obtained help to identify areas of psychophysical and other needs, and recurring problems of nursing students, as well as possible difficulties in their academic functioning. Formed categories and subcategories related to classroom teaching can largely be used in understanding the perceptions and experiences of students in all academic disciplines on a global scale, because classrooms are mostly enclosed spaces where students are exposed to the risks and fear of possible infection. Furthermore, the results related to clinical training could be useful in understanding the experiences of nursing students around the world, as well as experiences of other future health care professionals (those, for example, studying medicine, physiotherapy, or biomedicine), who are, during their studies, trained in real clinical environments, in direct contact with patients and hospital staff. The theoretical basis of this study (cognitive theories of emotions, fear, and stress) allows the results to be useful in analyzing the experiences of students from different geographical areas and cultures affected by the pandemic, and possibly the experiences of their peers, regardless of their academic status. Given the rapid dynamic changes of events and the unpredictable variability of situations, which is essential to the state of every global crisis, student perceptions and experiences are very variable, and often unstable components. Therefore, in analyzing and interpreting the results of cross-sectional studies, one should be aware of the temporal (in)stability of the established data, therefore, it is necessary to conduct multiple assessments of student perceptions at different stages of crisis development. Furthermore, the study provides details that can facilitate the design of student support strategies and provide a safe learning environment. Therefore, in order to establish effective support mechanisms for students in a timely manner, it is important to have a comprehensive insight into the students' perceptions, feelings, and experiences occurring in crisis situations. Different methods in helping them include: providing psychological support to students so they can confront and control their reactions in crisis situations; providing relevant and true information for students during the crisis; protecting students from possible infection during class teaching, clinical training, and other activities that are part of their student life; applying teaching forms and methods, which will make it easier for students to learn in crisis situations; providing conditions in which students will be active factors in preventing the spread of infection, etc. Additionally, the results give useful feedback on students' perceptions of the effectiveness of actions taken by the faculty executives and teachers in this crisis situation. This study could also be an incentive for higher education institutions and the academic community to undertake similar comparative studies. In addition, the inductively formed categories in this study could be a stimulus and a possible basis for the development of newly structured instruments, and the design of further qualitative and quantitative studies. Thus, future comparative studies could cover a wider geographical area and include students of other professions, with the possibility of additional involvement of experimental and control groups of respondents, in order to strengthen the objectification and generalization of results. Finally, but equally importantly: this study expands existing global knowledge about the psychological and behavioral aspects of student functioning in crisis situations, and points to the importance of timely assessment of their perceptions and experiences during global pandemics.

5. Conclusions

In this study, we described students' perceptions of the COVID-19 pandemic and their experiences while studying during this global crisis. To best of our knowledge, this is the first qualitative study to describe nursing students' perceptions and experiences during the COVID-19 pandemic. The results indicate that students have somewhat divided opinions about the effectiveness of state institutions and their information policies. All students are describing the dissemination of misinformation through social networks and seek to use only relevant sources of information. Most students describe the high-risk behavior of the population during the COVID-19 crisis. Fear of contagion and concern for family members is common in all students, which is why they adhere to the instructions given by state institutions and continuously implement measures to control the spread of the infection. During the crisis, most of them became aware of their responsibility to the community and recognized the true importance and risks of the nursing profession. Students feel a mild fear of being infected during classroom teaching, but they are very afraid of future visits to the clinical setting. However, they are aware of the importance of working in a realistic clinical environment, directly with patients, to acquire professional competencies. Through student perceptions, emotions, and experiences, one can sense the impact of the theoretical concept of professional identity in nursing and humanistic nursing theories. Due to the crisis, participants describe their lack of motivation, poor concentration, and significant learning difficulties. The organization of work at the faculty, and the efforts of teachers in this crisis are assessed as being very effective. Students fully support the plans for long-distance teaching, and see the postponement of clinical internship as a life-saving solution. They also hold that the faculty is effectively implementing measures aimed at the protection of students, teachers, and the wider community.

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Article

Online Delivery and Assessment during COVID-19: Safeguarding Academic Integrity

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Abstract: Globally, the number of COVID-19 cases continues to rise daily despite strict measures being adopted by many countries. Consequently, universities closed down to minimise the face-to-face contacts, and the majority of the universities are now conducting degree programmes through online delivery. Remote online delivery and assessment are novel experiences for many universities, which presents many challenges, particularly when safeguarding academic integrity. For example, invigilated assessments, often considered as more secure, are not an option given the current situation and detecting any cheating would be significantly challenging. This paper reviews assessment security in the digital domain and critically evaluates the practices from different universities in safeguarding academic integrity, including associated challenges.

Keywords: academic integrity; COVID-19; remote learning and teaching

1. Introduction

Due to the COVID-19 pandemic, most governments around the world have temporarily closed educational institutions in order to contain the spread of the virus. These closures impact over 60% of the world's student population [1]. According to the UNESCO Institute of Statistical Data, the closure of schools has affected 67.7% of total enrolled learners in 144 countries that have implemented closures. This figure corresponds to learners enrolled at pre-primary, primary, lower-secondary, upper-secondary levels and tertiary education levels. In a recent survey, 86% of college presidents find summer enrollment numbers as their top pressing issue in the face of COVID-19 [2]. In addition to that, graduation ceremonies worldwide have been postponed indefinitely and student/graduate unemployment rates have risen drastically [3–5].

Education providers that cater to all levels of students are transitioning to remote learning and online assessment despite the many challenges that entail. Remote learning or online teaching has affected all branches of education. For example, this has substantially affected the primary education sector since students are overly dependent on teachers, whereas, in both secondary and higher educational sectors, students are faced with the challenge of completing their curricula and preparing for benchmark examinations or final examinations in a short period of time. However, there looms uncertainty about conducting benchmark examinations, particularly in secondary and higher education sector. Examinations cannot be conducted online since they require strict invigilation. Among the challenges faced by educators is academic integrity and student assessment when students are not physically in the classroom. Periodical assessment and evaluation are possible through take-home assignments, although it poses a threat to academic integrity in certain cases. Much of the writing assignments in the higher education sector that happen without proctoring can still continue to operate during the COVID-19 pandemic.

On 23 March 2020, Cambridge International Examinations (CIE) released a statement announcing the cancellation of Cambridge IGCSE, Cambridge O Level, Cambridge International AS and A Level, Cambridge AICE (Cambridge Advanced International Certificate of Education) Diploma, and Cambridge Pre-U examinations for the May/June 2020 series across all countries [6]. Advanced Placement Exams, SAT (Scholastic Assessment Test) administrations, and ACT (American College Testing) administrations have been moved online and cancelled. In Sub-Saharan Africa (SSA), the West-African Examination Council (WAEC) has issued a notice postponing the WASSCE examination until further notice, due to the COVID-19 outbreak. For Ghanaian, candidates taking the West African Senior School Certificate Examination (WASSCE), the West African Examination Council (WAEC) has indicated its readiness to organise an independent exam this year [7]. Tests have been affected in all countries in SSA as a result of COVID-19 precautions [8]. In Sri Lanka, IELTS (International English Language Testing System) examinations have been temporarily suspended, and, starting from the onset of the pandemic in March, the British Council issued a notice prohibiting candidates with recent travels to China from taking the IELTS examination [9]. Moreover, major international exams such as Cambridge IGCSE, Cambridge O/L Exams, Cambridge International AS and A Level, Cambridge AICE Diploma and Cambridge Pre-U have been suspended temporarily [6].

To provide a quick overview of the topic to a wider readership, the Introduction is organized under three subheadings that are crucial to understanding the topic addressed in this paper: Section 1.1 presents an overview of the concept of academic integrity from which branches out the discussion in Section 1.2; the practices of academic integrity in the pre-COVID scenario; and Section 1.3 introduces the concept of assessment security.

1.1. *An Overview of Academic Integrity*

Defining academic integrity is complex and the definition of academic integrity is mostly based on consensus. According to the International Center for Academic Integrity, academic integrity is defined "as a commitment, even in the face of adversity, to six fundamental values: honesty, trust, fairness, respect, responsibility, and courage" [10].

Teresa 'Teddi' Fishman believes that academic integrity movement in the United States was informed by the early turn towards concepts of academic integrity based on the British Higher education models that addressed ethical and moral issues [11]. Universities and higher education providers in the United States enjoy a high degree of autonomy and this autonomy was reassured in 1819 when the "US Supreme Court" ruled that "the government of New Hampshire did not have the legal right to exert managerial authority over a university" [11]. According to Fishman, higher education in the US is autonomous from state or national governance [11] and higher education quality control falls within the mandate of private accrediting agencies [11].

