Lab at Home: an innovative approach for online delivery of a practical civil engineering laboratory during the Covid-19 pandemic

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Abstract: The Covid-19 pandemic has forced many higher education institutions worldwide to suspend traditional face-to-face teaching and shift to online learning. This has presented many challenges for educators and students alike. In the engineering education sector, an important component of the curriculum is represented by practical, team-based activities such as laboratories and design projects. Laboratories provide an invaluable opportunity for engineering students to develop practical, problem-solving and team-working skills, in addition to deepen understanding of module-specific technical content. One of the main challenges to address during the Covid-19 pandemic and the sudden shift to online learning was therefore how to effectively transition these activities to an online format while preserving the quality of the learning experience and student engagement.

This paper presents an innovative approach to deliver a practical team-based first year civil engineering laboratory in an online format. A carefully selected, small scale laboratory kit was delivered to students' homes, and the laboratory activity was redesigned to a certain extent in order to replace laboratory equipment with common household items. The approach includes the use of interactive videos, online quizzes, team meetings through video conferencing platforms. The paper reflects on the challenges and successes in the transition of the laboratory activity to the online format. The lessons learned from this experience can enhance student learning and inform strategies to improve the quality and effectiveness of online engineering education even after the Covid-19 pandemic.

Keywords; Covid-19; online engineering education challenges; online laboratory.

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1. INTRODUCTION

The outbreak of the Covid-19 pandemic at the end of 2019 and beginning of 2020 has had a widespread impact on all aspects of life, including the education sector. Many governments responded to the outbreak with emergency restrictions which included social distancing, lockdowns and limitations on group gatherings. As a result, educational institutions all over the world were forced to close their campuses; this is estimated to have affected more than 1.5 billion students in the first six months of the pandemic (UNESCO, 2020). Most institutions were forced to shift from face-to-face to online teaching in a very short period of time, regardless of their level of preparedness and resources available.

Engineering education traditionally relies on a strong component of hands-on teaching, with many educators adopting active learning as one of the tools to enhance their students' learning experience (Lima et al,. 2017). Laboratories and practicals constitute a substantial part of the curriculum in many engineering programmes. It has long been recognised that laboratories play a key role in helping students achieve a deeper understanding and develop their problem-solving and team-working skills (Krivickas and Krivickas, 2007).

With the transition to online learning, access to laboratory spaces was no longer available, presenting an additional challenge in the shift to online learning. Remote and virtual labs, whilst being effective approaches for the online delivery of laboratory activities, usually require significant time and resources to be developed successfully (Grodotzki et al., 2021). This made it impossible to adopt such methods during the Covid-19 pandemic, due to both the sudden nature of the online transition and the lack of resources required to pivot entire degree programmes online in such a short timeframe. An alternative approach is offered by video laboratories, either live or pre-recorded, in which an instructor conducts the experiment on behalf of the students while showing all the steps of the process. Video laboratories are easier to develop, quick and relatively low cost; on the other hand, student engagement tends to be much lower, and the practical, hands-on component of the learning experience is somewhat weakened and reduced.

This paper presents an innovative approach for the online delivery of a first year civil engineering laboratory in the Engineering Mechanics module. A carefully selected, small scale laboratory kit was sent to students' homes, and the laboratory activity was delivered by combining the use of interactive videos, online quizzes and synchronous teaching through a video conferencing platform.

2. METHOD

2.1 The tallest toy tower laboratory

The tallest toy tower laboratory is part of the Engineering Mechanics module, which is a compulsory class for first year Civil and Civil and Environmental Engineering students at the University of Strathclyde. This module is the first time students experience mathematics applied to engineering and they traditionally tend to find some theoretical concepts quite challenging. The laboratory activity provides an invaluable opportunity for students to experience some of the practical applications of basic mechanics principles. In particular, the aim of the laboratory activity is to measure, derive and apply relationships between basic dimensions which are essential in civil engineering.

During the laboratory activity, students work in groups to determine and compare the properties of different types of toy block and calculate the maximum height of the tower it would be possible to build with each type of block. The laboratory aims to assess the first learning outcome of the module, i.e. "Derive and apply relationships between basic dimensions and convert their units". In addition to the learning outcomes linked to the technical content of the module, this laboratory activity has a strategic role in the curriculum. It is the first group activity completed by first year students and it runs very early in the semester in order to encourage team building among the students and facilitate a smooth transition to university.

