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Developing a Virtual Engineering Lab Using ADDIE Model

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ABSTRACT

In recent years, digital competence has become essential at the workplace. There is a growing demand for engineers with both employability and digital skills. As a result of the technological advancements, the Virtual Laboratory (VLab) concept was created to provide students with a safe environment to acquire the skills and enthusiasm to enhance the delivery of STEM (Science, Technology, Engineering, and Mathematics) subjects. This study presents a VLab developed using ADDIE model design criteria that allows users to perform VLab in engineering education. Users were able to carry out experiments individually or collectively, creating an effective, flexible learning environment for students. This was integrated smoothly into the Campus Moodle platform learning environment. The VLab design and implementation details are explained and validated through Alpha and Beta acceptance testing. A mixed-methods research design was used to collect and analyse the data. Questionnaires were used to collect quantitative data from 144 students, and 17 of them were interviewed to collect qualitative data. The findings revealed that the VLab is a collaborative, effective, and interactive learning environment that develops graduates' knowledge, soft skills, and digital skills while also improving their competencies relevant to the enhancement of digital skills at their workplace. As a result, lecturers are recommended to use VLab to enhance the quality of teaching and advance the learning experiences of their students.

Keywords: virtual lab, experiment, technology, digital skills, engineering

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1. Introduction

The ability to apply theory to practice is an essential component of engineering programmes. Engineering is a subject that emphasises laboratory sessions and design-oriented teaching, which enables students to better understand the content by providing opportunities for them to develop analytical thinking skills (Bourne et al., 2013). Laboratory activities with modern equipment are essential in engineering learning since they allow the students to perform various types of hands-on activities, increasing student motivation and improving teaching quality (Demircioğlu and Yadigaroğlu, 2011). The laboratory is not just a place where the students test the theory, but also where they acquire specific practical skills and get used to solving practical problems and designing creative solutions in their future careers as engineers. Students' inventive skills are impaired by several barriers, such as the short laboratory lesson time, educators' schedules, limited resources, and the large number of students in the laboratory, which reduces their ability to follow up on an experiment and repeat it for accuracy. Developments in the field of information technology can be utilised to carry out current experiments (Tüysüz, 2010). The integration of high-quality virtual tools alongside traditional laboratory activities into curricula to enhance learning in a considerable way can provide substantial educational benefit. Each other's learning is simultaneously complemented, reinforced, and enhanced. Kennepohl (2011) defines virtual labs as a kind of technology that can be incorporated into the teaching process to enhance current teaching methods. With all of these benefits and the ongoing advancement of computer simulation technology, virtual labs are becoming increasingly important in scientific research and college education. Particularly in the last few years, the experimental teaching method of virtual labs (Hashemipour and Manesh, 2011) has developed exponential demand as effective solutions to avoid phasing accumulation and combat COVID19 spread. VLab can also be used for experiments that are difficult or dangerous to run in real life (Chen et. al., 2010). Furthermore, students have the option of conducting their experiments multiple times (if necessary), allowing them to explore the impact of varying parameters as the experiment progresses (Keeney-Kennicutt and Winkelmann, 2013). In collaboration with other students, they can construct individual lab data sets and combine them with their classmates' data sets to examine and assess the impact of additional parameters. Therefore, this study intends to design virtual laboratories for engineering education and propose a development platform prototype for virtual labs. This paper is structured in five sections as follows: Section 1 provides engineering education challenges and analyses the requirements of VLab. Section 2 presents the research goal, methodology, and materials. Section 3 explains the structure and development of VLab framework in detail. Section 4 will present the discussions and findings used to develop a VLab using the proposed platform in order to validate the effectiveness of VLab. In the final section, Section 5, the work is concluded.

1.1 Digital Skills

In addition to being commonly used in everyday life, digital technologies such as mobile devices and online collaboration platforms are also commonly used at work (Cascio & Montealegre, 2016). The existing job market is being transformed by this digital shift, which is having a huge impact on the skills needed. The global economy is driven by digital technologies, which are the key drivers of innovation, growth, and job creation. Digital Competence 2.0 - a Framework for Digital Competence has been published by the European Commission. The document categorises critical elements of digital competence into five key competencies: data literacy, communication, and collaboration, creating digital content, security, and problem-solving. Digital Competence 2.0 revised the proficiency framework to include eight crucial proficiency levels instead of three (Vuorikari et al., 2016), describing the characteristics of each level (knowledge, skills, and attitudes). Three main dimensions are distinguished, namely: (1) A technological dimension that focuses both on problem solving capacity and, with the ability, on making flexible solutions to the changing technological environment; (2) A cognitive dimension focusing on "reading, selecting, interpreting, evaluating, and presenting information;’’ and (3) Moral dimension, connection and communication with others based on responsible use of technology. The concept of a virtual laboratory is a relatively new but well-known technology because of its potential value in education. The VLab provides a collaborative, interactive, and distributed online laboratory learning environment that allows students to access a variety of laboratory facilities to prepare for physical lab experiences. There are many approaches with potential value in education for implementing virtual laboratories, mostly in science education and the education of future engineers. There are examples of visualisation (e.g., in physics, electronics, and electrical engineering) using a variety of programming assurance – MatLab, LabVeiw, Java Applets, etc. (Wyatt et al., 2000, Massimiliano 2005, Ulrich 2000, and Cui et al., 2005). Campbell et al. (2002) investigated the efficacy of software simulations using a pre- and post-test design. They discovered that groups that used both simulated and physical labs showed significant improvement than groups that only used physical labs. Using technology and instructional activities, VLab can encourage and facilitate student interaction. In order to ensure that learning occurs, educators can use technology to monitor the laboratory process and assess student activities. Educational institutions should provide a convenient, flexible, and accessible online learning platform that facilitates learning. It is essential to select a learning platform that will facilitate collaboration and communication between students and educators (Abrami et al., 2012). To improve student interaction, VLab has been proposed to be integrated with a learning management system (LMS). Graduate engineers must possess digital competence in the 21st century to compete in the job market, and implementation of the VLab can help them acquire enhanced digital skills.

