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ARTICLE

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Pre-lab video demonstrations to enhance students' laboratory experience in a first-year chemical engineering class

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Abstract

The limited capabilities of teaching laboratories, combined with an increasing number of students enrolled in university, require constant augmentation of instructional approaches. By enhancing laboratory demonstrations with digital technology, these structural issues can be addressed while at the same time enhancing student understanding and learning. Our case study focuses on the fermentation lab part of the Reaction Equilibria and Thermodynamics (RET) module, a first-year chemical engineering course at the University of Birmingham. Video demonstrations were used to introduce students to the laboratory set-ups and walk them through each step and technique. The video demonstrations allowed the students to attend the in-person lab sessions having established knowledge and understanding of the processes involved and the outcomes desired, which decreased the burden on the facilities and the staff. A knowledge-based quiz and a student survey conducted at the end of the module showed that the pre-lab videos encouraged more active participation in the laboratory sessions and reinforced learning. Approximately 70% of the students polled in the first survey conducted within this project felt more confident going into the laboratory sessions after watching the pre-lab videos and attempting the knowledge quiz, while 92% of the students polled in the second survey judged the pre-lab video sessions as beneficial to them. Overall, the teaching method has the potential to improve student participation and access, boost confidence and learning, and provided a more structured and flexible approach to laboratory learning outcomes.

KEYWORDS

blended teaching and learning, chemical engineering, student assessment, virtual laboratory, visual communication

1 | CONTEXT AND OBJECTIVES OF THE STUDY

An effective engineering education includes theoretical knowledge and practical skills delivered via hands-on laboratory sessions.[1] Hence, teaching chemical and biochemical engineering to undergraduate students involves both lectures and laboratory-based classes. Laboratory sessions in chemical engineering education form an integral part of an undergraduate degree course. They offer students the opportunity to develop technical skills, practice careful observation, reaffirm theoretical concepts, develop problem-solving skills, learn how to interpret observations and data, and develop report writing skills.[2]

While the traditional teaching approaches, which include lectures, and reading books and scientific articles, allow chemical engineering students to develop scientific knowledge and numeric skills, the lab-based classes are designed to enhance technical skills by learning concepts and theories experientially through practice. Thus, laboratory classes are a crucial experience for chemical engineering undergraduate students. Furthermore, laboratory sessions are mandatory for professional engineering and science bodies accreditations[1]; for instance, the Institution of Chemical Engineers (IChemE), the American Institute of Chemical Engineers (AIChE), and the Royal Academy of Engineering (RAEng) require a candidate to possess and demonstrate both scientific knowledge and practical skills needed for the practice and the advancement of chemical engineering.[3–5]

Additionally, laboratory activities allow students to experience and consolidate the knowledge and concept acquired during the course lectures and readings. In recent years, digital resources have been used to augment approaches to laboratory sessions in order to enhance teaching and learning.[1,6] The benefit of digital tools and communication platforms such as videos, audio recording, images and online lab simulators have been reported widely in the literature.[7–10] This demonstrates the potential to complement laboratory work with digital tools and instruction. Technology-assisted learning can be integrated into traditional laboratory classes through the use of computer simulations and video aids to instruct students on laboratory procedures, equipment use and methods, protocols and safety.[6]

One of the advantages of digital technology is that it allows the use of multimedia and/or online presentation of laboratory practices. It accommodates a large student population, maximizes classroom utilization, management and aids assessment and feedback provision. Recently, a study[11] investigated the impact of pre-laboratory video on students' preparedness to undertake a laboratory practical and receive marks. It was found that the level of preparedness and assessment mark increased as time spent engaging with the video increased. It was also shown that pre-laboratory videos should have a strong connection with the learning objectives of the experiments. A similar study was conducted[12] on pre-lab instructional videos prior to a general chemistry laboratory practical. It was reported that students who watched the online pre-laboratory videos were more efficient in time management and understood the laboratory protocols better. Pre-lab videos could also be used for both visual demonstrations and audio explanations of concepts and protocols to improve students' preparedness for analytical chemical engineering laboratory classes.[2] All these findings support the hypothesis that the use of pre-lab videos could be an exemplary approach in improving students' learning in chemical engineering laboratory sessions.

Laboratory classes are time-demanding to organize, manage, and assess, especially for a large number of students. Number of students in an undergraduate class makes laboratory classes challenging to run. Assessment and feedback on laboratory reports for large classes require significant amounts of time and are generally delivered at the end of the laboratory experience, thus with limited formative effect. Laboratory classes are an essential feature of many Science, Technology, Engineering and Mathematics (STEM) degrees and of chemical engineering. To address these issues, we decided to incorporate a fermentation laboratory into the Reaction Equilibria and Thermodynamics (RET) module that would benefit from its inception from the integration of educational technology. The most important element of the new laboratory teaching structure was the creation of pre-lab videos that offer the students the opportunity to visualize the theories, experiments and techniques they had been taught in lectures but not yet seen in real life. The apparent advantage of the videos, apart from their visual real-life impact as compared to pre-lab literature on its own, is their asynchronous and on-demand nature. Unlike a traditional laboratory class, students have the opportunity to revisit the pre-lab videos at any time, from any device and at their own convenience and pace. A study that investigated student perceptions of face-to-face (F2F) versus virtual laboratories showed promising results in students' appreciation of this kind of initiatives[9] -to-, albeit with important caveats that in many ways are still worth exploring, at least in our context. The recent changes brought about in Higher Education (HE) by the COVID-19 pandemic have reinforced the need to explore this area and, in our view, only added to the need and usefulness of virtual/online and/or blended teaching and learning experiences linked to laboratory sessions.

