Replacing laboratory work with online activities: Does it work?

Ivan Gratchev, Senior Lecturer, Griffith University, Australia. https://orcid.org/0000-0003-1452-3753

Shanmuganathan Gunalan, Senior Lecturer, Griffith University, Australia. https://orcid.org/0000-0003-1733-742X

Abstract

This chapter presents and discusses the student and academic experience of replacing laboratory work with online activities due to the COVID-19 restrictions. A set of pre-recorded videos of experimental procedures, online sessions with student-teacher interaction, and follow-up assessment quizzes were introduced into two engineering courses offered in the first two years of the four-year civil engineering program at Griffith University, Australia. The student feedback and teachers' reflections indicated that, although it was not feasible to provide students with hands-on experience, the online activities were found to be a valid alternative to the traditional face-to-face lab. Students noted several benefits of the online delivery, including a long-term access to the laboratory-related materials that allowed them to study at their own pace. The developed online resources were successfully employed the following year, when a blended mode was introduced and students were allowed to return to campus.

Introduction

Laboratories are commonly used in engineering and science to engage students in practical aspects of learning through hands-on activities and provide them with opportunities to test theoretical concepts from lectures and tutorials. Hodgson et al. (2014) noted that laboratories assist students with the development of practical, writing, and teamwork skills, which are important for their industry careers. During laboratories, students often work in small groups along with a lab instructor, creating a student-centered environment that promotes an appreciation of the lab and fosters metacognition (Matz et al., 2012). This interpersonal interaction can also lead to increased intrinsic motivation and enriched learning experiences, which are supported by face-to-face feedback in a timely manner (Hattie and Timperley, 2007). There are several advantages of in-person laboratories, such as giving students the ability to work with real equipment in authentic experimental settings and generate their own results (Brinson, 2015). In addition, laboratories tend to provide the most contact between students and the teaching team, which allows students to receive instant feedback on their performance.

Unfortunately, the COVID-19 pandemic led to the closure of universities following the public health authority advice to maintain social distancing. In response to this, many engineering schools swiftly adopted an online teaching mode, where all teaching activities were delivered remotely. As a result, the online labs became the only option available for many engineering programs during the pandemic; however, Qiang et al. (2020) suggests that online labs may become popular in the future, even after the COVID-19 restrictions have been fully lifted.

The literature shows that online labs can provide a cost-effective solution because students can access them from any location, thus eliminating the cost of lab space and material, and reducing the instructor’s time (Brockman et al., 2020; Flint and Stewart, 2010). In such laboratories, pre-recorded videos can provide a step-by-step overview of real laboratory tests so that students can easily visualize, and become familiar with, the whole experimental process. Students can also replay these videos as many times as they like, an advantage that can save lab resources and avoid safety problems (Yesiloglu et al., 2021). The online labs can give students long-term access to the lab content, compared to the in-person two-hour-long labs (Brockman et al., 2020), which provides students with more time to process the knowledge and better prepare for lab assessments. The lab assessment may include online exercises and quizzes, which can be attempted multiple times as well. In addition, virtual labs can be part of online activities as they provide an environment in which experiments are conducted or controlled through computer simulation either locally or remotely via the Internet (Chan and Fok, 2009).

However, despite several advantages, online laboratories can discourage students from becoming familiar with physical instrumentation and real devices (Chan and Fok, 2009). In addition, the remote access denies valuable hands-on experience (Gamage et al., 2020), and it may discourage direct collaboration and interaction between students and the teaching staff. Other issues with online laboratories (Gamage et al., 2020) include the internet connection, a lack of appropriate digital devices, and online cheating as students are not supervised. Recent experience indicates that students may not be satisfied with online labs when instructors use videos of experiments from video-sharing platforms, especially when it is not clearly related to the lab work (Yesiloglu et al., 2021).

