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Student Experiences of Practical Activities During the COVID-19 Pandemic

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***Abstract*—During the COVID-19 pandemic practical activities for undergraduate students have been severely disrupted. Activities in the field of computing, control, electrical and electronic engineering at the University of Sheffield have been taught during the autumn term of 2020/2021 academic year through socially distanced in-lab sessions, remote access to in-lab equipment, take-home kits, and other online methods. Students were asked to leave feedback for each activity using an anonymous online questionnaire, designed to capture their perceptions on their learning experience. Based on the responses received, a number of recommendations have been formulated to help practical educators make decisions on the modes of delivery of certain activities and for certain student cohorts, when pivoting to increased distance learning. Students indicated they would prefer to conduct some activities using take-home kits in the future, paving the way for beneficial long-term changes to the delivery of some practical activities beyond the times of the pandemic.**

***Index Terms*—undergraduate remote laboratory experiments, practical engineering teaching, COVID-19, take-home kits**

I. Introduction

The COVID-19 pandemic has forced educators around the world to adjust their teaching techniques, to accommodate the strict social distancing measures required for in-person interaction, as well as completely redesigning some activities for remote delivery [1]. While some activities are easier to move to distance learning, such as lectures, teaching of practical engineering skills within the higher education sector is a great challenge under these circumstances [2], [3]. Particularly of concern is that students must still learn and demonstrate the "*ability to apply relevant practical and laboratory skills*", a requirement for Engineering Council accreditation [4].

Some prior work has already compared the effectiveness of remote labs to hands-on lab activities [5] and reported that 90% of students rated their remote labs to have comparable or better effectiveness than hands-on lab activities. Students were found to learn equally well from remote and hands-on labs in [6], with some even reportedly appreciating the practical advantages of remote labs. The advantages of remote labs to instructors and institutions include scalability, safety and the potential for sharing between institutions [7].

Students' perceptions of their remote practical activities may vary depending on the activity delivery format. Students have been found to be unaware of the difference between a realistically designed simulation and a remote access mechanism [8]. The boundaries between simulation activities and other laboratory types are blurred, considering that most experimental equipment now uses a computer interface [9]. Remote lab users have been observed to have higher engagement and a more scientific approach to their experiments [10], and perceive such activities to be more reliable and easier than in-lab equivalents [11]. Specifically in electronic engineering, a remote access circuits lab was shown to be useful for introductory courses [12]. However, students were found to need a hands-on session to gain familiarity with processes and equipment, before fully appreciating their remote work, an approach also verified as effective in a robotics activity [13]. For distance teaching in general, a lack of interactivity and instantaneous feedback from staff were identified by students as key disadvantages [14]. Measurement of motivation and participation is challenging, and individual learners' situations are highly influential on their engagement [15].

The research presented here therefore aims to focus on students' own perceptions of their enjoyment and skills development from the practical activities in the field of computing, control, electrical and electronic engineering. This article directly compares distance learning of practical skills with in-person delivery by breaking down distance learning modes into several sub-types of activity, and exploring student perceptions of each method. This is made possible by exploiting the scale of practical teaching delivery by the Department of Multidisciplinary Engineering Education at the University of Sheffield. The focus is on how students consider the effectiveness of the activities on their own learning. Although students may overestimate their competency developed through labs performed at distance [8], this study has a unique background context where access to in-person laboratories is unavoidably reduced, which may influence student perceptions.

II. Method

This research seeks to compare student perceptions of the four distinct categories of practical teaching employed by the Department of Multidisciplinary Engineering Education at the University of Sheffield during the COVID-19 pandemic. These are: 1) face-to-face in-lab activity with the support of teachers, technicians and graduate teaching assistants, but with strict social distancing restrictions mandating greatly reduced capacity, with students working individually, and staff only providing support from a 2m distance; 2) take-home kits, which were prepared in advance for a series of mechatronics practical activities (such as building and controlling a robot arm using an Arduino); 3) remote access to real in-lab equipment (such as oscilloscopes, waveform generators, servo motors and HVAC systems) with web interfaces and/or cameras to show real-time operation of systems, controlled using the same interfaces as in-lab equipment; 4) fully online delivery that either consisted of students performing simulations of physical systems (e.g., using LTSpice, TinkerCAD, MATLAB, LabVIEW), or watching recorded/live video demonstrations of experiments and then analysing provided data and completing a quiz to check their understanding of the material.