2.2 The traditional face to face delivery

In its traditional face to face format, this laboratory activity takes place in the teaching laboratories and is carried out by groups of four or five students. Each group is provided with four different types of toy blocks (Jenga, Alphabet, Lego and Duplo) as shown in Figure 1. Each group is also given all necessary instruments to measure the blocks' mass, dimensions and volume, i.e. a high precision balance, a calliper, and a 1 litre measuring cylinder. Taps are available in the laboratory space and students are able to fill the measuring cylinders as required. After measuring the properties of the blocks and filling in the first part of the laboratory assignment sheet, each group is required to test the blocks in the compression machine in order to measure their compressive strength. The compression test is carried out by the technician who then provides the value of the compressive strength of each block to the groups. The activity has an overall duration of about 90 minutes, and the instructor is available at all times to answer any questions, encourage all group members to contribute to the task and provide guidance when required.

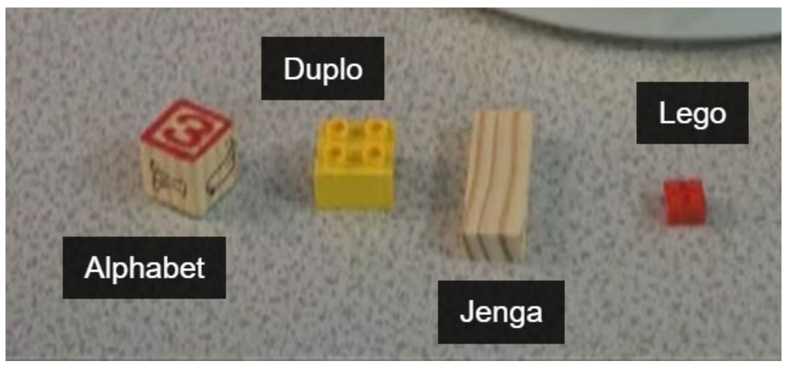

Figure 1. The four types of toy block tested in the laboratory activity.

2.3 The Lab at Home approach

In the academic year 2020-21 the laboratory was reviewed and adjusted in order to accommodate the transition to online delivery of all teaching and learning activities during the Covid-19 pandemic. The primary aim when redesigning the laboratory was to ensure that the practical components of the activity could be completed by students remotely, while preserving its essential features in terms of module-specific learning outcomes and other key aspects such as groupwork. This was achieved with a combination of a small scale laboratory kit, interactive online videos, team meetings through video conferencing platforms and synchronous online teaching.

Each student was sent a small kit including one random toy block among the four shown in Figure 1 and one small 150 mL measuring cylinder, as shown in Figure 2. The kit was sent to students' home addresses before the start of the semester, to ensure they would be delivered well in advance of the laboratory activity taking place. In addition to the kit provided, in order to complete the practical tasks each student was expected to have the following items:

- a ruler to measure the dimensions of the block, as a replacement for the calliper;
- a kitchen scale to measure the mass of the block, as a replacement for the high precision balance;
- water to fill the measuring cylinder as required.

An allocated 1 hour slot in the students' timetable was scheduled for an online, synchronous class fully dedicated to the laboratory activity, which took place on the conferencing platform Zoom. After the instructor introduced the laboratory activity and explained the handout, students were asked to join breakout rooms in groups of five in order to start working on the laboratory activity, while the instructor remained available to answer any questions and provide assistance when required.

In the breakout rooms, groups were asked to complete the first tasks set out in the handout. Each group member was asked to measure the mass, dimensions and volume of the toy block they had been provided, compare measurements with the other group members and then report the findings in the assignment sheet.

Students were not expected to complete all the tasks and the assignment in the allocated slot, which was created primarily to encourage team building, ensure all students had an opportunity to meet their group in a structured environment and receive support from the instructor if necessary. Students were then encourage to organise and set up subsequent Zoom meetings within their groups to complete the remaining tasks and the assignment.

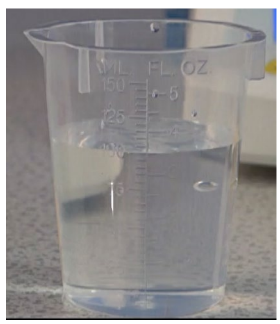

Figure 2. 150 mL measuring cylinder.

The laboratory handout was carefully reviewed to provide detailed instructions about the tasks to be completed. In addition to the handout, instructions were also provided through an online interactive video which was made available in the virtual learning environment (Moodle) during the synchronous class. The first part of the video was a recording of the instructor introducing the laboratory activity and providing general instructions. In the second part of the video the instructor carried out practical demonstrations of the measurements that students were required to take in order to complete the tasks set out in the handout.