This paper discusses the learning and teaching experiences obtained from two undergraduate courses, namely Engineering Mechanics (EM), and Soil Mechanics (SM), in 2020 and 2021. These courses are part of an undergraduate engineering degree program offered at the School of Engineering and Built Environment (EBE), Griffith University, on two campuses (Gold Coast and Nathan campuses). Both courses teach students the fundamentals of engineering mechanics, utilizing a project-based approach in which students work on large projects throughout the whole trimester. The laboratories are an important component of each course because they help students better understand theoretical concepts, which can be rather difficult to visualize during lectures. The first part of this chapter discusses the structure of the EM course, the changes in the learning and teaching activities caused by the COVID-19 restrictions, student feedback, and academic reflection with a focus on student experience and engagement. The second part deals with the SM course in a similar way. As these two courses are offered to the student cohorts in their first and second years, the final conclusions provide an indication of the student experience with online laboratories at the early stage of their four-year undergraduate program.

Engineering Mechanics course

EM is a first-year course that develops a foundation and framework for many engineering disciplines such as civil, mechanical, and environmental. This course aims at developing a sound understanding of mechanics principles and problem-solving skills. EM contains a large amount of technical content, and consists of weekly lectures and workshops (Table 1). During the workshops, students perform a series of laboratory activities and discuss the obtained results with a laboratory instructor.

EM was redesigned in 2017 to better align with the experiential learning principles (Kolb, 2011; Kolb, 2014). The course delivery was structured around a trimester-long project with scaffolding laboratory activities, which were performed during the workshops to facilitate a student-centered learning approach. This project-based approach built on real-world engineering problems provided students with authentic learning experiences (Crawley et al., 2014). The lab work helped students 1) to better understand the engineering mechanics concepts, and 2) to connect theory with practice (Kober, 2015). The laboratory hands-on activities were also used to promote self-learning by observing and reflecting on different engineering mechanics concepts (Table 1). Students employed a few physical models to experiment and learn about forces, moments, equilibriums, reaction forces, and deflections. Another series of experiments were designed to observe the truss member forces resulting from different nodal loads, the shear force, and the bending moment distribution in beams. During these lab activities, students worked in groups at their own pace, collected experimental data, and discussed it with the lab instructor, who provided students with instant feedback. The lab activities were followed by weekly quizzes that assessed student problem-solving skills and their ability to critically reflect on the laboratory results.

The student feedback on the face-to-face laboratories was mostly positive. It appears that the hands-on experience helped students better understand the engineering mechanics principles and mathematical concepts. Students mentioned that they could 1) apply the fundamentals of physics and mathematics to analyse the equilibrium of simple systems under static loading, and (2) apply the concepts of sectional properties and internal force characteristics of beams to solve real-world engineering problems. Students were also able to predict, operate, and observe engineering mechanics concepts and reflect on the degree of agreement between estimation, calculation, and observation.

Table 1. Course contact hours before and after COVID-19 restrictions and workshop activities. Note that Griffith University uses a trimester system with 12 weeks of teaching in one trimester. One week is used as an employability week (no teaching).

Contact Hours				
Activity	Hours per Week	Total Hours	Before COVID-19 2017- 2019	After COVID-19 2020
Lecture	3	33 (11 weeks)	On Campus	Online (Live)

Workshop	2	22 (11 weeks)	On Campus	Pre-recorded videos and Online Drop-in-sessions
Workshop Activities				
Activity 1	Calculating the forces, moments, and components of forces using work board, plywood beam, string, weights, spring balance, pulley, and protractor.			
Activity 2	Solving the equilibrium equations of a concurrent force system using work board, weights, strings, pulleys, and joint ring.			
Activity 3	Understanding the free body diagram and calculating the support reactions of a non-concurrent force system using plywood beam, kitchen scales, and weights.			
Activity 4	Performing truss analyses to find member forces and nature using cantilever and simply supported truss models.			
Activity 5	Calculating second moment of area and deflection using PVC beams with different cross-sections, weights, dial gauge, and different support conditions.			