The decision of which of the activities would be delivered by which method was based on the original activity learning outcomes, as well as the availability of the required hardware and software. For example, one of the main learning outcomes of the mechatronics course was for the students to be able to build and control systems themselves from scratch. Such an exercise could only be properly carried out in a laboratory or by using a specially prepared take-home kit. Since the kits were low-cost and low-voltage systems, powered by an Arduino, there were no inherent barriers for students to perform these experiments safely at home. This freed up the limited lab time and space for other activities, such as soldering or high voltage transformer experiments, to happen in a safe environment in the presence of experienced staff.

An example of remote access laboratory sessions were several practical activities involving time and frequency domain analysis of servo motor control. These activities utilize in-house LabVIEW programmes connected to a DC motor with position sensors, which were easily adapted to enable remote access to the laboratory equipment. An example of an activity delivered through the online video/quiz method is the micro-measurement activity, which was designed to provide students with experience of the cleanroom environment and expose them to error identification and calculation, which would normally have been delivered in-lab with students measuring the resistance of thin-film metal samples using probe stations.

Following the completion of each practical activity, students were encouraged to optionally leave feedback using an anonymous online questionnaire, via adverts on the virtual learning environment and cohort-wide emails. Each questionnaire asked contextual data, including their programme and year of study, and whether they consider English as their first language. The majority of the remaining questions were on a likert scale of: Strongly agree, Agree, Disagree, Strongly disagree; and were intended to assess the students' experience during the activity, including their enjoyment, whether they felt challenged, and whether they felt their practical skills had been enhanced thanks to the activity. In addition, some questions explored their time management skills, preference for future practical teaching delivery methods, and their ability to experiment further beyond the provided structured activities. There were also several open-ended free-text questions for students to provide detailed comments about anything they particularly liked, or thought could be improved, about the activities.

Online questionnaires were selected as a research tool for practical reasons, to minimise in-person interaction while still maintaining a reasonable response rate. The use of likert scale ensured that the questionnaire was efficient for student completion and data analysis, although the underlying reasons why students agree or disagree with a statement can only be ascertained if they also left supporting contextual quotes [16].

During the COVID-19 pandemic, the majority of higher education teaching was moved to a predominantly online format. At the University of Sheffield, the laboratories programme was the central part of the in-person teaching provision for undergraduate engineering students. As such, students may have rated their in-lab experience based on it being a rare in-person interaction opportunity rather than inherently on the lab experience. Students have also been under pressure when working at home, including physical and mental health concerns and isolation, which may also have caused underlying bias in the results [17]. Care should be taken that these results should not be generalised to infer student preferences for practical delivery outside the pandemic scenario. Some results and recommendations may hold for other situations when access to laboratory facilities is severely limited, but others may only be valid for the specific pandemic scenario.

III. Results and Analysis

The questionnaire was completed by 254 first- or second-year undergraduates in programmes such as Mechanical, General, Aerospace, Electrical and Electronic, and Automatic Control and Systems Engineering at the University of Sheffield. The respondents break down into 59 for in-lab, 29 for take-home kits, 108 for remote access, and 58 for online. Preliminary analysis of the data showed that the individual simulation activities received considerably different feedback both to simulation tasks performed as a group and to the video/quiz activities. As such, the online delivery responses were further split into three distinct sub-groups in Figs. 1 and 2, to provide more insightful recommendations on delivery methods.

Fig. 1 compares the delivery methods of practical teaching in terms of student enjoyment, the students' own perceived challenge of the activity, and their ability to "do more" following its completion. For the distance learning methods, the survey also asked students' view of the quality of the activity as a replacement for an in-lab experience. In-lab activities were enjoyed by 100% of respondents, in comparison to 90% for take-home kits, 82% for remote access, 79% for the individual simulation, 57% for the video/quiz and just 31% for the group simulation activities. This result may not be due to the practical activity being particularly enjoyable itself, but could just be due to inclusion of a contrasting in-person activity in their programme when most teaching has been moved online.