In Australia, academic integrity means "acting with the values of honesty, trust, fairness, respect and responsibility in learning, teaching and research" [12]. Four major legislations and supporting regulations in Australia require universities to uphold academic integrity central to educational standards. These legislations include: (1) The Tertiary Education Quality and Standards Agency Act 2011, (2) The Higher Education Standards Framework (Threshold Standards) 2015, (3) The Education Services for Overseas Students Act 2000 and the related National Code of Practice for Registration Authorities and Providers of Education and Training to Overseas Students 2007 and (4) The Australian Code for Responsible Conduct of Research 2007. Much like the US, Australia also considers primacy of institutional autonomy as the topmost priority concerning academic integrity [12]. Principle 2 is based on collective responsibility of the staff and students, while Principle 3 states the importance of the wholistic university approach to academic integrity. In practice, however, international students in Australian universities, specifically the Chinese students, are reportedly less accustomed to academic integrity practices in Australia. Tracey Bretag writes how Ballard and Clanchy (1991) first identified the difficulties Chinese students had in citing others' work according to Western academic conventions [13] (p. 24). In Australia, academic integrity is referred to as "educational integrity" since academic integrity is understood as a commitment not only from students but also from everyone involved in higher education [13]. The idea that academic integrity is more than a commitment from students resonates with UK's understanding of academic integrity. Bretag quotes an excerpt from the Asia Pacific Forum on Educational Integrity (APFEI) website explaining that "educational integrity" is "multi-dimensional" and it is only possible through a joint effort of everyone in the "educational enterprise, from students to teachers, librarians, advisors, research colleagues and administrators" [13]. With this explanation, it is evident why APFEI introduces 'integrity' with 'educational' rather than just pairing 'integrity' with the conventional term 'academic'.

Academic from Vriie Universiteit Amsterdam reveals that "not everyone is bothered to think about integrity. Integrity doesn't always come on the agenda. Paying attention is a challenge" [14]. Another academic from the University of Reading highlighted "pressure to perform, academics are under pressure to offer high-quality education to students, Students are under pressure too, financial pressure, families, parents, society", which makes them take shortcuts [14]. Speaking of academic integrity, an Education Fellow from the University of New South Wales shares the following: "We have moved from a world of information scarcity to a world of information overload. It makes it difficult for institutions to assess whether the work of students is the work of their own or not" [14]. Contrary to these perspectives is another academic who recognised that students do not deliberately engage in academic misconduct and believes that plagiarism is caused by "lack of familiarity with plagiarism in general—lack of familiarity with plagiarism software". He further states that "even the staff fails to understand the difference between similarity and plagiarism" and this has created a change in the role of the staff: "Instead of being a mentor, they take on a detective role. It is not productive for the student's development. My personal experience is that students do not want to plagiarise but they are very often unaware of referencing if they had come from a different culture" [14]. The different attitudes (of academics) enumerated under this section show the different perspectives on academic integrity across different countries and contexts which makes it intriguing for us to examine how academic integrity is practiced across academia.

1.2. Practices of Academic Integrity—Pre-COVID-19 Scenario

Academic integrity practices in different countries in the pre-COVID-19 context is diverse. Universities in certain countries pioneered academic integrity policy. In the context of academic integrity in the USA, establishing the International Center for Academic Integrity (ICAI) was a leap in the development of academic integrity. The ICAI was founded (as the Center for Academic Integrity) in 1992 in response to alarming research on the subject conducted by Founding President Donald McCabe [11] (p.16).

As Australian universities were addressing issues around internationalisation, academic standards, plagiarism, and higher education a similar challenge was faced by the higher education providers in the UK. In particular, the Office of the Independent Adjudicator for Higher Education in the UK "called attention to inconsistencies in penalties for plagiarism across the higher education sector" [13] (29). Eventually, this developed the project Academic Misconduct Benchmarking Research (AMBeR) and led to a nationwide approach to detecting and dealing with plagiarism. This approach relies heavily on the text-matching software Turnitin [13] (29). Academic integrity is an overarching term for the commitment to uphold six fundamental values in academic practice in order to prevent a wide range of dishonest activities. However, discourses on academic integrity extensively discuss the issue of plagiarism and the most widely used strategy to cope academic integrity at present is text-matching software. This sidelines other threats to academic integrity. Yet, discussing plagiarism is particularly important in the discourse of academic integrity for two reasons: It is the most common act of academic misconduct that threatens academic integrity and it is the most frequently detected act of dishonesty.

Text-matching software is, therefore, in the forefront in the academic integrity discourse. The constant connection made between academic integrity and text-matching software perpetuates the fallacy that academic dishonesty means plagiarism when, in fact, academic dishonesty is constituted by a wide range of dishonest activities.

While most universities worldwide uncritically employ Turnitin as their sole tool in detecting plagiarism, writers in the USA and elsewhere have been less welcoming of the software (13) (29). These writers maintain that Turnitin is erroneously marketed as "plagiarism detection software". Bretag also states that no software can "detect plagiarism" and the only way in which Turnitin achieves this is by highlighting text matches [13] (29). It has now been established to a considerable extent across academia that text-matching software or the so-called plagiarism-detection software is not foolproof and that its use is mostly limited to identifying potentially problematic cases, which are then reviewed and addressed by respective authorities. A considerable number of academic staff are concerned about Turnitin's risk of establishing an adversarial relationship between teacher and student. Howard states that grappling with plagiarism makes the staff become enemies rather than the mentors of students and that this situation replaces the "student-teacher relationship with the criminal/police relationship" [13] (p. 29). It also resonates with Ken Tann's idea about academics becoming "detectives" in order to track plagiarism and its negative impact on student development [15]. Howard further states that academic staff may run into the risk of "categorising" all students as "criminals" if plagiarism is considered a "unitary act rather than a collection of disparate activities" [13]. Most importantly, Howard recognises the need of major pedagogical revision [13].

Australia's concerns for academic integrity encouraged academics, researchers, and policy planners to take on research projects on academic integrity and policy development. One such project is the Academic Integrity Standards Project (AISP) that aimed at developing shared understanding about academic integrity across Australian higher education providers and "improving alignment of academic integrity policies and their implementation" [13] (p. 31).

The UK's Higher Education Review process implemented by the Quality Assurance Agency (QAA) is the national system in place for assuring the quality and standards of higher education [15] (43). They monitor and advise on standards and quality in UK higher education and ensure students working towards a UK qualification get the higher education experiences they are entitled to expect [16].

In Canada, the practice of monitoring higher education quality assurance remains within the compass of the provincial level rather than the national level. For instance, quality assurance in the University of Calgary is done by a separate body within the state of Alberta where the University is situated in. In the province Alberta, quality assurance is overseen by the Campus Alberta Quality Council. It operates separately from the government, but "makes recommendations to the provincial Ministry of Advanced Education" [17].

Perspectives from China show a lack of understanding of academic integrity and lack of adherence to practices of academic integrity. Until 2000, there was just one Chinese academic research article on academic integrity and this figure has risen to 1074 by 2013 [18] (p. 101). By 2013, the majority of articles focused on academic integrity from the angle of academic misconduct [18]. Since 2009, the Ministry of Education in China has issued six policies on academic misconduct and there is evidence denoting that a considerable number of persons have been penalised for academic misconduct between 1999 and 2010 [18]. Apart from that, Chinese higher education institutions are taking institutional approaches to address challenges related to academic integrity. Peking University established its own policies in 2001 to combat academic misconduct and it was based on the American FFP formula which stands for "falsification, fabrication, and plagiarism" [18].

In Sri Lanka, universities are under strict observation of a powerful overseeing body, the University Grants Commission (UGC). What is significant about the UGC in Sri Lanka is that both state universities and certain private universities come under the purview of this powerful body. Even private universities that are established in Sri Lanka seek recognition and endorsement from the UGC as students do not enrol in private universities if universities are not recognised by the UGC. Therefore, academic integrity policy and practice do not show much difference among Sri Lankan universities.

1.3. Overview of Assessment Security

According to CRADLE (Centre for Research in Assessment and Digital Learning) [19], academic integrity is meant to equip students with the competences and values necessary to engage in ethical scholarship while assessment security focuses on securing assessment against cheating, and on detecting any cheating that may have occurred. CRADLE also states that both academic integrity and assessment security are necessary to ensure that students who have completed their university education have met the required learning outcomes. Threats to assessment security can be mitigated by designing assessment methods that are resilient to challenges of contract cheating. Such methods increase learning productivity while developing essential skills in students.

A basic principle in assessment design is to ensure that assessments enable students to demonstrate their learning practically. However, assessment methods other than benchmark examinations and viva have the risk of contract cheating. Even though formal written examinations may reduce contract cheating, written examinations do not accommodate assessing all types of learning [20].