The third part of the video was a recording of the compression test carried out on each toy block. This part of the laboratory activity could not be completed remotely by students. Due to the high compressive strength of the toy blocks involved in the experiment, it would not be possible to replicate this part of the activity by using common household items; a professional laboratory instrument is required to test the strength of the materials in a controlled and safe environment.

The interactive video had several functions. First of all it duplicated the information included in the handout in a different format, in order to cater to different learning styles. In addition, it was used as a replacement for the activities that could not be carried out remotely, such as the compression test. Finally, it provided the option of offering an alternative delivery of the entire laboratory activity for the students who did not have the opportunity to complete the practical tasks remotely, either because they had not received the laboratory kit, or because they were unable to complete the measurements if they did not have some of the required equipment, such as a kitchen scale or a ruler.

Throughout the video, interactive content was developed in order to enhance students' engagement. The interactive content included links to external resources, references to the teaching material used during lectures and tutorials, and formative online quizzes. Students also had the opportunity to use bookmarks within the video to skip to or rewatch sections of interest.

3. DISCUSSION

Student engagement with the online laboratory was good, with 80% engaging with the interactive video and 97% attending the synchronous laboratory session on Zoom. The average grade for the laboratory assignment was 73%, proving that learning outcomes were successfully achieved.

One of the main advantages offered by the Lab at Home approach, compared to other online formats for the delivery of laboratories such as virtual, remote or video-laboratories, is that it allows students to engage in the practical tasks as if they were in the physical laboratory space. This helps students develop their problem-solving skills, which are further enhanced by the additional challenge of having to partially source their own equipment to complete some of the tasks.

Having one kit sent to each student ensured that everyone would have the opportunity to complete the practical tasks and also that every student would feel responsible to contribute to the assignment. This helped to achieve a better student engagement overall, compared to the traditional face to face delivery, where it could often be observed that some group members would naturally assume a leadership role, while others would not fully engage with the measurements and practical tasks to be completed, despite encouragements from the instructors.

The main challenge with the Lab at Home approach is that it may not be possible to have all the practical tasks completed remotely by students for experiments which may require the use of specialised equipment or specific health and safety protocols. This was the case for the compression test carried out in the tallest toy tower laboratory. The interactive video offered a good alternative to deliver this part of the experiment. When recording the compression test it was possible to film at the same time the structural response of the blocks and the dial recording the force applied to the block, where the compressive strength should be read at the end of the test. This allowed students to monitor at the same time the deformation of the block and read their own measurement of compressive strength. This was an improvement compared to the traditional face to face delivery, in which students were asked to monitor the deformation of the blocks, while the technician operating the machine provided the value of compressive strength at the end of the experiment.

In terms of time and resources, the Lab at Home approach is more efficient and cost effective compared to virtual and remote laboratories. From the instructor's perspective, it is important to plan in advance to provide students with a structured and clear guidance, and to anticipate any issues that may arise that would normally be addressed in real time with a traditional face to face delivery. In addition to instructions about the tasks to be completed, the reviewed handout was designed to include suggestions about how to organise groupwork and prompts for discussion within the group. In the traditional face to face delivery, this process would normally be facilitated by the instructor checking in and engaging with all the groups in the laboratory space. This was more challenging in the online format due to team meetings taking place in the breakout rooms over Zoom.

4. CONCLUSIONS

This paper has presented a new approach to the delivery of an undergraduate laboratory in the civil engineering curriculum based on a combination of miniature equipment, interactive videos, synchronous and asynchronous online teaching. This approach was developed in the first place to cope with the sudden shift to online delivery of all teaching and learning during the Covid-19 pandemic. The Lab at Home approach ensured the same learning outcomes could be achieved as in the traditional face to face delivery of the laboratory activity. It preserved the hands-on and practical aspect of the laboratory by allowing students to complete most of the tasks from home using the kit provided. This was integrated with an interactive online video in the virtual learning environment. Team meetings through Zoom were used in order to encourage team building among the students and facilitate groupwork. Extra support was provided with a revised laboratory handout including structured and detailed instructions and through synchronous teaching with an instructor available to answer questions and provide guidance when required.

This innovative method can contribute strongly to the enhancement of engineering undergraduate curriculums, which rely heavily on practical laboratories, especially in the first years. This approach can be used to both integrate the delivery of the laboratory activities in a traditional face to face format and offer laboratory activities to the online and distance learning student communities, leading to a general improvement in online engineering education.

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