Similar responses are shown in Fig. 1 for students' ability to "*do more*" after completing each of the activities, with the in-lab activities scoring the full 100% again, followed closely by the take-home kits (86%), the remote access (85%), the individual simulation and the video/quiz (71%), with the group simulation scoring the lowest at just 38%. It is notable that the top-scoring activities involve working on systems with real time cause-and-effect. A student commented: "*It was really*

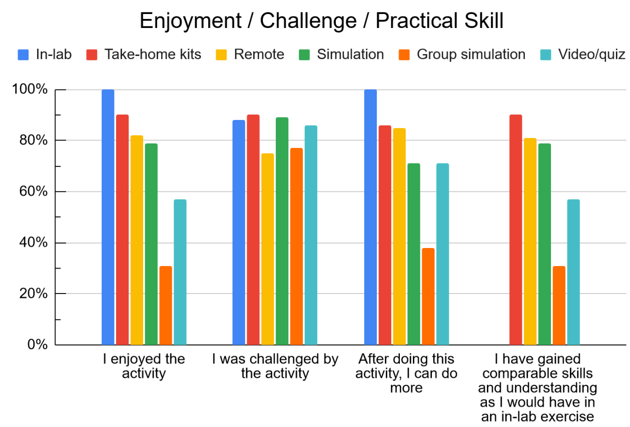

Fig. 1. Student assessment of the different teaching methods.

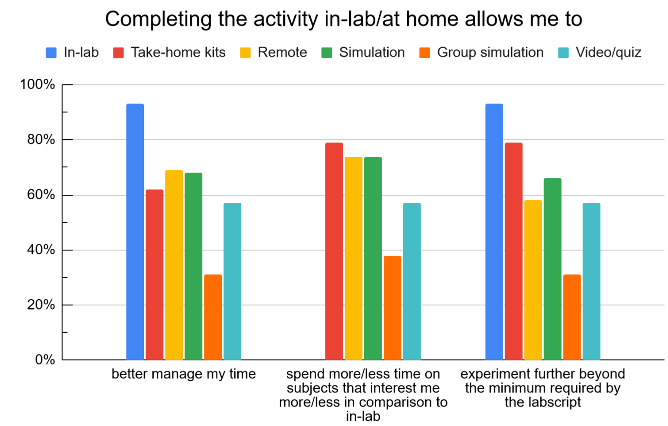

Fig. 2. Time management and open-ended experimentation while performing practical tasks using different methods.

fulfilling seeing the servo system on the camera [...] and I think this definitely improved the experience; felt less like a virtual replacement lab as I could see the physical system in action, mapping what I was seeing on the computer screen to the actual behaviour of the servo :)". Prior work has found that the camera feed was instrumental in providing an authentic lab experience in comparison to simulation activities [10].

When students are asked whether they were challenged by the activities the result is slightly different, with take-home kits scoring the highest at 90%, followed by individual simulation (89%), in-lab (88%), video/quiz (86%), group simulation (77%) and lastly remote access activities (75%). The perceived difficulty of each delivery method appears to be relatively similar. However, we cannot be certain whether the challenge from the activity can be separated from the challenge posed by the delivery method. For example, one student undertaking take-home kits activity pointed out that "*The main problem is when someone has a tiny mistake that can be solved [...] in a matter of seconds if [staff] actually saw the circuit*".

Students undertaking distance learning were asked whether they thought they had gained comparable skills and understanding as they would have in the case of in-lab activities. The percentage of students selecting agree or strongly agree was 90% for take-home kits, followed by remote access (81%), individual simulation (79%), video/quiz (57%), and group simulation (31%).

The in-lab activities have clearly been the most highly regarded by students. However, the high percentage agreements with the four key measures so far (enjoyment, challenge, ability/doing more, gaining comparable skills) for take-home kits, remote access and individual simulation activities suggest that students have been generally satisfied with their practical teaching experience delivered using these distance learning methods. This might be indicative of suitable choices being made with regards to the mode of delivery for each practical teaching activity during the pandemic, as not every practical task can be delivered equally well by all three of these distance delivery methods.