Across universities in the higher education sector, assessment security is maintained through adherence to deadlines. In the past, deadlines were set with the view that limiting or controlling the time available to complete assignments will prevent cheating. However, there is increasing evidence to say that deadlines no longer prevent students from cheating. "Essay mills" and freelancers or "ghost-writers" offer their service for high-stake assignments within a short duration for a higher charge. Another means of maintaining assessment security is the use of checkpoints. Education providers can reduce the risk of cheating by setting up "checkpoints" for detection. With 'checkpoints' or advanced drafts, academics are able to verify if students actually engage in their academic work. It is helpful in tracking research findings and discussions, conducting online testing and evaluating group work. Many universities employ vivas to combat academic misconduct and to maintain assessment security. Apart from that, institutions have institutional approaches to maintaining assessment security. They could be annual reviews in universities, aiming to improve the learning experience for all involved, including students, staff, and programme leaders. This further aids programme teams in programme revisions as part of the review process. The central mission of such review is to use both quantitative and qualitative data provided by students and staff to shape and define assessment and feedback strategy for the future [21]. Not many higher education providers worldwide were prepared for a crisis like the COVID-19 pandemic. Until the COVID-19 outbreak, many universities still used conventional classrooms/contact education that required the physical presence of students and universities still maintained strict attendance policies. Due to the conventional mode of delivery, many universities were not fully prepared to facilitate online delivery and assessment. For instance, South Asia does not have prior experience in coping with a pandemic. Countries that have prior experience in coping with pandemics and natural disasters have better disaster preparedness and disaster management. Countries in South East Asia, Canada, New Zealand, United States and many universities in Europe have conveniently shifted to online delivery due to their disaster preparedness and contingency plans. However, South Asian universities are far behind in terms of adapting to remote online delivery. The need to develop online platforms, policy for online learning and teaching, rules and regulations is greatly felt at a time like this.

Eaton [17] elaborates on the contingency action plans of the University of Calgary and its resilience in the face of crisis. The floods that affected Calgary in 2013 have created a sense of disaster preparedness, and, due to this, Eaton believes that they "are in a unique position" now that they have already responded to a crisis which occurred during their Spring term that year. The University of Calgary's approach to integrity seems to be people centered. Eaton mentions how the University's Provost encouraged the entire University to 'start from a place of trust'. Aligning with the institutional mandate of prioritising people, as articulated in the Academic Plan, the University emphasised prioritising health and safety. Bearing these principles in mind, the Taylor Institute for Teaching and Learning provided support for the university's smooth transitioning to remote learning. Two websites were developed to provide direction and guidance to students and faculty (respectively): The Learning Continuity website and Teaching Continuity. In the meantime, a separate website was developed for Academic Integrity in Online Learning, linking it to additional resources to help staff. In addition, a series of free virtual training sessions are offered on a weekly basis since March 2020 benefitting the faculty, TAs and members of the public [17].

This paper examines the changing landscape of higher education by reviewing assessment security in the digital domain and critically evaluating practices from different universities in safeguarding academic integrity and challenges associated. The significance of this study is that it attempts to present an overarching picture of academic integrity in digital domain in the COVID-19 context. In this manuscript, the authors review information from selected countries and higher educational institutes. The reason for being selective with the countries and institutions is convenience and accessibility to information. Information on the impact of coronavirus on education and academic integrity is scant. Therefore, this paper reviews information that is readily available on the internet as well as publications available through a range of subject specific databases, such as Web of Science and ScienceDirect. Data collection for the study employs documentary research from multiple sources of data. The documents reviewed in this study are books, websites of selected universities, newspapers and national and institutional policy documents on academic integrity.

2. Assessment Arrangements under COVID-19

2.1. Assessment Practices—Pre-Covid-19

Universities, in general, use formative assessment and summative assessment for different purposes [21]. Formative assessment monitors student learning while providing ongoing feedback to staff and students. This form of assessment is largely for students' learning through understanding their strengths, weaknesses and improving their skills. Faculties can use formative assessment to gather information about student weaknesses in order to provide further support for their development. They can be tutor-led, peer or self-assessment. Most importantly, formative assessments are low-stake assessments and this assessment does not contribute to the final grade/mark they receive for the course. Some examples of formative assessments are peer evaluation, in-class worksheets, pop quizzes, presentations, journals, and diagnostic tests. On the other hand, summative assessment evaluates student learning or meeting learning outcomes at the end of an instructional unit by comparing it against some standard or benchmark. Summative assessments often have high stakes as they contribute to the final grade of a student. It provides little feedback to help them improve before the conclusion of the program.

In the UK, the Quality Assurance Agency (QAA) for Higher Education provides guidelines and guiding principles to higher education providers through its Quality Code for Higher Education [20]. It is mandatory that all higher education providers in all parts of the UK follow the UK Quality Code for Higher Education. It is generally referred to as the Quality Code and it consists of Expectations, Core Practices and Common Practices advisable to higher education providers. 'Core Practices' are mandatory for all part of the UK while 'Common Practices' are only mandatory in Scotland, Wales and Northern Ireland. In the UK, in terms of maintaining educational standards, it is a core practice that education providers use external expertise, assessment and classification processes that are reliable, fair and transparent [20]. The UK has a range of assessment practices in the pre-COVID-19 context. Some of them are, time-constrained unseen exams, in-class presentations, portfolios, viva voce exams, posters, lab work, Objective Structured Clinical Examinations (OSCEs), and theatre, drama and performance [21,22].

In Nigeria, summative assessment is the predominant form of student assessment [23] (p. 156). Since summative assessment carries a considerable score, more attention is given to summative assessment. Due to this reason, academic misconduct that is associated with formative assessment are less likely in Nigeria. Academic misconduct in Nigeria is largely cheating in examinations and in-class tests where students can be found "helping each other". There are reported cases where Nigerian academic staff use pop quizzes as a form of summative assessment. Other forms of summative assessments allowed in Nigerian educational institutions are "controlled examination, open-book examination, essay or report, term paper, critical analysis, portfolio, dissertation, oral presentation, skill performance, and attendance" [23]. Not all these assessment types are used in most Nigerian universities. Therefore, the predominant use of one form of assessment has created a notion of integrity in relation to the most used type of assessment. Due to this, students may overlook the requirement of academic integrity when it comes to other forms of assessment [23].

Institutions across the higher education sector use diverse innovative assessment practices. One innovative assessment method practiced by the Department of Psychology of the MMU is using student conferences as assessment [21]. The Department has used this mode of assessment for the past 12 years as a space for Year 3 students to present their final projects. It resembles any other national conference with keynote speakers and "the presentation is assessed and moderated by three members of staff" [21]. Certain universities use detailed summative feedback by breaking down the marking criteria and marking grid into sections with very detailed band descriptions. Students have access to the marking criteria via Moodle and it gives them the chance to identify their areas of strength and areas for improvement. One of the assessments on Engineering programmes includes presenting to industry panellists where they receive feedback from professionals as well as academics. Students in Manufacturing postgraduate course, work with life clients on authentic tasks. Students are assessed on "a group report, a poster, and gives a presentation to a large group of academics, students and industry specialists" [21]. The group presentation carries 70% of the grade, while 30% is allocated to individual performance. Furthermore, postgraduate students are assessed on authentic work with real companies to which they provide live consultancy. Students provide written reports to companies and present the findings and recommendations verbally which is assessed by the department [21]. Apart from that, the University of Glasgow piloted the use of social media to encourage active participation in lectures and seminars. Twitter is used as a form of assessment in order to encourage active participation in lectures and seminars; the staff at the University of Glasgow piloted the use of social media as a form of assessing students' skills [21].

The University of Greenwich in the UK uses multiple innovative assessment practices as a substitute for traditional written essays. For example, one assessment practice employed in the Public Relations study programme is designing assessments in which students are required to use technology when they address past briefs from clients. Secondly, the Department of Law holds a Virtual Law Clinic which is a collaboration of Law Department staff. This Virtual Law Clinic uses technology to bridge the gap between "academic and professional practice by involving students, staff and professional bodies into addressing legal queries from the public" [21]. Students are assessed on the legal advice they provide to the clients during the Virtual Law Clinic [21]. History students are assessed on video presentations that have come to replace traditional essay writing. Another innovative assessment practice is to employ a project for peer guidance via podcasts, in which Level 5 students created audio assessment guides for junior students. In addition to that, creating podcasts are utilized as a form of assessment and academic staff assess students based on a podcast submission [21]. Audio-visual feedback is another assessment practice at the University of Greenwich. For example, Adobe Connect is used by academic staff to provide feedback to MSc students [21].

2.2. Take-Home Exams under Current COVID-19 Condition

Many universities have resorted to alternative forms of student assessment during the COVID-19 pandemic. Among the types of practical assessments that may be moved to online assessment are: laboratory-based practicals (e.g., chemistry, physics, health sciences); performance-based assessments (e.g., fine arts, dance); physical artefact development (e.g., engineering, fine arts); psychomotor skills (e.g., physiotherapy, nursing and other health professions); interpersonal skills (e.g., medicine and other health professional consultation skills); language skills (vivas). The suggested alternatives for these practical assessments include video-based uploads using Cloud technology; online simulation-based tasks; submitting online portfolio; real-time observed practicals/vivas via Zoom or Blackboard Collaborate [24].