1.2 Engineering Education Challenges

Current students are the "digital generation," and advanced technologies play a big part in their lives. Together, institutes, industry, and students should approach the development of high-quality virtual tools, utilising emerging technologies, offering flexibility, and improving communication and learning methods (Meccawy, 2017). When used in the process of education, the VLab is a solution to the problem since it has been proven to be effective in teaching complex science topics (Babateen, 2011). Based on the evolution of information and communication technology for science subjects, the VLab concept was developed (Mohammed and Khan, 2015). Preparation for the physical lab is its main objective. This supplement to practical laboratories enhances students' learning experiences, promotes lifelong learning, and engages students in inquiry-based learning where they can design and perform their own experiments (Corter et al., 2004). Different student learning styles, preferences, and needs should be accommodated. They will continue to receive the skills they need. Also, interactive, and user-friendly applications maintain student motivation while allowing them to share costly equipment and resources in a hybrid of real and virtual forms that would otherwise be unavailable due to constraints on resources, time, and space. This will also improve their digital competence (Feisel and Rosa, 2005). Technological awareness is changing among the "digital generation", so there's a trend to seamlessly integrate it into traditional learning environments. The use of technology can facilitate communication, assess learning activities, and create high-quality learning materials (Che Ku et al., 2014). Over the next few years, there will be a rapid growth of engineers with employability and digital skills.

Today's fast pace of change and global challenges make it more important than ever to prepare engineering students not only to meet the expectations of students, but also to meet the requirements of industry. The VLab provides students with a platform to develop digital skills and soft skills (e.g., collaboration, communication, critical thinking, teamwork, problem-solving, and creativity), as well as other employability skills that are vital on the job market today (Ma and Nickerson, 2006). It is imperative to convert traditional laboratories into virtual ones. This paper describes the development of a VLab as a complement to the engineering discipline labs (Mechanical Engineering, Electronic and Electrical Engineering, and Oil and Gas Engineering) to enhance teaching quality. VLab is a virtual learning management and practice environment designed using the ADDIE model to enable students to conduct engineering laboratory experiments individually or collaboratively in a safe and interactive environment (Herga, 2016). Educators can also use the management learning system to set laboratory tests, monitor students' progress, and evaluate their performance.

2. Research Goal

Students in the 'digital generation' are becoming more computer literate, making traditional learning environments more technologically integrated. Technology can also be used for collaboration, communication, learning activity measurement, resource sharing, and the creation of high-quality instructional materials (Che Ku et al., 2014). Engineers with employability and digital skills will be in high demand in the years ahead. We need to prepare our engineering students to be digitally literate now more than ever to prepare them for the challenges of globalisation and to stay current with industry requirements. VLab can help students develop digital and employability skills such as collaboration, critical thinking, innovation, teamwork, communication, problem-solving, and creativity, which are highly valued in industry. The need for traditional design projects to be converted into virtual forms is urgent and timely. This study proposes to establish best teaching and learning practices, as well as design and develop a VLab, in order to improve the university's reputation as a producer of "industry-ready" graduates.

2.1. Research Methodology/Materials

This study begins with the rationale and concept of virtual laboratories in engineering education, and then goes on to describe the advantages of learning this strategy. A review of previous research literature, such as reports, conference proceedings, and journals, identifies key design challenges. The research objectives and conceptual framework served as the research design's foundation. The variables in this study were students' soft and digital skills. The population of this research study included students, school staff experts, and non-academic staff (during the design phase). Krejcie and Morgan's (1970) sample size table was used to calculate the sample size. According to Krejcie and Morgan, a sample size of 144 respondents would represent a population of 230 when the VLab strategy was applied to them, and the questionnaire was collected. A sample of 17 students from the questionnaire participants were selected for the interviews. The questionnaire was given to several school employees who had experience with curriculum and instruction learning design so they could share their thoughts and suggestions about the tool's suitability for achieving the goal it was intended to achieve, the validity of the content, the sufficiency of the content, the integrity and accuracy of the phrases, and their clarity. Changes were made to the questionnaire after taking their suggestions into account. As a result, construct validity was employed to verify the validity of the instrument. Finally, questions were posed to identify the role of students and educators while using VLab, the most significant advantages of the VLab strategy, and the most significant challenges to learning application within that strategy. A group of curriculum and instruction experts were presented with these interview questions. The wording was changed based on their recommendations. The current study was viewed as an opportunity to gather feedback on the effectiveness of VLab from engineering students. The goal of this study, however, was to propose a new LMS environment framework strategy for the School of Engineering. VLab was designed to develop an engineering teaching procedure that will improve engineering instruction. The Vlab learning platform provides a virtual learning environment based on the ADDIE model that allows students to communicate and collaborate safely while working together on engineering real world projects. Using the LMS, educators can create groups, monitor, and record discussions, as well as assess students' performance. The prototype must function properly. As a result, Alpha and Beta acceptance testing was carried out. The data was collected and analysed using a mixed-methods research design. It is common practice to use a questionnaire to assess students' satisfaction with the VLab and their soft and digital skills after a virtual lab session or an experimentation period. Subjective questions about the student's experience in the virtual lab are typically included in questionnaires. These questionnaires are designed to assess how simple or difficult it was to use the VLab, as well as how effective and enjoyable the learning activity was. The experience of users of the virtual lab after assigned tasks should be accurately measured by the questionnaire. The questionnaire must be simple to complete, fit on a single page, have no more than seven questions, and all of them must use a five-point Likert scale. The instrument for this study was a pre-designed questionnaire. Questionnaires were used to collect quantitative data from students, and interviews were conducted with a sample of them to collect qualitative data. The interview sample was chosen using a variety of questionnaire responses. The research population consisted of students who had completed the hands-on experience (two groups of Mechanical Engineering, two groups of Electrical Engineering, and three groups of Oil and Gas Engineering). After using the VLab, questionnaire responses were collected anonymously. For processing and analysis, the data were exported to a single data set. The questionnaires were given out to the students during the planning and execution of the VLab sessions, and they had plenty of time to complete them. The 5-point Likert scale is utilised in the methodology to create the questionnaire, generate thorough and understandable results, and assist students in self-evaluation (Table 1). The questions were categorised based on how they related to the soft skills dimensions and the Framework for Digital Competence, as well as how well they could be applied to the specifics of the VLab being used. A five-point Likert scale from 1, the lowest rating, to 5, the highest rating (Strongly Disagree, Disagree, Cannot Decide, Agree, Strongly Agree) was used in the survey. The mean scores of each variable related to soft skills and digital skills were interpreted in accordance with the range of scales because they were intended to measure a variety of dimensions. In order to support a proposal environment features framework for the school strategy, a questionnaire was developed to solicit feedback from students and educators regarding students' soft and digital skills during VLab implementation and evaluation. The interview begins with a series of preliminary questions designed to identify the students' data, teaching methods, and knowledge of VLab and the differences between VLab and traditional lab styles.