In 2020, due to COVID-19, the workshop activities were pre-recorded and uploaded to the course webpage so that students could watch the videos before each workshop. The workshop contact hours were utilized for drop-in sessions, where an instructor could answer student questions and clarify the content related to the pre-recorded videos. Many students watched the videos before each workshop and used the workshop time to interact with the instructor. However, there were some students who utilized the workshop contact hours to watch the videos.

Results and Discussion

The implementation of the online lab activities seems to have engaged students in learning. This is evidenced by the data from the Student Evaluation of Course (SEC) survey (Table 2).

The results for the Q1 question (*Overall I am satisfied with the quality of this course*) indicate that in terms of the total score, the student experience with the online delivery (2020) was similar to the on-campus experience before COVID-19 in 2019. The Q2 question (*The workshop activities and tutorials in this course assisted my learning*) specifically targeted the workshop and laboratory activities. When the on-campus lab activities were replaced with the online mode, it was found that the score for student experience slightly improved for the student cohort at the Gold Coast campus (from 4 to 4.3), while the student experience score at the Nathan campus decreased from 4.4 to 4. It is still not clear why there was such a variation in the SEC score between two campuses; this can be related to the student demographics.

Table 2. Student feedback regarding the EM course and laboratory activities.

Feedback	Campus	2019 (on campus)		2020 (online)	
		Score (out of 5)	Student response rate (%)	Score (out of 5)	Student response rate (%)
Q1	Gold Coast	4.5	28.1	4.3	28.4
	Nathan	4.7	37.7	4.7	28.1
Q2a or Q2b	Gold Coast	4.0	28.1	4.3	28.4
	Nathan	4.4	37.7	4.0	28.1

Note: Q1 *Overall, I am satisfied with the quality of this course*. Q2a (in 2019) *The workshop activities and tutorials in this course assisted my learning*. Q2b (in 2020) *The videos of workshop activities and tutorials in this course assisted my learning*.

Student comments in the SEC survey give a better understanding on how the online delivery has influenced, motivated, and inspired students to learn. In 2019 (on-campus delivery), students enjoyed the course with the scaffolding lab activities. They appreciated the fact that these activities were hands-on, which helped them to understand some theoretical concepts. However, students also felt that the lab activities and quizzes had a great deal of content to cover within the two-hour workshops, and for this reason, the workshop activities were often rushed. As a result, they could not clearly understand some parts of the workshop material presented. According to the student feedback in 2020 (online delivery), students appreciated the online workshop videos and tutorial solutions. They felt that these videos helped them better engage in learning, and they even requested more videos to be produced. The students commented that they enjoyed the workshop structure in which they could independently complete the activities at their own pace and attend the online workshop only when they needed help.

From a teacher's point of view, even though the online delivery of the lab activities provided students with a relatively good learning experience, there were still a few issues to be addressed. The main concern was that students were not able to experience the hands-on part of the laboratory. In addition, students could not effectively work as a group by using the online tools provided.

In 2021, the COVID-19 restrictions were relaxed, and the university allowed smaller classes to be held on campus. The workshops were delivered in a blended mode in which the online videos were available for students before online or on-campus drop-in-sessions. The students who could attend the on-campus classes (note that not all students could do so as some restrictions were still in place) were able to experience the laboratory activities in person. For such students, the pre-recorded videos served as additional learning tools.

Soil Mechanics course

SM is designed to provide second-year civil and environmental engineering students with the fundamental knowledge of soil behavior and opportunities to develop the critical skills necessary to apply this knowledge into practice. The weekly lectures deal with the theoretical aspects of soil mechanics while weekly tutorials scaffold student knowledge and assist students in developing problem-solving skills (Gratchev and Balasubramaniam, 2012). Five laboratories (scheduled fortnightly) are used to provide students with hands-on experience and connect theory with practice through practical work. Students are required to perform a series of laboratory tests, interpret and analyse the obtained results, and discuss their practical applications with a lab instructor (Gratchev and Jeng, 2018). Students commented that the labs were helpful in connecting the theory to real-world applications. They also noted that the face-to-face labs gave them some real exposure to the type of work done outside of university in this field.