Take-home exams are one such alternative mode of assessment where the original assessment cannot be completed in the usual way. Formal examinations that were scheduled to take place as face-to-face examinations have now taken the form of take-home online examinations. These exams can be completed by students in the comfort of their homes with access to subject notes, texts and resources. This does not mean that this is not time-bound. Take-home exams are time-bound and due to that reason, they also come under time-constrained assessments. However, instead of writing during a set time period (for example, 2-h or 3-h exam), students have a window period of about few days and up to a week to submit their answers. Take-home exams generally contain one or more questions that require essay or long-form responses. Most importantly, take-home exams require citing examples and references. As take-home exams are not under the same time pressure as a sit-down exam, the criteria for grading take-home exams include argumentation, organization, evidence, citation, and language fluency. In terms of adaptability, take-home exams are considered relatively easy to convert to online environments as they do not need change. Essay questions and problems designed for examinations can be conveniently translated to a take-home, open-book exam with slight modifications depending on expected learning outcomes [25]. It is also important that tasks are reconsidered and revised to make sure that students can still produce their writings with the limited resources available to them.

In the UK, certain universities make examination papers available to students through virtual learning environments [25]. Students are then required to download the examination paper, complete the examination on the student's own computer and submit their completed examination paper through Turnitin. The time duration of the take-home examination is the same as the conventional exams taken in person. Furthermore, in most cases, the take-home examination is given a 48-h window within which students can complete the take-home examination and submit it. This 48-h window is given to resolve technical issues, glitches or allow students to grapple with unexpected situations if they arise. It also facilitates students with a Learning Support Plan who have Special Arrangements for examinations such as additional time, rest breaks, individual exam room, or the use of a computer. What is noteworthy is that this 48-h window provides an equitable opportunity for students with physical and mental disabilities even in this difficult time [25].

2.3. Time Constrained Assessments (TCAs)

Deakin University in Australia uses time-constrained assessments [26], even though different Australian universities seem to practice different approaches to assessment under COVID-19. For instance, Monash University offers the option of withdrawing from a course unit without having to face an academic penalty [27]. The University of Bristol in the UK also allows alternatives for time-constrained unseen exams, and these alternatives include open-book exams, Multiple-Choice Questions (MCQs) or free-text questions [22]. Open-book exams are somewhat similar to take-home exams. However, the distinction between these two is that open-book exams are similar to traditional campus-based exams: They are more restrictive in terms of time and space, and citations are not required unlike in take-home exams. Students are generally required to log on to the respective online examination system remotely, download the exam paper, answer the questions and upload the answer script within a more constricted time window than what is given for take-home exams. Certain universities transform traditional exam papers to computerized papers where students are required to take the test by remaining on their personal computers for a specified time period (for example, 2 h or 3 h).

In Sri Lanka, social interaction among students is high and it is further heightened on social media platforms such as Facebook, WhatsApp and Viber groups. Therefore, there is a relatively higher chance of students communicating with other students. Academics in Sri Lanka have found that it creates a higher chance of knowledge sharing among students, making it difficult to assess students.

2.4. Pass/Fail Option Instead of Conventional Exams

Oxford University announced that the "majority of examinations for first year undergraduates will be cancelled, and students will be deemed to have passed" [28]. This arrangement excludes Law and Medicine students since assessments will be rearranged for professional qualification reasons. For second- and third-year (non-finalist) undergraduates, and first-year MPhils, examinations will be postponed to the next academic year. Third-year undergraduate exams are given an exception since these exams are taken by a mix of continuing and leaving students. For that reason, exams will be continued. Moreover, final-year undergraduates and taught postgraduate exams in Trinity term 2020 will be replaced with alternative forms of assessment such as open-book versions of papers and longer pieces of work completed over several days [28]. Oxford's reason for this approach is its aim of supporting students with various circumstances, whilst mitigating the impact of the pandemic to the best of their ability. Oxford strives "to develop a workable solution—to reduce complexity, minimise disruption, and provide an equitable approach for all candidates" [28].

Similarly, a considerable number of universities worldwide follow No-Detriment policies as a safety net for students who fail to perform their best in this unprecedented time [29–31]. No-Detriment policies have enabled students to freeze their grades and not be negatively affected by the challenging circumstances they have to work in. In the UK, No Detriment policies are considered the popular "blanket" that helps students retain their grades for exams and periodical assessment; this blanket allows students to improve on their grades and not fall below its current level. A total of 23 universities out of 24 Russell Group Universities in the UK have adopted the policy [31]. However, there are slight changes in the implementation of this policy. For instance, in the University of Oxford, this blanket policy applies only to students with a current average of above 50 per cent [31]. Some universities have completely turned down student requests and petitions calling for No-Detriment policies. These universities maintain that No-Detriment policies compromise academic integrity and undermine education standards of universities [31].

In terms of assessment strategy, certain universities show willingness to have blanket policies in place. For instance, during the COVID-19 pandemic, the University of Calgary shows a willingness to compromise [17]. According to Eaton, on March 22nd the University proposed to implement an alternative system for final grades for the Winter 2020 term, which gave students "the option of their usual letter grades or Credit/Fail" [17]. On 22 April, the University announced: "a return to the regular grading system for the Spring 2020 semester onwards, so as not to affect students' grade point average for an extended period of time" [17].

3. Challenges to Safeguarding Assessment Security

This section makes extensive reference to the UK Quality Code for Higher Education, which presents a set of guiding principles for education providers to encourage assessment security. The reason for making reference to the UK Quality Code extensively is due to its clarity and overarching nature—most countries do not have such overarching national level documents that provide guidance to HE institutes. In the UK Quality Code, Guiding Principle 10 encourages assessment security and highlights the importance of ensuring integrity through all aspects of the assessment process [20]. In the UK, assessment security is understood as a bilateral scenario. On the one hand, the UK Quality Code for Higher Education is meant to protect students against unfair assessment activities, unfair assessment criteria and unfair grading. On the other hand, it is meant to help academics abide by university academic integrity policies, maintain academic standards, and grapple with plagiarists, contract cheaters and other forms of academic misconduct. It could be understood as a two-way shield that protects both parties involved. The UK Quality Code identifies the following as potential risk areas in student assessment:

"transit of draft assessment questions/tasks between staff and between campuses and transit of materials to external examiners"

"invigilation of examinations"

"confirming the identity of students undertaking assessments, whether in an examination room or online, and when student work is submitted in person, online or through other means. Students' marks and related information (such as extenuating circumstances applications) are held securely and disclosed only to those who need access and have a right to see it" [20].

What is noteworthy is that, the UK Quality Code encourages university lecturers to bear in mind the reflective question, "What measures do you have in place to ensure the security of your assessments?" as they design assessment activities, assessment criteria, benchmark criteria, and grading" [20]. Bearing this in mind, a question worth examining is what makes assessment security difficult to enforce.

3.1. Assessment Restrictions Are Harder to Enforce Remotely

According to the Irish Universities Association, there is a high probability for online students to cheat on assessments when compared to campus-based students. Students are highly likely to use the same opportunities to cheat on homework, take-home assignments, essays and group-work when they are under high pressure. Assessment restrictions such as invigilation of examinations, quizzes and presentations are highly impossible in remote online teaching. For example, in a remote online examination, students are able to refer to other sources and seek the support of a friend or a freelancer to answer the questions on time. If students take un-invigilated computerised online exams, it is a major challenge to student identity verification. Not verifying student identity leaves room for third parties to take the exam on behalf of students and this could result in a serious breach of examination regulations. A lack of online proctoring or invigilation leaves room for various modes of contract cheating. However, one-on-one invigilation is impossible in the present situation. One alternative mode of assessment is virtual invigilation, which is highly expensive [32].

Invigilation in the UK is known as "proctoring" in the US, which is why remote invigilation is also known as 'online invigilation', 'online proctoring' or 'remote online proctoring'. TestReach [33] defines online invigilation as the experience of sitting an exam in a physical test centre or recreating an exam hall in an online environment. Unlike in conventional exams, where candidates travel to an exam venue to sit their exam, online invigilation facilitates exams from any location using their computer with internet connectivity. During the exam, the candidate is supervised live by an online supervisor over the web employing various communication and security technologies. It is the duty of the supervisor to authenticate the identity of the student to monitor the candidate throughout the exam to ensure that no cheating occurs. This process entails, (1) "pre-checks" to ensure the candidate's technical environment is set to support a remote online exam, (2) "candidate authentication" to verify that the correct person has presented to the exam, (3) "securing the environment" to ensure that the candidate is in a secure environment with no resources that breach examination regulations, (4) candidate supervision to ensure there are no infringements of the rules, and (5) reporting, which means informing the examining body of the candidate's behaviour during the exam [33].