Table 1.
VLab activities related to digital and soft skills

Skills	Statement Group	Options
Information processing	The VLab supported me in processing digital data. Look for specific information in internet using online manuals, video tutorials, technology. Improved ability to adapt to new technologies.	Strongly disagree (1) Disagree (2) Cannot decide (3) Agree (4) Strongly agree (5)
Problem solving	Work with simulator tools and applying personal knowledge. Improve decision-making and analytical skills (i.e., the ability to visualize and solve both complex and simple problems and concepts).	
Communication	Using different communication tools to collaborate. Developing communication skill. Enhancing creativity in thinking.	
Collaboration	Enhancing collaboration and teamwork skills.	
Content creation	Creating operational products for measurement, control, and monitoring.	
Security	Enabling remote access to online environment. The VLab helped me in resolving digital issues.	
Content	Creating synthesised report information. Enhancing time management skills.	

3. VLab Environment and Design Features Development

As part of active practice learning by doing, which includes research, hands-on experiments, and expert guidance, collaboration and experimentation are the latest trends in education. Learning through collaboration leads to constructivism (Vygotsky, 1978), an educational strategy widely used for several years (Ashton Hay, 2006). A number of studies have shown that virtual learning has been found to improve academic achievement, promote soft skills development, and increase satisfaction with the learning process (Kabilan et al., 2011, Lee and

Lim, 2012; Nurbiha et al., 2012, Zhu, 2012). Learning is most effective when students are in a position to work collaboratively by exchanging ideas, discussing and challenging other ideas, and tackling a problem together. According to Chen (2011) and Chiong and Jovanovic (2012), undergraduate students who interact with their peers perform better academically. There are several methods and tools that educators can use to improve the quality of teaching and learning, such as active learning (Lima et al., 2017) and project-based learning (Mills and Treagust, 2003). Technology can be highly effective when it is combined with flexible instructional design practices. Morrison (2010) describes ADDIE as a model typically used by instructional designers. This framework provides educational designers with a flexible approach to implementing an effective support tool in five phases: Analysis, Design, Development, Implementation, and Evaluation. Instead of traditional curriculum development, Branson (1978) used ADDIC to create instructional systems across the United States military branches. According to a study, the ADDIE model was adopted and used in educational design and found to be both practical and useful (Tzu-Chuan, 2014). Among the improvements made was the rapid prototyping of the model (Ahmad, 2013). Through constructive feedback and continuous assessment, it allows for continuous improvement throughout the whole process of creating materials. The ADDIE model was the basis for implementing the VLab management learning system. Figure 1 illustrates the five phases involved and adopted in this research. The adoption of technology in the classroom is considered a significant enabler for improving student-learning outcomes. Best practices for flexible learning environment design are critical to getting the most value from technology. Several studies have shown that computer-supported learning facilitates soft skills development (Ahmad et. al., 2011, Sancho et. al., 2011). During the learning process, the analysis phase is the first step, which defines the learning theory. This study incorporated three theories, constructivism, online collaborative learning, and experiential learning. During this phase, the design factors that make online experiential learning effective have been determined.

Learning design and interaction were factors determining the learning environment. Therefore, learning outcomes, learning materials, and learning assessments should be defined by the module curriculum. Continuous feedback from peers and educators was crucial to developing thoughtful communicators as students developed experiments (Olivo, 2012). Providing feedback comments should allow students to reflect on the challenges they may encounter in their real-world work while also providing them with an opportunity for revision. By implementing these best practices, students can learn more, interact with their peers, and become motivated to work on experiments. During VLab work, students faced several challenges (Alden, 2011), and educators were crucial in developing fair assessment mechanisms that accurately measured students' performance. In the development phase, modules and interactive activities are developed, utilising modern training platforms and information systems, to promote lab outcomes.

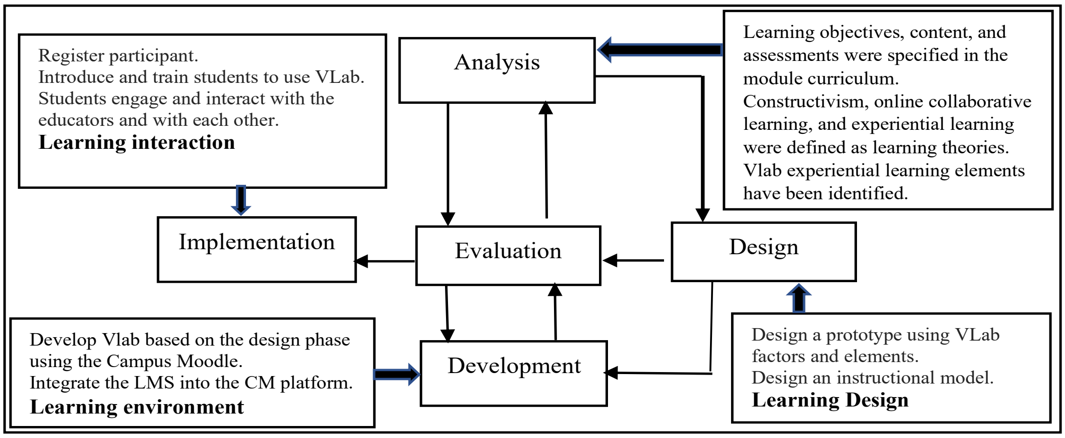

Figure 1. VLab development model framework (modified after Morrison, 2010)

Most educational institutions have migrated to online learning management systems in the last decade, such as Moodle, Blackboard, and Sakai, in order to create one single environment for centralising academic materials, learning activities, and assessment (Carlos et al., 2013). According to student and educator preferences, data was collected based on current Campus Moodle learning. After that, a formative evaluation is conducted with subject-matter experts to ensure the analysis data aligns with the module curriculum. Campus Moodle (CM) is a learning environment platform that provides educators with tools for facilitating and enhancing both teaching and learning (García-Peñalvo, et. al, 2011). In fact, university Campus Moodle provides both lecturers and students with tools and resources to help them manage their teaching and learning. A campus Moodle feature, such as discussion forums, aids in student communication and collaboration by allowing them to use external applications in addition to those built into the system. In this context, the collaborative learning subject approach was supported by the VLab instructional design. In addition, they offer a platform where a variety of pedagogical activities can be conducted online. CM features like discussion forums are used to facilitate communication and collaborative work among educators and students. In addition, external applications are used instead of those that are built-in with similar functionality. In this context, the VLab project instructional design (within the design phase) supported preferences for subject-based learning. Adapted from Ellis and Hafner (2009), the educational design has been revised. The interface was designed to support data collection during the analysis phase. As the students worked with the VLab content, they were able to engage and connect with the educators and with each other. Using the designed system, students were able to engage and interact with one another as well as with the teachers while working on the project content.