In 2020, all teaching activities were shifted online. Online laboratory sessions were still held fortnightly while all lab experiments were pre-recorded and made available to students from the beginning of the trimester. Several videos created by the teaching team and technical staff explained a step-by-step procedure for each test, starting from the soil sample preparation using the relevant equipment, and to the analysis of the obtained results. The videos were edited to include text explanation of the key aspects of each experiment. This highlighted important details of the testing procedure and helped direct learners' attention (Ibrahim et al., 2012). To maximize student attention, the videos were kept short, when possible, as according to Guo et al. (2014), the student engagement tends to drop when the video length becomes longer than six minutes. A total of 14 videos (Table 3) were recorded to cover the practical aspects of all lab sessions. The videos were uploaded to YouTube because this platform provided a variety of useful tools for both students and the teaching team.

The videos and online lab sessions were arranged in a way to replicate, to a certain extent, the experience that students would have during a face-to-face laboratory. Students were expected to watch these videos before each online lab session. The lab sessions were mostly used to discuss the results of each test and its practical application (Table 3), and they also served to answer students' questions. For each lab, a follow-up one-hour quiz, with a set of multiple-choice questions on the test procedure and short-answer questions related to data analysis, was given to the students on the next day. The quiz was available for 12 hours, and students could use all course materials, including the video of each experiment. The previous experience with online quizzes suggested that this timeframe was sufficient for students to complete the test. To minimize online cheating, a pool of different problems was used to randomize quiz questions. Correct answers were provided on the following day to give students timely feedback. This also assisted students with their preparation for the course major assessment items such as Project 1 (25% worth) and Project 2 (35% worth).

Table 3. The content of laboratory sessions and online videos for Soil Mechanics in 2020.

	Tests	Online laboratory sessions.
Lab 1	Dynamic cone penetrometer Vane shear test Pocket penetrometer test Water content test	Discussion of test results, data interpretation and analysis. Discussion of practical application of all four tests.
Lab 2	Specific gravity Grain size (sieve) test	Focus on the use of test results to classify coarse-grained soils.
Lab 3	Proctor compaction test	Discussion of test procedure, data analysis, and application in construction.

Lab 4	Liquid limit test Plastic limit test Linear shrinkage test Constant head permeability test Falling head permeability test	Application of test results to classify plastic fine-grained soil based on soil plasticity. The use of soil permeability to estimate water flow under engineering structures.
Lab 5	Oedometer (consolidation) test Shear box test	Use of oedometer tests to estimate the time and settlement of soft soil under loads.

Results and Discussion

The data obtained from the YouTube statistics dashboard indicates a few viewing peaks around the day of the online lab session. It was clear that students watched the videos on the day before each session; however, the largest viewing peaks were observed on the day of the lab session, as well as on the day of the assessment quiz. This can be attributed to the fact that 1) students were required to watch the relevant videos prior to each online lab session; 2) several questions in the quiz were related to the test procedure, which "forced" students to watch the videos before and during the quiz. No peaks were observed at any other time, suggesting that the students only watched the videos when absolutely necessary.

Although being unable to fully replace the student experience of face-to-face labs, the online lab sessions combined with the pre-recorded videos and online assessment quizzes provided students with the opportunities to engage in practical aspects of the course. Student feedback on the online videos was mostly positive, as they liked the opportunity to learn at their own pace and watch the videos at any time. However, there was on average about 10% of the student cohort who did not attempt the assessment quiz. The average mark of 7 (out of 10) for all five quizzes suggested that students acquired some knowledge of test procedures and developed skills to interpret the test results.