3.2. Lack of Support to Students Due to Remote Delivery and Students' Perception of Academic Integrity

Remote delivery has restricted student access to information and support. On the one hand, library services are not accessible to students worldwide and open-source journals, free digital libraries and resources are the only information materials available to students. While some students have free access or the ability to purchase academic papers online during the pandemic, there also exist students who cannot access or afford to purchase reading materials from internet sources. This results in a knowledge gap which could eventually lead students to engage in acts of academic misconduct. On the other hand, Information on academic integrity policy, rules, regulations, types of misconduct and information on how to overcome academic writing challenges are not readily available to students during remote delivery. Therefore, students may consciously or unconsciously tend towards academic misconduct. A lack of support encompasses a lack of support to students with special needs as well. In virtual classrooms, students are compelled to become comfortable with a virtual environment which may not even cater to their individual learning styles. For instance, kinaesthetic learners may be placed at a disadvantage since remote delivery does not cater to kinesthetic learners. Similarly, visual learners may not benefit from remote learning that relies heavily on oral lectures. In such a backdrop, academic misconduct may happen.

3.3. Technological Issues (As a Result of Remote Delivery)

Assessment restrictions are difficult to be imposed as students are challenged by various technological issues. For instance, online delivery may get affected by even the most mundane issues, such as bad weather in different locations from which students access online teaching platforms. Students in low-income countries and middle-income countries do not have the infrastructure and resources to shift their delivery to online remote learning. In such contexts, a considerable number of students are excluded from remote learning, which is accessible to only a minority of students with resources and the means to fund themselves. Another issue is computer literacy or the lack of computer literacy in certain students. Online examinations and quizzes may be challenging for students who are challenged by technologies. Similarly, students with special needs may also be excluded due to this mode of learning. Technological issues also challenge the implementation of online time-constrained assessments and examinations and it is difficult to enforce assessment security in such a setting.

In countries such as Sri Lanka, poor infrastructure affects student learning. Students who do not have access to laptops and computers use Learning Management Systems (LMS) software on their mobile phones which places them at a disadvantage. Buying internet facilities and downloading content is also not affordable for many students. Due to these reasons, students are inclined to resort to acts of academic misconduct. In Sri Lankan universities, students who engage in remote online learning using smartphones are challenged as they submit their assignments and papers via LMS and Turnitin. Therefore, universities have given alternative modes of submission to students. Students are allowed to write on physical papers and upload photos of their answers on the LMS. However, this makes the use of text-matching software impossible, leaving a modest chance for students to commit acts of academic misconduct.

3.4. Contract Cheating

'Contract cheating' is when a student uses the help of a third party to complete their work and then submits it for grading as their own work [34]. These third-party essay writers can either be companies or individuals and they are generally known as 'essay mills'. Contract cheating is not permitted in higher education. Third-party essay writing personnel is contacted (but not limited to) using a website that promotes themselves or receives orders. 'Essay mills' often outsource the work once again to individual writers [34]. Even though these companies are often referred to as 'essay mills', their products can range from "essays to lab reports, reflective journals, dissertations, computer programming, film editing and other services" and their work range across many disciplines [34]. This contract cheating between a student and a third party may involve payment or other favours. Contract cheating is undetectable unless academic staff pays close attention to student in-class performance and assessment performance. To grapple with contract cheating, QAA suggests organisation-wide detection methods such as linguistic analysis tools to complement text-matching software [34] (p. 4). Contract cheating does not always involve monetary exchanges; it has other facets, such as sharing work that is subsequently submitted as students' original work which then constitutes another academic misconduct—'collusion'. Whether third-party essay writing involves monetary exchanges or not, it is a threat to assessment integrity. Assessment integrity is founded on fair, equitable and reliable processes of assessment in order to assess the extent to which students have achieved the learning outcomes desired from a particular program. As students who engage in contract cheating are assessed for the work done by a third party, it is a clear threat to maintaining standards in higher educational institutions.

Examining assessment security during the COVID-19 period calls for a comparative study of the pre- and post-COVID-19 periods. As evident from research reviewed above, assessment security is difficult to enforce even in on-campus study environments. Considering the challenges to assessment security even in on-campus study programmes, enforcing assessment security in a remote study environment is definitely much more challenging. Remote teaching and learning is carried out globally with minimal resources such as limited learning support, teaching aids, library resources and monitoring. Since on-campus examinations, mid-semester tests, pop quizzes and presentations are impossible to be administered remotely, alternative modes of take-home assessments are employed by academics. Some of these alternative modes of assessment are vulnerable to many forms of academic misconduct, which makes it easier for students to cheat on homework, take-home assignments, essays, remote-online exams/quizzes and group-work. Many forms of contract cheating also go unnoticed due to loopholes in alternative remote assessment methods. Therefore, fairness in assessment during remote delivery and remote assessment cannot be guaranteed due to difficulties in monitoring students.

4. Challenges to Safeguarding Academic Integrity

Educational Developers from Victoria University recognise contract cheating as, "the real ongoing challenge. Contract cheating websites provide the option of doing the assignment in 2–3 h, the student will pay more but there is no detection using the existing tools. They are sophisticated contract cheating services" [14]. In the present global context, new challenges have arisen in the remote learning landscape. According to another academic, "instructors who try to prevent contract cheating by conducting in-class writing assignments, there may be new challenges in this remote learning landscape" [14]. For instance, in-class examinations and assignments are aided by freelancers on platforms such as Fiverr.com. This too is a form of contract cheating. Virtual test takers cannot be invigilated strictly just as students who are physically present in a physical classroom, and this has increased the risk of freelancers aiding online real-time tests [14].

In the UK, the UK Quality Code for Higher Education, Academic integrity is understood as a mutual commitment. Education providers are encouraged "to operate effective processes for promoting academic integrity and identifying, investigating and responding to unacceptable academic practice. Providers implement effective measures to encourage students to develop and internalise academic values and good academic practice" [20]. Practical steps towards academic integrity include (1) avoiding the recycling of work and assessments too regularly, (2) training invigilators appropriately, (3) having good exam room etiquette and procedures in place, as well as appropriate security measures for exam questions and (4) making everyone aware of the consequences of cheating. The UK Quality Code also stresses the importance of ensuring that students do not obtain credit or awards through any form of unacceptable academic practice relating to assessment (including plagiarism, cheating in exams, contract cheating, collusion and impersonation) [20]. Providers in the UK implement clear processes through which unacceptable academic practice can be reported by anyone with relevant knowledge and investigated objectively and fairly. Furthermore, it also encourages proportionate, consistent and equitable penalties for proven cases of unacceptable academic practice. Most importantly, the UK Quality Code for Higher Education recommends staff to reflect on the question, "How do you ensure that you operate effective processes for promoting academic integrity and identifying, investigating and responding to academic misconduct?" [20].

With the COVID-19 pandemic and the shift to online delivery of study programmes, academic integrity has moved into unchartered territory. Academic integrity is now mainly challenged due to the wide availability of contract cheating services and the increasing pressure on students to perform even during the COVID-19 pandemic. With institutional systems in place for detecting plagiarism, there is faint hope that the recycling of work and intellectual property theft may have been prevented to a considerable extent despite the COVID-19 pandemic. However, the preparedness of academic staff to grapple with other forms of academic misconduct is still very little. Even though academic staff in most countries receive considerable training for proper invigilation activities, such training has proved pointless in the face of the COVID-19 pandemic since on-campus examinations are out of the equation. Except in high-income countries, academic staff worldwide had very little preparedness for assessing students through alternative modes of assessments carried out remotely. Another factor that affects remote assessments is the discipline-specific nature of assessment design. Even though many academic programmes employed diverse modes of assessment for evaluating students in the pre-COVID-19 period, certain study programmes in the science, technology, engineering and mathematics (STEM) fields cannot shift to a remote delivery with entirely different alternative modes of assessment. For example, even though take-home exams, quizzes, papers and presentations are widely employed in the Social Sciences and Humanities, it is impractical for STEM fields to transform their assessment practices to take-home exams, quizzes and papers entirely. Most study programmes in the STEM fields rely on practical hands-on field experience and empirical knowledge. Therefore, students from STEM fields are largely affected by this situation due to the restricted study conditions they face. This situation has the same impact on students from research-based study programmes. For instance, research-based Masters and PhD programmes are greatly affected by students' lack of access to continuing research work. In this challenging setting, falsification and fabrication of data, plagiarism, and contract cheating are anticipated.

4.1. Policing Academic Integrity and Associated Challenges

Detecting academic misconduct and policing academic integrity entail a number of challenges and complexities. Firstly, academic staff also lacks consensus about what constitutes academic misconduct, which results in certain acts of academic misconduct going undetected. Secondly, detecting academic misconduct is extremely difficult unless close individual attention is given to student performance and assignments. Thirdly, complexities arise in enacting academic integrity policies/laws as procedures are not clear and pronounced. These already existing challenges are heightened in the COVID-19 period where faculty operations are restricted or largely happen remotely. In virtual study environments, individual assessment of student performance is extremely challenging. This poses a challenge to academic staff in distinguishing A-grade students from students who engage in academic misconducts. Hence, detecting academic misconducts during remote online delivery and remote assessments is challenging and what is even more challenging is processing cases of academic misconduct with limited faculty operations.