Following the completion of the design phase, a VLab architecture draft was developed and integrated into Campus Moodle's development phase. A formative evaluation form was given to students and staff at the end of the prototype to collect their feedback and improve the VLab learning management system based on suggestions from users. Lastly, the prototype was implemented for practical application and evaluated after being designed and developed. VLab management learning system was formatively evaluated to improve the system, and an assessment of learning satisfaction and outcomes was conducted as part of the evaluation stage. Evaluation is essential to improve application of VLab and to revise content that is insufficient. The ADDIE teaching model is a system for measuring the quality of teaching design projects that educational designers employ. It provides a consistent and flexible structure for the design of teaching in higher education through the integration of learning activities and the ADDIE model (Fang et al., 2011).

3.1. Model and Type of VLab Interaction

Throughout a VLab learning environment, learners interact with content, educators, and their peers. Moore (1989) published the first systematic study of learning environment interaction. Through active learning-content interaction, Moore contends, student understanding and perspectives on learning was enhanced. It is imperative to develop engaging activities in order to motivate students to engage with content (Ali et al., 2011). Learning activities should be designed so they can increase interaction between their students (Zimmerman, 2012), which will ensure students complete their courses and achieve their learning goals (Shea & Bidjerano, 2014). Kyei-blankson et al., (2019) suggest that students' interactions with educators can reinforce their understanding of course materials, which in turn contributes to enhanced learning. Online interactions between learners broaden and deepen the learning experience and improve student satisfaction (Sher, 2009) and academic performance (Al-rahmi & Othman, 2015). The concept of integrating existing knowledge allows students to construct new knowledge and understand their learning content (Frisen & Kuskis, 2013). The cooperative learning structure can be used to promote student interaction, and educators can provide guidelines to facilitate this interaction (Rossi et al., 2013; Fear & Erikson-Brown, 2014).

4. Discussions and Findings

The Alpha and Beta testing phases have been evaluated. Staff performed Alpha testing during the development process to ensure the quality of the prototype before moving on to the next stage, Beta testing (Oladimeji, 2007). In this testing, participants were asked for their general impression of the VLab learning environment (Q1) and whether the integration of a learning management system with CampusMoodle can facilitate online interactive learning (Q2). Table 2 presents the results.

Table 2.
Alpha testing result

Tester	Feedback
1	Q1: Using technology in the teaching and learning process is desirable. Q2: It could empower students to learn a content area.
2	Q1: Students can exchange experiences and develop their communication skills. Q2: Since the majority of students actively use CampusMoodle, it can improve learning facilitation.
3	Q1: Excellent for improving student performance. Q2: It can be used anywhere to facilitate the teaching and learning process with students.
4	Q1: It can make it easier for students to communicate with one another. Q2: Good technique is necessary to enhance student skills.
5	Q1: Student can improve their soft and digital skills. Q2: Yes
6	Q1: Increase more student-centred learning. Q2: For the demonstration tab, it would be ideal if we can use video recording and use another tab for more information, reading and background knowledge. Q3: Yes
7	Q1: It assists with the physical lab and course materials. Q2: Yes

Compared to Alpha testing, Beta testing focuses not only on the quality of the prototype but also ensuring the prototype is ready for real-world use (Jones & Richey, 2000). This stage of the study involved five educators and five students. Several questions were raised during the Beta testing stage, including: (Q1): Did you find the system easy to use? (Q2) Did you find the instructions to be helpful and clear? If not, please explain. (Q3) How stable was the system when you tested it? (Q4) Do you have any suggestions for system improvements? If so, please describe them and (Q6) Please provide feedback on the entire interface based on text, colour, and layout. Table 3 below provides a summary of respondent comments. As they completed the cooperative VLab, the students collaborated as a learning community. They used discussion forum to plan and keep track of activities, and they were engaged and motivated during meetings. They improved their capacity to listen to and respect the ideas of others as a result, as well as their understanding of the concepts, VLab objectives, or resources utilised in the projects.

Students thought they learned more when they engaged in discussions and VLab activities. 90% of the students participated in group problem-solving activities and contributed ideas, according to the findings. 95% of students said they used technology, specifically the internet, to finish their project. 90% of students indicated that collaborative learning in VLab was more efficient and greater to individual work, improved their understanding of the subject, and provided them with knowledge of significant value. Discussion forum, emails, and meetings are other tools that promote social interaction by giving students more chances to communicate to their peers while completing project tasks. Final summative evaluation: test procedure to check that the prototype is fully functional and user expectations are aligned with the curriculum (Sefton-Green et al., 2009). It is crucial that feedback be provided in order to ensure the prototype will work as intended in a real-world study.

Table 3.
Beta testing result

Respondent	Comment
Educator 1	The experiment's instructions are concise and easy to understand. Due to its use within the CampusMoodle platform, the system is reliable. Good use of colour and text font. Layout and structure are well-organised.
Educator 2	The system is clear and easy to use for teaching and learning. The system instructions are helpful, clear, and easy to understand. Interfaces are intended to be clear, simple, and user-friendly. The strategy is well thought out. The design is efficiently organised. The learning instructions are clear and facilitate the teaching and learning process.
Educator 3	The user can locate the system icon they're looking for with the help of the on-screen instructions. It is beneficial to have uniform text and colour. You need to have a section for health and safety and hazard. It could be about the PPE, the work environment.
Educator 4	All instructions are clear for students to use the system. The menu is also more interesting and straightforward. The experimental theory of the facts is clear.
Educator 5	The information is appropriate for students to carry out the experiment. Colour is suitable for students. Login and access to the system are good. Attractive and clear information.
Student 1	It is easy to use. The learning environment helped integrate theory and practice.
Student 2	To complete tasks, all information is available.
Student 3	It provided me with all the tools I needed to communicate with my colleagues.
Student 4	It supports the physical lab. Create a login step or manual to guide users on how to login to the simulator database.
Student 5	I did not find health and safety instruction related to the experiment. I recommend including a video demonstration for this.