Student responses to the question regarding the level of satisfaction with the course are summarized in Table 4 for both campuses. It can be seen that, for Gold Coast campus the overall level of satisfaction (4.4/5) was the same for both years; that is, 2019 (on-campus) and 2020 (online). However, there was a noticeable change in the score for Nathan campus, where it dropped from 4.8 to 4.0. It is noted that the relatively low student response rate, especially for Nathan campus, suggests that the overall score may not accurately represent the opinion of the whole student cohort. In addition, there might be other factors that influenced student satisfaction with the course.

Table 4. Student satisfaction with the SM course.

Feedback	Campus	2019 (on campus)		2020 (online)	
		Score (out of 5)	Student response rate (%)	Score (out of 5)	Student response rate (%)
Q1	Gold Coast	4.4	27.7	4.4	33.3
	Nathan	4.8	41.7	4.0	9.7

Note: Q1 *Overall, I am satisfied with the quality of this course*

In 2021, the lab sessions went back to a face-to-face delivery mode while the online videos were used as supplementary learning resources. As the videos were available before each lab, the time taken by the lab instructors to explain the test procedure significantly decreased, which allowed them to focus on the data analysis and practical aspects of each test. From an instructor's point of view, it is evident that the combination of online videos and face-to-face lab classes can enrich the student learning experience. Online videos of lab tests allow students to better understand the procedures and real-life applications while in-person labs can help them develop practical skills (Colthorpe and Ainscough, 2021). Therefore, for a blended mode, online lab videos can be effectively used as a preparation tool for other learning activities (Salter and Gardner, 2016).

The online labs, run in the same way as in 2020 during the COVID-19 restrictions, were also used in 2021 for offshore students and those students who could not attend the campus due to the lockdown or health concerns. This online lab arrangement proved to continue to be useful as it provided the students with an alternative way to engage in the practical aspects of the course.

Concluding remarks

COVID-19 has made academics explore and adopt different approaches towards teaching. They were required to replace in-person laboratory sessions with appropriate online activities. This was a challenging task as it required extra time, effort, and resources to produce new learning tools within a relatively short period of time. This paper presents and discusses the experience obtained for two engineering courses, in which face-to-face labs were replaced with pre-recorded videos and online activities. Based on the obtained results, the following conclusions can be drawn:

- Students understood the necessity of switching to online delivery and tried to adopt and engage in online activities. Students from different cohorts (first and second years of the four-year engineering undergraduate program) provided similar feedback on the use of online activities, in particular online laboratories. Students generally liked the idea that online videos and other online resources were available from the beginning of the trimester so that they could access them at any time and work on them at their own pace.

- The follow-up quizzes used to assess the student knowledge and understanding of the laboratory work were designed in a way that not only "force" students to watch the videos, but also to help them understand the important aspects of each lab experiment. The videos prepared by the teaching team explained a step-by-step laboratory procedure so that students could understand how the laboratory equipment was used and how the experimental results were obtained.
- The online sessions were used to discuss the details of each test and different approaches to interpret and analyse the lab data, as well as to answer student questions. However, compared to face-to-face labs, the major disadvantages of online labs included the lack of hands-on experience and the lack of communication between students, and between students and the teaching team.
- The online videos and other teaching resources developed during the pandemic can be successfully used as additional learning tools when face-to-face or blended delivery modes return. Watching online videos before a face-to-face laboratory can help students understand the experimental procedure and prepare them for the hands-on activities. It also allows the teaching team to save time during each lab, which can be used to focus on data analysis, discuss practical applications, and answer student questions.

In to the question put forward by the title of this chapter, the authors would like to note that online activities cannot completely replace the hands-on laboratory experience. However, pre-recorded videos of experiments combined with online sessions that facilitate student-teacher interaction and follow-up quizzes can provide a valid alternative to face-to-face labs, and can be effectively utilized when face-to-face sessions are not possible.