Some academic staff believe that existing policy for minor acts of dishonesty is disproportional to the offence or the penalties are not calibrated. Often, academic staff tend to ignore acts of academic misconduct even when they are detected, because the procedure is not clear to them or it is overcomplicated or time consuming. Since teaching staff has a range of professional commitments, such as teaching, assessing, grading and producing new research, academic misconduct goes unnoticed due to the workload. Morris and Carroll [35] explain how cases of academic misconduct have been overlooked in the US as they were viewed as "minor" offences and that they would eventually be penalised by someone else. Perspectives from Canada show similar behaviour on the part of academics due to the lack of consistent guidelines and lack of support for implementing academic integrity policy [35]. In this backdrop, there is no guarantee that academic misconducts done by students during the COVID-19 period will not be overlooked. If academic misconducts had gone unnoticed in on-campus study programmes, there is a much greater possibility for academic misconducts to go unnoticed during online remote delivery and assessment.

Considering the facts enumerated in previous research, it is evident that academic integrity policy is in place in every higher educational institution even though they are not consistently used. The reason for the poor implementation of academic integrity policy is that there is no proper system in place with officers specially dedicated to execute such a policy. In most universities, academic staff is expected to perform the role of guardians of academic integrity. Even though the support of academic staff is essential in detecting acts of academic misconduct, there exists the need for an independent body of officers to implement academic integrity policy further from the point of detection. Trained specialist officers are necessary in shaping institutional academic integrity policy, upholding academic integrity policy and practice, training and mentoring academic staff concerning such issues [35] (p. 456).

Morris and Carroll maintain that addressing gaps in academic integrity is not a one-off event but rather a continuous process that needs to be sustained through regular initiatives [35]. Changing technology, including text-matching software, changing online test-delivery, invigilation strategy and assessment strategy needs careful scrutiny. Furthermore, effective monitoring and policy review is also integral to implementing academic integrity policy. However, the challenge is that institutional solutions consume time and require resources. These resources include human resources as well. As cited by Morris and Carroll, Sutherland-Smith [35] explains the risk of "relying on executive or senior management initiatives" (p. 458) in pushing improvements in "academic integrity associated policy documentation". The risk is that new policy developed and documented by a third party may not be reasonable to the relevant academic staff who are responsible for detecting academic misconduct and implementing academic integrity policy. Another challenge is the time-consuming nature of academic policy development, implementation, monitoring, reporting and reviewing. Strong responses that require vigilance, severe punishments and short-term campaigns are less effective than carefully and meticulously developed long-term project plans. Long-term projects are gradual and time-consuming, yet they focus on a more holistic approach than short-term plans [35] (p. 458).

The COVID-19 situation calls for a revisal of academic integrity associated policy documentation to accommodate regulations regarding online delivery and assessment practices. Yet, the compilation of academic integrity policy documentations alone does not guarantee academic integrity as it needs constant vigilance, supervision, and a system of punishments in place.

4.2. Financial and Social Pressure on Academics and Universities

Despite strict academic integrity policy frameworks that are in place in the higher education sector, many factors challenge the implementation of these policies. For example, universities across the globe are competing with one another to improve their world university rankings. In this race among universities, there is an alarming issue: grade inflation. Foster [36] (p. 309) discusses grade inflation extensively and explains the distinction between "earned grades" and "bona fide grade inflation". 'Bona fide' grade inflation means the awarding of a higher grade due to the decline of grading standards. Grade inflation occurs when grades do not rise commensurately with the quality of student work. This could happen due to many reasons. Competition among universities, commercialisation of education, and competition for more student enrolment and funding. Private universities that operate in foreign countries remotely from their main institutions are vulnerable to grade inflation since it directly increases their student enrolment and income. Academic staff who work in such private universities are unable to maintain academic integrity due to financial and institutional pressure. However, just as private universities, publicly funded universities are also vulnerable to the issue of grade inflation due to the public rhetoric that public universities should increase access and fairness [36] (p. 309). In middle and/or low-income countries, grade inflation can occur simply out of pity for the less privileged students who are grappling economic hardships.

In the COVID-19 context, both students and universities are under financial pressure. For instance, self-funded students who are unable to work their part-time jobs faced the financial pressure more than scholarship-funded students. Similarly, many universities worldwide faced financial crises due to the less number of international student enrollments during the COVID-19 crisis. Students who are burdened financially are ambitious to obtain good grades for their study programmes, making them resort to academic misconduct. On the other hand, universities and faculties burdened with limited student enrollments tend to overlook issues such as academic misconduct.

4.3. Discipline-Specific Nature of Academic Integrity

Defining and understanding academic integrity is complex since what constitutes 'academic misconduct' is diverse across disciplines. Bretag [37] (p. 673) notes that Wilhoit called for academics in every field to define plagiarism from their discipline's perspective, the reason being that what constitutes plagiarism in the sciences is very different from that of the music field. Furthermore, Bretag [37] (p. 678) notes that Lampert calls for collaboration between librarians and faculty, and argues that it is important to develop "effective ways to capture student attention about required citation styles, the ethics of information in various disciplines, and assess [students'] understanding of these concepts". Stenmark and Winn [38] (p. 678) maintain that research on ethics in the Humanities is being largely ignored as prominence is given to ethics in business and science. He then calls for extending knowledge of ethical issues into the Humanities domain. Furthermore, Stenmark and Winn state that, due to the highly creative nature of the Humanities, academics in these fields are much concerned about protecting their intellectual property and the information they collect [38] (p. 690). This is all the more reason why it is important to delineate academic integrity and ethics in the Humanities too.

James [39] (p. 696), writing extensively on academic integrity in legal education explains that a "breach of the rules by a law student is considered to be particularly serious" due to the importance of integrity in the legal profession. Academic dishonesty or any breach of the rules by a law student may demand disclosure when the student applies to become a lawyer [39] (p. 696). Similarly, the rigorous admission requirements to the legal profession urge law students to comply with academic integrity policies. James [39] (p. 696) citing Sheldon and Krieger states that law students have a higher tendency to cheat and engage in academic malpractices due to extrinsic values placed on "prestige of winning medals", "academic competitions", and the potential employment opportunities with corporate law firms. James extensively discusses the challenges faced by legal educators in striking a balance between academic excellence, and academic integrity and ethical legal practice.

In the larger world, academic integrity upholds best practice in research and writing. While plagiarism constitutes a breach of academic integrity, it happens outside of academia too. For instance, breaches of copyright and other forms of intellectual property cases also constitute plagiarism. However, according to James [39] (p. 702), in the legal education the system of rules for referencing and acknowledging the work of others are different from the rules outside the academic domain. James states that "academic misconduct" ceases to apply after the graduation of a law student. In simple terms, the "use and re-use of precedent documents, forms, and paragraphs" is common and almost routine in legal practices whereas "collaboration in drafting documents" is considered collusion and a breach of the rules in academic discourse [39] (p. 702).

In Economics and Business Studies, students enrolled in business programmes seem to engage in academic misconduct relatively more than in other disciplines. Citing Bretag, Lofstrom [40] (p. 717) writes that Business attracts international students who are often perceived as academically dishonest due to their unawareness or unfamiliarity with Western conventions of referencing. International students more often than not struggle with the English language and may require induction and successful integration to their new learning environment.

Research shows that in sociology and social work, academic misconduct is considerably lower than in other disciplines. According to Collins and Amodeo, this may be because these programmes are intrinsically grounded in values and ethics and in which formal codes of ethics are applied and academic staff often pays strict attention to student misconduct or integrity breaches [40] (p. 718). Lofstrom citing Butterfield states that, similar to psychology students, sociology and social work students may be frequently exposed to moral content in their disciplines [40]. In these disciplines, academic integrity is mostly framed in terms of the very lack of it. In simple terms, academic integrity is understood as opposed to academic misconduct such as misappropriating others' work as one's own, inaccurate or misleading referencing, data fabrication and manipulation, concealing information when disclosure is essential, or conducting research without ethical standards and practice. Defining academic integrity in the STEM (science, technology, engineering and mathematics) fields is also based on the very absence of academic integrity. For instance, citing Korenman et al., Gilmore et al. state that scientists funded by the National Science Foundation identified, in a survey, fabrication, falsification (in other words, cheating) and plagiarism as the most serious forms of unethical scientific practice [41] (p. 731).

5. Understanding Why Students Take Shortcuts

Despite the increasing efforts of academics, researchers and university administration in grappling with academic misconduct, it is important that we understand why students tend to engage in academic misconduct. Students who are well aware that academic misconduct can result in serious repercussions still choose to do it for many reasons. Even though students have many reasons to engage in academic misconduct, it is also worth exploring why students find it difficult to perform while abiding by academic regulations. Research shows that one reason for increasing acts of academic dishonesty has more to do with academic staff who do not engage in curriculum and assessment design that mitigate academic misconduct/dishonesty. A lack of education training is argued to be one cause for this as educationists/educators do not receive proper training related to pedagogical literature, and teaching and learning pedagogy.