4.1. Case Study – Lab Selection

We have detailed the design and implementation of the VLab environment, which is integrated into the LMS learning platform of school engineering (e.g., Campus Moodle), and 26 VLabs have been completed. The drilling hydraulics optimisation (DHO) VLab was selected for study because the topics related to the experiments were formulated within a common shared module between the courses. The DHO VLab is designed to provide hands-on experience to students who are primarily studying oil and gas engineering courses. The lab comprises a total of four experiments related to three major aspects of DHO Vlab design: the prediction of pressure drops and equivalent circulating density in the wellbore, optimising drilling performance, and the design of optimum hydraulics for effective wellbore clean-up and stability. The VLab study was conducted on students enrolled in oil and gas engineering courses at the School of Engineering. In the lecture, students were first introduced to the theoretical aspects of drilling well engineering. The students were then given a quiz to see how well they understood the concepts taught. The quiz was designed to assess conceptual understanding rather than recall ability.

Following that, students were instructed to access and use the DHO VLab, which was equipped with a software simulator. Students were assigned two laboratory rheological experiments related to the theory taught in class. Students can use this as an opportunity to review the key ideas. After that, the same group of students took another quiz. The quizzes were thoughtfully created to prevent one from being more challenging than the other. The post-test also included a feedback section. The achieved results proved that there is an improvement in the post-test and the Likert scale is used to assist students in developing questionnaires, producing thorough and understandable results, and self-evaluation. The questions were organised into groups based on how they related to the soft skills and the dimensions of digital competence and the Framework for Digital Competence, as well as how well they would apply to the particulars of the VLab being used. The work results of the students in the VLab proved that it has an add-on value and that it can be measured. To further improve the design system, an online and formal Likert scale questionnaire has been developed. The questions were constructed according to Table 1 and presented to the students, and they could choose their preference on the five-point Likert scale (Strongly Agree, Agree, Cannot decide, Disagree, Strongly Disagree).

Lack of real-life experience and no instruction on health and safety were two of the drawbacks. In addition to the introduction to health and safety, interactive video and live videos were also used to overcome the challenge. A VLab offers all the benefits of a traditional laboratory experience while providing students with an immersive experience. Health and safety concerns have been addressed through safety education workshops (Teng et al., 2001, Keeney-Kennicutt and Winkelmann, 2013, Wang and Guo, 2015). Responses from staff and students are positive, with comments related to the addition of laboratory safety resources. These have been incorporated into the template design of the VLab. According to students' feedback, VLab offers students a flexible learning environment and multiple opportunities for better knowledge retention (Feisel and Rosa, 2005), builds confidence and critical thinking without actual risk, and prepares them for the physical lab experience. In addition to performing better and developing the necessary skills for higher education, they find themselves focused more on learning rather than the risk factors found in traditional labs. Moreover, the Moodle learning platform does not allow access to the engineering simulator application. The reason is that the systems are not linked, and single sign-on is not an option. In order to overcome the problem, the platform was adopted and integrated with a link to the instructions page for users who had never used MyApps before.

The VLab environment design features consisting of the login interface, main menu interface, module interface, topic interface, and forum interface have all been developed after taking feedback from respondents into consideration. To convey important information and involve students in the engineering design process, an interface system with icons has been developed and is dependent on, but not limited to, theories, testing procedures, risk assessments, lab demonstrations, simulations, assignments, feedback, staff support, animated demonstrations, and self-evaluation. Students were able to turn from passive listeners to active participants in the learning process through VLab's interactive environment. The VLab implemented at the University includes the login interface (Figure 2a), main menu interface (Figure 2b), module topics interface (Figure 2c), VLab simulator interface (Figure 2d) and VLab design menu interface (Figure 2e).