References

Brinson, J. R. (2015). Learning outcome achievement in non-traditional (virtual and remote) versus traditional (hands-on) laboratories: A review of the empirical research. Computers & Education, 87, 218-237.

Brockman, R. M., Taylor, J. M., Segars, L. W., Selke, V., & Taylor, T. A. (2020). Student perceptions of online and in-person microbiology laboratory experiences in undergraduate medical education. Medical education online, 25(1), 1710324.

Chan, C., & Fok, W. (2009). Evaluating learning experiences in virtual laboratory training through student perceptions: a case study in Electrical and Electronic Engineering at the University of Hong Kong. *engineering education*, *4*(2), 70-75.

Colthorpe, K., & Ainscough, L. (2021). Do-it-yourself physiology labs: Can hands-on laboratory classes be effectively replicated online? Advances in Physiology Education, 45(1), 95-102.

Crawley, E.F., Malmqvist, J., Östlund, S., Brodeur, D., Edström, K. (2014). Rethinking Engineering Education: The CDIO Approach, Second Edition. New York: Springer.

Flint, S., & Stewart, T. (2010). Food microbiology—design and testing of a virtual laboratory exercise. Journal of Food Science Education, 9(4), 84-89.

Gamage, K. A., Wijesuriya, D. I., Ekanayake, S. Y., Rennie, A. E., Lambert, C. G., & Gunawardhana, N. (2020). Online delivery of teaching and laboratory practices: continuity of university programmes during COVID-19 pandemic. Education Sciences, 10(10), 291.

Gratchev, I., & Balasubramaniam, A. (2012). Developing assessment tasks to improve the performance of engineering students. In 23rd Annual Conference of the Australasian Association for Engineering Education 2012.

Gratchev, I., & Jeng, D. S. (2018). Introducing a project-based assignment in a traditionally taught engineering course. European Journal of Engineering Education, 43(5), 788-799.

Guo, P. J., Kim, J., & Rubin, R. (2014). How video production affects student engagement: An empirical study of MOOC videos. In Proceedings of the first ACM conference on Learning@ scale conference (pp. 41-50).

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of educational research*, *77*(1), 81-112.

Hodgson, Y., Varsavsky, C., & Matthews, K. E. (2014). Assessment and teaching of science skills: whole of programme perceptions of graduating students. Assessment & Evaluation in Higher Education, 39(5), 515-530.

Ibrahim, M., Antonenko, P. D., Greenwood, C. M., & Wheeler, D. (2012). Effects of segmenting, signalling, and weeding on learning from educational video. Learning, media and technology, 37(3), 220-235.

Kober, N. (2015). Reaching Students: What Research Says About Effective Instruction in Undergraduate Science and Engineering. Washington, DC: The National Academies Press.

Kolb, D.A. (2011). Experiential Learning Theory: Previous Research and New Directions, Perspectives on Thinking, Learning, and Cognitive Styles. pp. 227-246.

Kolb, D.A. (2014). Experiential Learning: Experience as the Source of Learning and Development.

Matz, R. L., Rothman, E. D., Krajcik, J. S., & Banaszak Holl, M. M. (2012). Concurrent enrollment in lecture and laboratory enhances student performance and retention. *Journal of Research in Science Teaching*, *49*(5), 659-682.

Qiang, Z., Obando, A. G., Chen, Y., & Ye, C. (2020). Revisiting distance learning resources for undergraduate research and lab activities during COVID-19 pandemic. Journal of Chemical Education, 97(9), 3446-3449.

Salter, S., & Gardner, C. (2016). Online or face-to-face microbiology laboratory sessions? First year higher education student perspectives and preferences. Creative Education, 7(14), 1869.

Yesiloglu, S. N., Gençer, S., Ekici, F., & Isik, B. (2021). Examining Pre-Service Teachers' Views about Online Chemistry Laboratory Learning Experiences Amid the COVID-19 Pandemic. Journal of Turkish Science Education, 18, 108-124.