5.1. Pressure for Performance

Among the various factors that motivate students to cheat, the increasing pressure on modern students is attention worthy. Students are under pressure due to the competitiveness in the job market. At the same time, pressure for performance is influenced by massification and commercialisation of higher education. As large numbers of universities compete with one another to achieve excellence, universities also experience pressure to perform and excel in academics and research. In such a backdrop, very often quantity overshadows quality.

An average student in a university has to compete with the peers offering the same courses in the same university. In the broader society, when it comes to competing for job prospects or scholarship opportunities, the same student has to compete with peers from other universities with the same or better qualification. Pressured by these reasons, students may be under pressure for performance to maintain their standards. The high cost of higher education also drives students to cheat as failing exams and resubmitting a thesis may cost additional charges. Students who carry student loans throughout their undergraduate years are driven by the need to find employment and pay off their debts. Therefore, the need to cheat can be explained through the cost–benefit analysis framework as students assess their benefit since grades directly impact student employability. The commercialisation of education and high financial investments are causes for acts of academic misconduct [42].

5.2. Lack of Time, Motivation and Interest

Students in different regions are faced with diverse challenges and difficulties. For instance, the major problem in the US is the educational debts of students. The Federal Reserve Bank of New York Staff Reports show that only about 27% of 25-year-olds had student debt in 2004 and that in 2012, the proportion of 25-year-olds with student debt increased to about 43% [43] (p. 7). The delay in educational loan repayments constitutes a major issue in the US banking sector and economy. Many borrowers delay loan repayments due to "continuing education, deferrals, forbearance, and through income-based repayment plans" [43] (p. 7). In the US, student loan delinquency is the highest of debt production second to only credit card delinquency [43] (p. 10). In this context, students in the US are motivated to engage in acts of academic dishonesty due to the lack of time.

Brimble [42] highlights that lack of time to complete assessment is a common driver of dishonest behaviour. Apart from that, both higher education providers and employers seek students who excel both in academics and extracurricular activities that create work readiness and flexible personalities. With such high expectations and commitments, along with academic deadlines and exam schedules put too much pressure on students. This often leaves students underprepared, causing students to engage in academic misconduct.

In Sri Lanka, the majority of university students rely on parents' funding and they are under great pressure to finish their education in the due time. Working students are rare in Sri Lankan universities since part-time study options are not available. Undergraduate courses are full-time and they require 80% attendance/contact hours from students. Therefore, students are required to attend university on a daily basis. Since undergraduate students are full-time students, they are under immense financial pressure mostly due to two reasons: (1) students who are funded by parents feel obliged to perform their best in order to pass with excellent grades and (2) students from low-income families are obliged to balance their studies with part-time work while they support their families. Apart from financial pressure, students in Sri Lanka are pressured by immediate family and friends who constantly ask about student grades and performance even at university level. Due to these kinds of pressure, students resort to acts of academic misconduct.

5.3. Lack of Understanding about Plagiarism

Pecorari [44] (p. 357) writes that there is only a thin line between academic integrity and academic literacy. A student who has poor academic literacy may easily be misconstrued as a dishonest student. Similarly, Ken Tann maintains that plagiarism is caused by a lack of familiarity with plagiarism in general and also due to a "lack of familiarity with plagiarism software" [14]. According to Tann's personal experience, students do not intend to plagiarise but they are very often unaware of referencing if they are from a different culture [14]. This opens up the discourse on inexperienced writers using a second language in academia and its pitfalls which the authors do not attempt to address in this paper.

5.4. Cultural Issues/Background

Diverse cultural backgrounds of students are also a root cause for academic malpractice. To begin with, academic integrity does not have a universal definition nor consensus on what constitutes academic dishonesty. Higher educational providers across the same country may understand academic integrity in diverse ways. Moreover, academic integrity policies and institutional policy differ from one higher education provider to another. When higher education providers across the same country understand academic integrity in diverse ways, it is not possible to have a universal model or policy on academic integrity that cuts across different cultures. Due to this diversity of academic environments and cultures, certain scholars maintain that academic writing is culturally determined.

An interesting observation from the Australian higher education sector is that many international students in Australia show difficulties in acknowledging and citing outside sources according to Western academic conventions. Ballard and Clanchy [13] first identified that the majority of these students are Chinese students [13] (p. 24). Scollon [13] maintained that the difficulties faced by the Chinese international students were due to their longstanding adherence to Chinese cultural rhetorical conventions that may have shaped their writing behaviour. Scollon [13] (p. 24) further explains the impact cultural identity has on non-native speakers of English when they express their opinions in English. On the contrary, scholars such as Bloch and Chi, and Watkins and Biggs [13] (p. 24) challenged the idea that writing and thought is culturally determined. Nevertheless, this debate concludes with the general acceptance that an induction into the Australian academic environment is essential for international students to integrate into the Western academic sphere. Special training is encouraged for "essay writing and other writing genres, referencing, academic voice and register, and articulating opinions" [13].

The research works cited above are works published in the pre-COVID-19 context. They do not address the challenges to academic integrity in the COVID-19 context. However, understanding the state of academic integrity in the pre-COVID-19 context is crucial in understanding the nature of challenges that can be anticipated in the COVID-19 context. The same reasons that compelled students to engage in academic misconduct in the pre-COVID-19 period compel them to do acts of academic misconduct in the COVID-19 context. For instance, pressure for performance; a lack of time, motivation and interest; a lack of understanding about plagiarism; and cultural issues/background are factors that also come into play in the context of the COVID-19. Students' pressure for performance is doubled in the COVID-19 context as they are burdened with financial, social as well as emotional pressure. Only a selected few universities employ No-Detriment policies and alternative systems of grading such as using 'pass' or 'fail' options instead of awarding grades for courses. Apart from academic pressure, some students in the COVID-19 context were pressured by immigration laws. For instance, international students holding F1 and M1 visas in US universities faced additional pressure due to the US Immigration and Customs Enforcement (ICE) guidelines that were announced on July 6th [45]. With the increasing pressure on students and the limited access to university resources, orientations and seminars, more acts of academic misconduct can be anticipated.

6. Encouraging Assessment Security and Academic Integrity

6.1. Assessment Security and Academic Integrity: Creating the Right Culture

Building on Cohen and Swift's "Spectrum of Prevention" and other tiered approaches, Jason Stephens provides an overarching framework with recommended practices for creating cultures that nurture academic integrity [46]. He proposed a three-tier model of intervention (see Figure 1) that is directed towards "school-wide education (SWE)", "context-specific prevention (SSP)" and "individual remediation (IR)" [46] (p. 996).

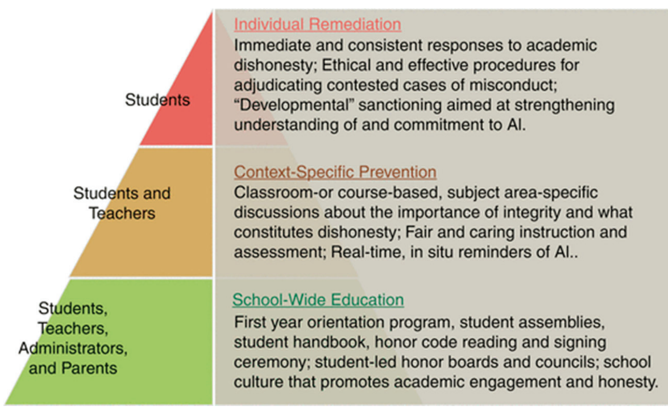

Figure 1. Creating cultures of integrity: a three-level model of intervention by Jason Stephens [46].

In this model, the biggest emphasis is placed on the base that stands for School-Wide Education as it is considered the primary level of intervention that happens on the first day at school/college or sooner. It is intended for all school/college or community members and aims at inculturation of academic norms, attitudes, and skills necessary for acting honestly in an academic culture. The implication of this is that the first step of securing academic integrity is by providing a thorough introduction to academic integrity and assessment security in school and college level. This introduction may take the form of an enrollment package, print materials, a student handbook and orientation where students learn the honour system in that institution. The secondary level of intervention is Context-Specific Intervention where programmes, staff and courses use context-specific reminders and designed tasks that reinforce the principles and practices introduced through level 1. Finally, the topmost level is Individual Remediation, which is an intervention procedure that is limited to only a few students who are suspected of academic misconduct. This level aims at processing suspected cases and "developmental sanctioning" which promotes building knowledge, values and skills related to academic integrity [46] (p. 996).