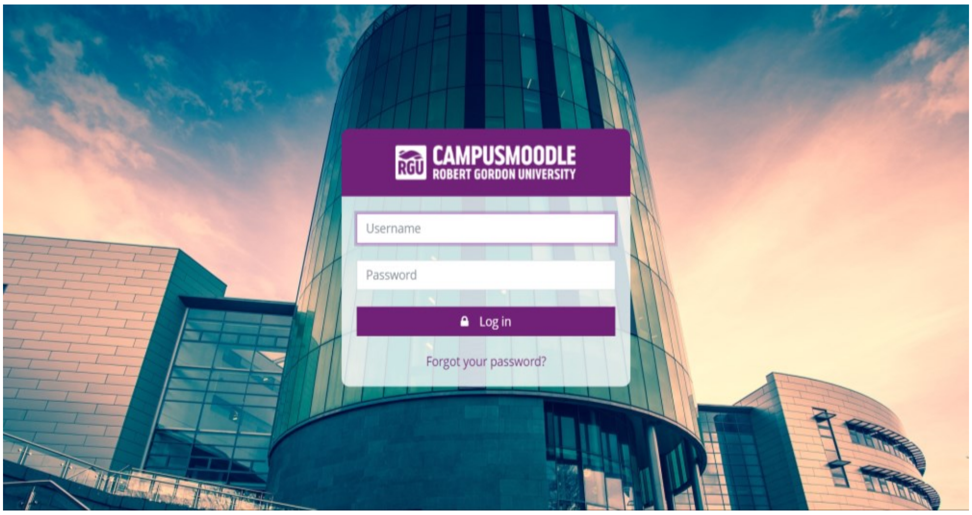

Figure 2a. Login interface

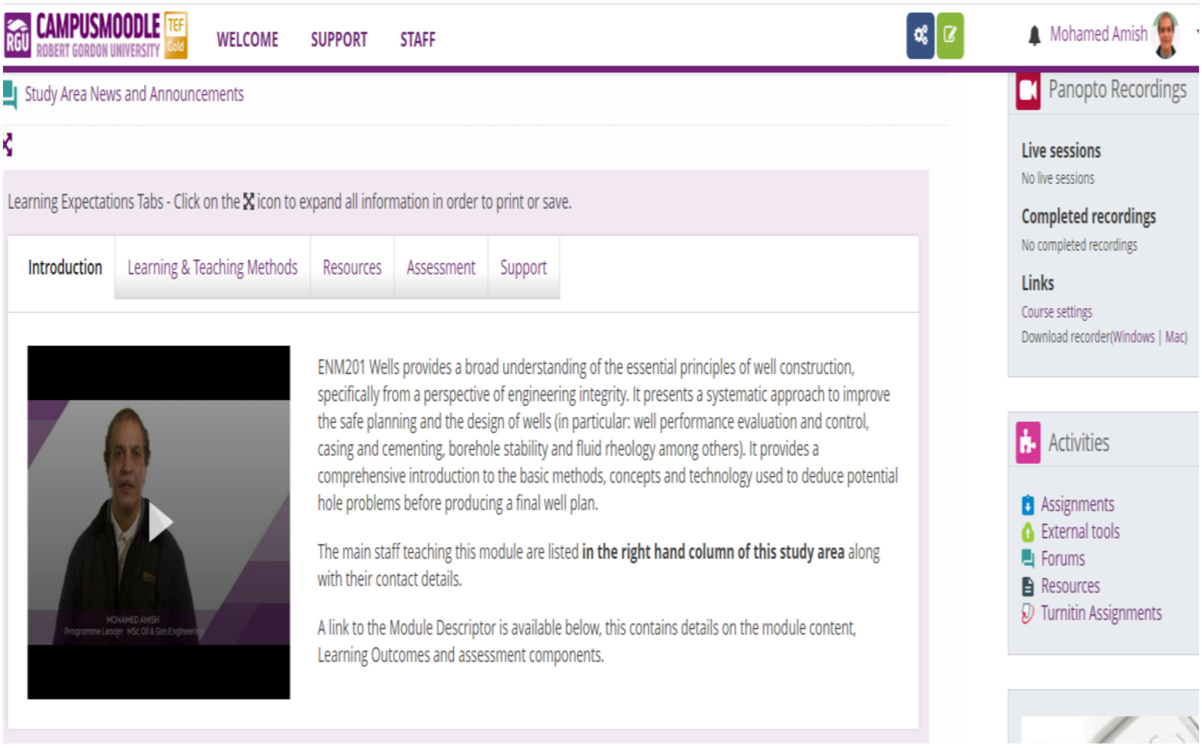

Figure 2b. Main menu interface

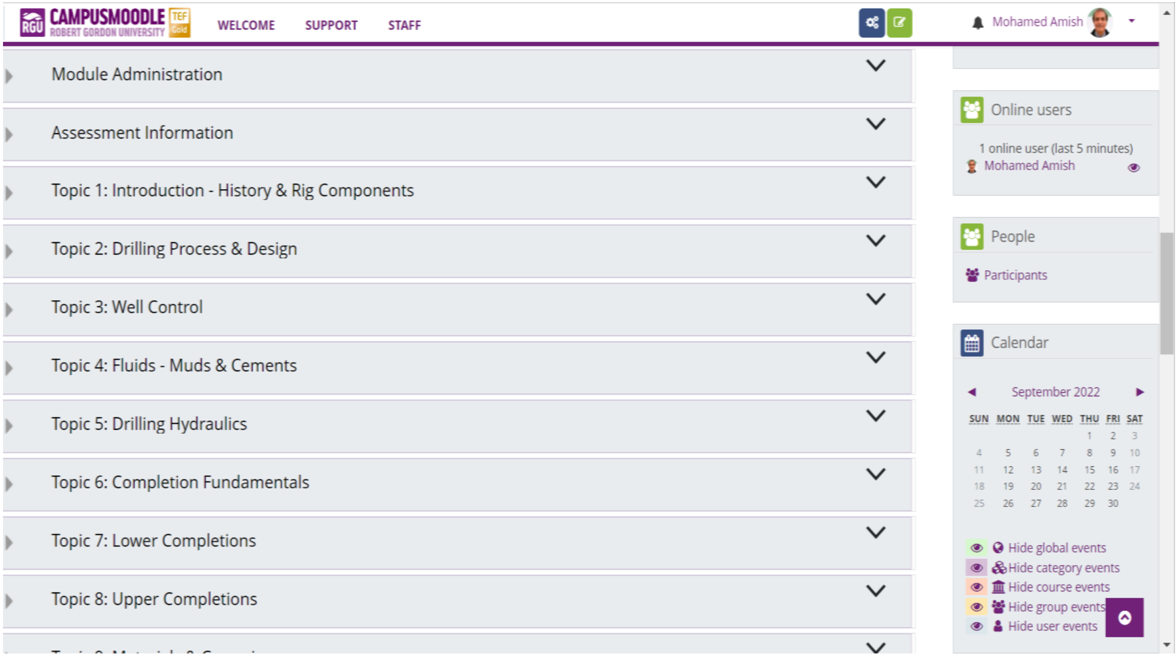

Figure 2c. Module topics interface

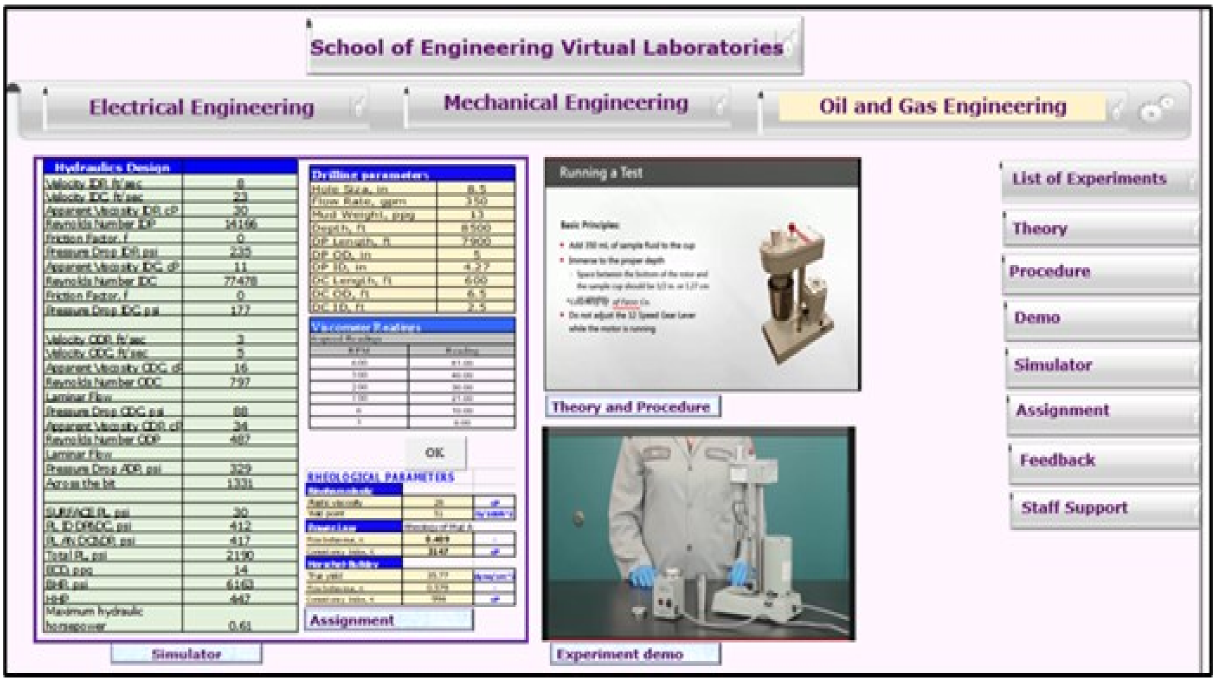

Figure 2d. VLab simulator interface

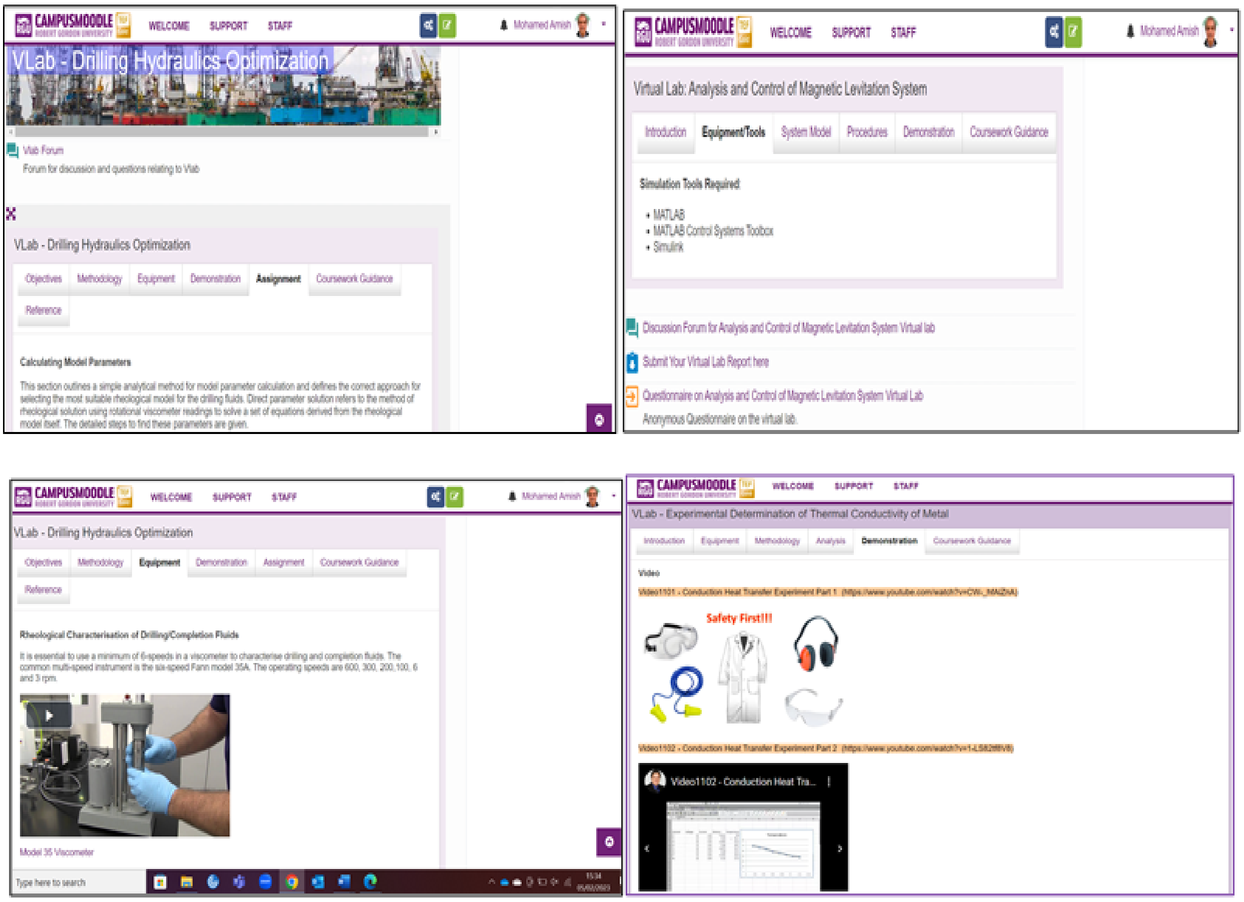

Figure 2e. VLab design menu interface

The outcome of the VLab implementation proved that it has an add-on value and that it can be measured. The questions were presented to the students in groups based on Table 1, so they could select which option they preferred using the Likert scale.

In Group 1: "The VLab supported me in processing digital data," the question asked was, "Do VLab activities improve my ability to use online guides, video demonstrations, and technology to search for specific information online?" The findings indicated that 95% of the students found the virtual laboratory's activities engaging and useful for locating the needed information using various digital technologies more quickly and accurately.

In Group 2, "The VLab helped me in resolving specific software issues, such as additional add-on engines." There were two questions. (1) Does the VLab help you work better with specific software tools and apply your personal knowledge? (2) Has the VLab enhanced my ability to install specific software such as add-ons, engines, etc.? The results showed that 96% of students found that the virtual laboratory assisted them in better problem solving in a digital environment and improved their analytical skills.