The video/quiz activities have scored considerably lower than the three distance delivery methods mentioned above, on measures of enjoyment and perceived gain of skills. Group simulation activities scored consistently lower on all statements associated with student satisfaction (i.e. the statements shown in Fig. 1). Therefore, neither video/quiz nor group simulations are recommended for distance practical teaching. A common dissatisfaction voiced by the students about group simulation activities was that group members were not contributing equally (e.g., "*[...] I ended up as the one who done (sic) all the work*"). This is a well known issue of free-riding [18], which might have only been exacerbated by the remote delivery. However, only year 1 students took part in this activity, with one student reporting not having the skills "*to engage with something large-scale and independent yet*". Future work could attempt a similar activity for year 2 students, and determine if this delivery method would be more appropriate in later stages, when students have had a chance to gain time-management and independent working skills [19].

Aside from a group simulation exercise, all other practical activities were conducted individually by the students this term, which was explored with the question "*I have missed having a lab partner for this activity*". While only 57% of students agreed or strongly agreed with the above statement after completing the in-lab activities, the proportion has risen to 70% for remote access, 78% for individual simulation, 83% for video/quiz and 88% for take home kits activities. During the in-lab teaching with reduced class sizes, the staff-student ratios were often unusually high (e.g., 1 staff : 4 students). This allowed useful and more frequent interactions between students and staff, meaning a lab partner may not have been missed. All of the individually performed distance learning activities would not have allowed such direct interaction with staff, potentially leading to students missing a partner to exchange ideas with.

Fig. 2 presents the student assessment of each of the delivery methods with respect to their ability to manage their time

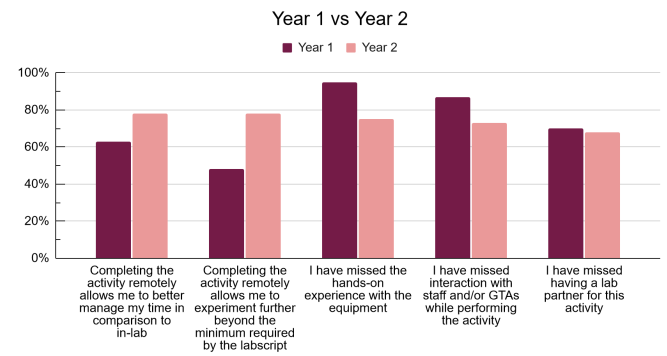

Fig. 3. Differences between Year 1 and Year 2 students' assessment of the remote access practical activities.

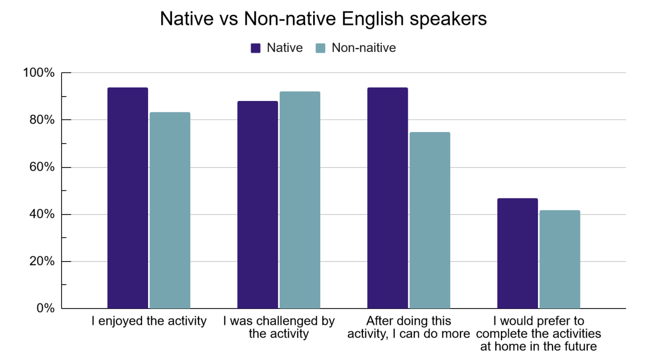

Fig. 4. Differences between native and non-native English speakers' assessment of the practical teaching delivered using take-home kits.

effectively, spend more time on subjects that interest them (or vice versa), and experiment further beyond the provided structured activity. It was unexpected that 93% of the students who completed an in-lab activity agreed or strongly agreed with the statement: "*completing an in-lab session at a scheduled time allows me to better manage my time in comparison to online activities*". This may be caused by the fact that so many of the teaching activities that are normally scheduled for students, such as lectures and practicals, have moved to distance learning this academic year and can be completed at any time, providing very little structure to students' timetables. As such, perhaps they appreciated the structured format here to support their time management [19].

A large proportion of students (over 60% for take-home kits, remote access and individual simulation activities) also agreed or strongly agreed with the statement: "*completing the activity at home allows me to better manage my time in comparison to scheduled in-lab sessions*". In addition, the majority of the students agreed or strongly agreed that completing the activity at home allows them to spend more time on subjects that interest them (or vice versa) in comparison to scheduled in-lab sessions. One student wrote: "*I have enjoyed the freedom of been (sic) able to complete this lab in my own time and not rust to keep to a time requirement. I find this module quite difficult to get my head around so the ability for me to go through this slowly at my own pace has really given me to opportunity to completely understand the content covered...*" An exception was the group simulation exercises, for which students' clear dissatisfaction with the task cascaded through all of the survey questions.