In terms of primary level of intervention in School-Wide Education, alternative modes are available even in the COVID-19 context. In the pre-COVID-19 context, some educational institutions provided

School-Wide Education on academic integrity through online tutorials or courses that are mandatory while some institutions use their own online programmes to promote academic integrity. The University of Auckland has made it compulsory to complete an online course on academic integrity by the end of the first semester. Institutions that do not create their own courses direct students to complete this compulsory education on a separate platform. One such platform is MOOC (Massive Open Online Course) created by FutureLearn, which requires students to complete a 4-week long course with an hour's commitment per week [46] (p. 1000). Apart from that, certain universities use a seminar approach to introducing academic integrity through philosophy and ethics programmes. For instance, Sri Lanka uses a foundation course on ethics, while Thailand [47,48] uses a seminar/online workshop approach to teaching research ethics. Such online courses and seminars on academic integrity and research ethics proved to be helpful in the COVID-19 context.

In the Context-specific Prevention level, intervention aims to reduce academic misconduct in a specific course or programme of study. It does not include all students in a batch, but all students participating in a course or programme of study. This process is a developmental intervention where students are encouraged to develop academic integrity practices with each milestone within their coursework. This involves "behavioural control or management techniques" as the classroom environment, and assessment design is manipulated to enable positive behaviour in students and to mitigate malpractice. One significant intervention strategy is providing multiple forms to students by randomising the order of questions and response choices. The paper or assessment form carries the same questions but their arrangement is different from one form to the other, reducing the possibility for students to exchange answers. Exam invigilation, proctoring and strategic seating arrangements are part of Context-Specific Prevention.

Meizlish [46] presents a typology of four-categories on "instructional best practices" related to academic integrity. The significance of this typology is its use of both behavioural and development approaches [46] (p. 1002). Among some of the developmental strategies proposed to lecturers are: (1) provide clear instructions on whose assistance and what kind of assistance is allowed for their homework, (2) demonstrate concerns on academic integrity and challenges, (3) teach/reinforce research and citation skills, (4) reiterate the institutional academic integrity policy and (5) sequence or stage high-stake assignments.

The third tier in the model is Individual Remediation, which deals with processing suspected cases. There are two types of sanctioning available at present: behavioural sanctioning and developmental sanctioning. Certain institutes that have traditional honour codes employ a "single sanction system" [46] (p. 1004) in processing academic misconduct and this falls under behavioural sanctioning. For instance, the University of Virginia and certain US military academies use expulsion as the only penalty, even though debates exist that such penalising is disproportional to the offence. Expulsion may be justifiable for major repeated offences but in minor offences, it is more apt to use developmental approaches that offer a chance for correction. What offers a chance for self-reflection and correction are remediation through education, which is why School-Wide Education and Context-Specific Prevention is necessary.

On the other hand, certain educational institutions have shifted from strict behavioural sanctioning and embarked on developmental sanctions for academic misconduct. Colby et al. write that the United States Air Force Academy (USAFA) which once employed the single sanction system shifted to adopting a developmental approach in the 1980s [46] (p. 1004). The expulsion was still prevalent for misconduct among older cadets but younger cadets identified for minor offences were made eligible for a 6-month probation and developmental activities such as "working with a mentor, writing a regular journal, undertaking special projects, and working to make other students aware of the importance of the honour code" [46] (p. 1004).

Considering Stephen's three-level model of intervention, the most effective intervention strategy in the COVID-19 context is Context-Specific Prevention as it is a developmental intervention aimed at developing academic integrity practices with each milestone within the coursework of students.

Individual Remediation which constitutes sanctioning is challenging in the COVID-19 context with university operations being restricted.

Another way in which academics uphold assessment security and academic integrity is by employing Bloom's Taxonomy of Educational Objectives in their teaching and learning practice. The initial framework introduced by Benjamin Bloom et al. consists of six major categories: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation [49]. This taxonomy is founded on knowledge, and the remaining five categories are presented as "skills and abilities". It works on the principle that knowledge is the necessary precondition for utilising "skills and abilities". This taxonomy was later revised in 2001 by a group of cognitive psychologists. However, Bloom's taxonomy is still used as a tool in pedagogy. It is found useful by many teachers as it helps them set learning objectives, and design teaching and assessment activities catering to those learning objectives. As learning objectives are established in a pedagogical interchange, learners and teachers have clarity on the purpose of that interchange. This provides a framework for teachers to design an assessment that covers only what they have covered in class. Designing assessments based on this taxonomy will provide protection for students against high-stake assessments that are outside of the curriculum. This, in turn, minimises the risk of acts of academic dishonesty as students are tested only on what they have been taught. Therefore, employing Bloom's taxonomy enables a high level of academic integrity as well as assessment security, and it is applicable to both the one-on-one and virtual delivery of study programmes and assessment.

Certain Sri Lankan universities use specific techniques to maintain assessment security. For instance, certain calculations in benchmark examinations in the sciences require students to use two to three digits in their university admission number. In such cases, each student is expected to have different answers which enable protection against cheating at examinations. Apart from that, university academic staff is vigilant of sudden increases in student grades or marks. A sudden increase in marks in an average or underperforming student in class gives the green light for lecturers to evaluate their performance discreetly. If such hints of suspicious activities are found, students are called for a viva to demonstrate their capacity. However, in the face of the COVID-19 pandemic, detection and sanctioning is both challenging. Conducting vivas is challenging in a remote online landscape and even students with excellent academic track records may also be challenged in such situations.

6.2. Talk with Students about the Dangers of Cheating

Academic integrity and assessment security can be reinforced through conversations with students. Apart from the risk to studentship, academic misconduct also poses personal threats to students. For instance, Yorke, Sefcik and Veeran-Colton examine how students are sometimes blackmailed by essay writing companies [19]. It is also important to discuss that risking expulsion from a university is not worth it considering the poor quality of assignments produced by "essay mills". A CRADLE study by Sutherland-Smith and Dullaghan found that most purchased assignments were not even of pass quality [19]. As faculties and academic staff engage in conversation with students regarding the dangers of cheating, the institutional academic policy is reiterated and reinforced [19].

7. Conclusions

Academic integrity policy and practices are not universal, and it is not practical to expect a universal model for academic integrity policy. Primary and secondary education in every country has country-specific approaches and examinations unless students sit for international qualifications such as Cambridge or Edexcel O/L and A/L, IGCSE and SATs. In a context where primary and secondary school education is diverse across the globe, expecting a universal model of higher education is unreasonable even though higher educational institutes insist on shared practices of academic integrity and assessment security. However, educational institutions are required to maintain standards and benchmarks for the purpose of ranking. Students are the stakeholder group that is most affected by academic integrity policy and management which, by default, places the main responsibility on them.

Even though, traditionally, it is believed that the main responsibility of maintaining academic integrity lies with students, there is a changing view that responsibility should be diffused as academic integrity needs to be a joint responsibility of the whole academic community [50] (p. 1014). Acts of academic misconduct go unnoticed if stakeholders or stakeholder groups are not clearly identified to actively engage in processing detected cases. Therefore, it is important to understand organisational structures for the viability of academic integrity management.

This paper examines the shift in the delivery of courses in higher educational institutes and elucidates the challenges associated with online delivery and assessment in the context of COVID-19. It is important to note how technology facilitating online delivery works otherwise to challenge academic integrity management. Diverse versions of exams and proctoring have enabled "low-tech" processes of behaviour control to academic integrity management. Similarly, modern technology has facilitated "high-tech" tools to detect academic misconduct. The use of plagiarism detection software and the open declaration of universities about the use of such software act both as behavioural control tools and as developmental tools [46] (1000). Despite the changing academic situation during the COVID-19 pandemic, academic integrity and assessment security are still indispensable in the higher education sector. However, there is still a lack of institutional provisions for academic integrity management in the context of COVID-19. Existing resources are inadequate to conduct high-stake assessments such as viva, thesis submissions and benchmark examinations.

For better management of academic integrity during online delivery and assessment during COVID-19, academic staff and faculties need to be equipped with procedural support that provides moral support for faculties. Resourcing and preparation are of the utmost importance in raising awareness and disseminating information on academic integrity policy, practices, expectations, disciplinary action and developmental tools to mitigate academic misconduct. Similarly, professional development is necessary for capacity building in academia to detect and process detected cases. Innovative assessment design and the designing of "low-stake" assessment tasks is another way of mitigating academic misconduct during remote online delivery. Designing assessment criteria and innovative assessment tasks help students understand the learning outcomes expected from them, leading them to adopt a mutually supportive approach towards assessment.

In the COVID-19 context, it is important to take into account the limited resources available to students and, therefore, establish attainable benchmarks. Since academic integrity policy cannot be compromised, the most plausible way of mitigating academic misconduct is setting attainable benchmarks that align with expected learning outcomes. Even though academic integrity policies are rigid and do not welcome regular changes, academic integrity is not a static concept. Practices that are considered acceptable academic conduct will undergo change in challenging times, as changing technologies come to challenge accepted practices.

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