In relation to communication in a digital environment the question (Group 3) asked was, "Does the VLab provide me with a variety of communication methods and improve communications?" The students responded positively to this question. 94% of students strongly agreed that collaborative learning was more effective and better than individual work, and that they understood the subject better and learned things of significant value. Discussion forums and meetings, which give students more opportunities to interact with colleagues while working on VLab tasks, also help to improve teamwork skills and encourage social interaction.

The Group 4 questions focused on the VLab's potential to enhance users' capacity to resolve digital problems and produce digital content. "Has the VLab improved my understanding of how to enable remote access to a particular online environment?" "The VLab assisted me in resolving issues with digital security." 90% of students who responded positively to that question showed that using a VLab can aid in students' understanding of particular issues related to the digital environment.

The following questions were posed to Group 5: (1) "Do you find the VLab useful in developing operational products for measuring, controlling, and monitoring? (2) Do you find the VLab environment to be helpful in creating reports? The findings indicated that 95% of the students strongly agreed that the VLab can provide students with a much more user-friendly environment when creating digital content.

It should be noted that more than 90% of the students consistently responded "agree" or "strongly agree" when the questions were more closely related to specific engineering tasks that are typical of laboratory work. This can lead to the conclusion that the technological aspect of digital competence is much more understandable for aspiring engineers and thus provides the opportunity for quicker and higher-quality work. Table 4 summarises the survey's overall design as well as the relationship between specific group work in the virtual laboratory and the enhancement of digital and soft skills.

Students perform experiments individually or collaboratively, collect data, and answer questions to assess their understanding and knowledge. Learning is shared or transmitted between students in a VLab environment, enabling them to work towards common learning goals such as an understanding of a subject as a whole or a solution to a problem. 95% of students indicated that through shared exploration, goals, and a shared process of understanding, the VLab helps students develop higher-level thinking skills and gain deeper levels of understanding, providing opportunities for self-learning and arranging the time needed depending upon their learning speed. The students found the work in the VLab stimulating, they were able to apply personal knowledge and find the necessary information to complete work tasks using different digital technologies. According to the findings, 95% of students contributed ideas and participated in group problem solving. The students had assessed the potential of the VLab to help them with better problem solving in a digital environment and provide them with different communication tools and exchange experiences. A 95% of students stated that they used technology, specifically the internet, to complete their VLab task. The VLab is able to increase students' learning motivation in engineering subjects through technology, make the lessons easier to understand, and improve student learning outcomes. The VLab provides students with a much more user-friendly and flexible environment that complements the physical lab and course material.

The management learning system enables educators to form groups, communicate with them, facilitate their progress, monitor, and evaluate their students' progress, and assess their performance. The results showed that the VLab strategy improved learning efficiency, student academic comprehension and achievement, as well as self-growth (such as confidence, self-esteem, and responsibility), participation in learning, and students' development of empathy for others.

This is because this strategy combines the advantages of traditional and electronic (digital) learning. We are all aware that technology has developed into the modern language, making it simpler for students to access the data they need. As a result, students take pleasure in using educational technologies in the contemporary learning environments at the university and take pride in interacting and communicating with others through a variety of media, such as university e-mail, a simulation database, discussion forums, written interaction, and others.

Additionally, the lectures' face-to-face instruction fosters communication between the school and students. Additionally, VLab gives user input and social interaction a high priority. The students acknowledged that they were able to develop their soft skills (Table 4), apply their academic knowledge to module related tasks, and learn more complex material through practical performance. The highest mean score among the top soft skills was for improving critical and creative thinking, which was followed by communication improvement, time management improvement, interpersonal communication improvement, learning to give and receive constructive criticism, skill development in listening, the capacity to think creatively and effectively communicate in a visual format, improvement in decision-making and analytical skills, the growth of responsibility, and the development of a sense of accountability.

Table 4.
VLab activities related to digital and soft skills

Skills	Statement group	Mean	Interpretation
Information processing	The VLab supported me in processing digital data. Look for specific information in internet using online manuals, video tutorials, technology. Improved ability to adapt to new technologies.	4.20	Agree
Problem solving	Work with simulator tools and applying personal knowledge. Improve decision-making and analytical skills (i.e., the ability to visualize and solve both complex and simple problems and concepts).	4.80	Strongly Agree
Communication	The VLab assisted me using different communication tools to collaborate. Developing communication skill. Enhancing creativity in thinking.	4.70	Strongly Agree
Collaboration	Enhancing collaboration and teamwork skills.	4.70	Strongly Agree
Content creation	The VLab facilitated and guided me in the creation of digital products, Creating operational products for measurement, control, and monitoring.	4.50	Strongly Agree
Security	Enabling remote access to online environment. The VLab helped me in resolving digital issues.	4.50	Strongly Agree
Content	Creating synthesised report information. Enhancing time management skills.	4.0	Agree

5. Conclusions

Technological awareness is changing among the "digital generation," resulting in the seamless integration of technology into traditional educational environments. Digital competence has become an essential part of engineering at the workplace, and it is projected to grow rapidly in the upcoming years. Transferring traditional laboratories to virtual forms is thus urgent and timely, particularly in cases where real-life lab work is impossible (for example, COVID-19). School disciplines (oil and gas engineering discipline, mechanical engineering discipline, and electrical engineering discipline) VLab have been developed using the ADDIE model of instructional design and have created an effective, flexible learning environment for students. This was integrated smoothly into the Campus Moodle platform learning environment. Students and staff collaborated on the design of virtual laboratories to cater to diverse learning styles, preferences, and needs, creating a more flexible pathway to engineering education and providing students with access to high-quality virtual learning materials. The students' survey results showed positive feedback and increased the students' achievement level. Students performed significantly better when they used VLab. The VLab is a distributed interactive practice learning environment that includes work-based learning activities, real experiments, and simulations that:

- Deliver attractive and employment driven student programmes.
- Address the limitations of hands-on labs and the skills gap in digital technology.
- Take advantage of globalisation.
- Stimulate the uptake of engineering by students.
- Support "in-person" programmes with the best learning environment.
- Meet the growing demand for seamless technology integration.

In conclusion, the VLab is interactive learning environment that improves graduates' knowledge, soft skills, and digital skills. As a result, lecturers are recommended to use VLab to enhance the quality of teaching and advance the learning experiences of their students.

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