The interaction with staff during practical activities, who can ask targeted questions to encourage deeper investigation, is generally seen as a key part of the in-lab experience for both instruction and social interaction. 98% of students who completed in-lab activities agreed or strongly agreed that "*being able to interact with staff during the activity enhanced my learning*". One student wrote that they enjoyed: "*Talking to the academic about extra things related to the lab*". However, only 52% of students who have completed take-home kit activities claim to have missed interactions with staff while performing the activity. This supports a claim that staff-student interaction during in-lab activities can to some extent be compensated by more open-ended experiments using take-home kits with optional online support sessions.

Out of the students who completed take-home kit activities, 45% also agreed or strongly agreed that they would prefer to undertake these exercises at home in the future, rather than during scheduled in-lab sessions. However, agreement with this statement was strongly activity-dependent. For instance, an activity teaching the fundamental skills of using an Arduino received only 24% agreement to preferring take home-kits, while 82% agreed that they would prefer a take-home session for a follow-up class where they apply their new skills to building and controlling a robot arm. This would suggest that students require more support in learning the fundamentals of new technology, and once they become familiar with it, they appreciate the opportunity to undertake independent, open-ended experimentation in their own time at home. One student wrote about this activity: "*I was able to appreciate the complexity involved in designing a robust robot arm. I also enjoyed learning further about arduino as a model and look forward to further experments*".

Fig. 3 presents some of the students' responses following completion of remote access activities by year of study for Year 1 (Y1) and Year 2 (Y2) students. There is a clear trend of Y2 students declaring they could manage their time better and experiment further than the labscript requires by completing activities remotely in comparison to Y1. This is complemented by Y1 students missing the hands-on experience with the equipment and interaction with staff considerably more than Y2 students. Both student cohorts seemed to miss having a lab partner to a similar extent. The data strongly suggests that in-lab experiences should be prioritised for Y1 students, who are less familiar with the specialised equipment and the principles of engineering experimentation [20], as well as time-management and independent working skills.

Fig. 4 compares students' experiences based on whether they consider English to be their native language, specifically for the take-home kit activities. Non-native English speakers are slightly more likely to be challenged by such activities and slightly less likely to enjoy them in comparison to native speakers. They are also much less convinced that they can "*do more*" after completing take-home kit activities, and less likely to want to perform these activities at home. This might be due to a language barrier that is less easy to overcome with written instructions rather than verbal staff-student interactions during an in-lab activity [21], as well as the culturally different teaching styles that students may be used to. In fact, one of the non-native students suggested: "*It would be better if you demonstrate how the machine is supposed to work, not only in the text*". This strongly suggests that short videos that demonstrate the anticipated behavior of a system, or illustrate certain practical tasks, might enhance student experience, particularly for non-native English speakers.

IV. Conclusions

This study of student experiences of practical engineering activities during the COVID-19 pandemic has led to the following recommendations. Firstly, take-home kits, remote access and individual simulation activities have all appeared to be enjoyed by the students, while being challenging and effective in teaching them new practical skills. These three distance delivery methods received a comparable level of appreciation by the students to the in-lab activities in terms of the above criteria. These delivery methods are, therefore, strongly recommended for distance learning of practical engineering skills when circumstances demand it. Group simulations and video/quiz activities have not proven satisfactory, and hence should be avoided if possible, certainly for first year teaching. Further work is required to assess their effectiveness for later years of undergraduate tuition.

Secondly, some of the take-home kits activities have been a great success, with over 80% of the students preferring to complete these activities at home in the future, rather than attending in-lab sessions. This unexpected outcome, precipitated by the constraints of the pandemic, could lead to enhancing student experience beyond the current circumstances, by incorporating take-home kits activities to the long-term delivery of the curriculum alongside in-person teaching.

Thirdly, if difficult choices need to be made with regards to prioritising limited in-lab access, Year 1 students who are less familiar with the equipment, experimentation and time-management skills should be prioritised over the Year 2 students who already have some experience of this.

Finally, short video demonstrations have been identified as potential tools for enhancing the experience of non-native English speakers during take-home kits activities. Such videos could turn out to be beneficial to any of the teaching delivery methods and for all student cohorts in the future.

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