As will be demonstrated in this work, the pre-lab videos have afforded us a time and cost-effective tool for managing the teaching and learning of a large cohort of first year students and allowing the students themselves to personalize part of their learning to a significant extent, even in the absence of any major additional investment in infrastructure or faculty members' time.

The small-scale nature of this study and the fact that it is limited to one context might not afford us the luxury of generalized conclusions on this approach. However, it represents, nonetheless, a useful case study for an innovative, low cost but highly effective approach to introducing personalization and flexibility in laboratory classes.

2 | MATERIALS AND METHODS

This study is based on the students' attendance to the fermentation laboratory of the RET module within the school between 2015 and 2019 (academic years 2014–2015 to 2018–2019). The pre-lab quiz and survey data collected were analyzed proportionally. According to our enrollment statistics, we have 156 (2015), 162 (2016), 167 (2017), 168 (2018), and 131 (2019) students in our Chemical Engineering programme each year. A total of 784 students enrolled between 2015 and 2019 in the laboratory, with a range of 131–168 students per year and 157 students on average.

The fermentation laboratory session of the RET course consists of five sections: pre-lab teaching material, educational videos, and corresponding pre-lab quiz, lab practical, report writing and student survey. The following sections explain how the pre-lab videos were created and how the quiz, report, and survey were constructed. The central objective of this study is to document the process of integration of the pre-lab videos into the course and assess student perceptions of this intervention and the effects on their learning. The main aim of the videos was for them to serve as a teaching tool prior to the actual laboratory session in the context of logistical and structural issues linked to large class sizes and limited fixed resources for laboratory work. The RET module is compulsory for all registered first year Bachelor of Engineering Students within the school of chemical engineering, and this is approximately 160 students yearly. The RET module is characterized by a series of lectures involving the application of biological processes and their effect on a final product. Moreover, to fully achieve the scope of this module, students had to attend two practical laboratory classes: one on fermentation (the object of this study) and one on reactors, which did not feature any video recorded pre-lab sessions.

The videos created for the fermentation lab were uploaded on YouTube and then linked to the Canvas® page of the module (Canvas® is the virtual learning environment [VLE] used at the University of Birmingham). The students were able to watch the videos as often as they wished and for any period of time they considered necessary. They were then asked to complete a compulsory but non-assessed pre-lab online quiz on the topics of the videos. The students' learning experience from the online pre-lab videos was subsequently evaluated using a postlab survey designed and delivered for the 2017 and 2019 cohorts.

In terms of summative assessment, the students wrote a laboratory report individually, which was marked, and feedback was given. Having assumed as our hypothesis that the pre-lab videos would have a positive effect not only on the practical workability of a laboratory session for a large cohort of first year chemical engineering students, data from the students' performance in laboratory session and final assessment mark was also taken into consideration to evaluate this tool, together with the more direct data coming from the pre-lab quiz and the final survey.

2.1 | Filming of laboratory techniques

The pre-lab videos, are used in our study to engage students prior to the actual lab work, which helps in preparation and allows them to visualize concepts and link them to the theory they had been taught. The use of videos in HE is encouraged as it offers a chance to improve student engagement and promote deeper learning.[13] More importantly, it has the potential to be combined with other approaches, encouraging enhanced learning as it can be revisited many times by the students.[14] In this study, pre-laboratory online sessions consisted of 10 short videos with a total duration of approximately 1 h, as shown in Table 1. Pre-lab videos were filmed using a Canon GL2 DV camera. The raw footage was rendered into digital form with a Sony Mini-DV deck and imported into windows media. All video editing was done at the University of Birmingham Media Centre thanks to an internal grant. Videos were then uploaded to a dedicated YouTube® channel (https://www.youtube.com/playlist?list=PLw3Be3qTtwmKNtzZpxK4UIWppKGLz73ns) and linked to the Canvas® page of the module. The videos feature lab technicians and teaching assistants demonstrating the lab's location, the use of the equipment and the procedures and outcomes of the experiments, as described in Table 1.

2.2 | Pre-lab quiz

To assess the impact of the learning delivered through videos on student performance in class, the students completed a compulsory but not assessed pre-lab online quiz

TABLE 1 Pre-lab online video sessions

Video	Content	Duration (min)
01—Introduction	Welcome video with instructions on where personal belongings should be stowed, basic handwashing techniques, where personal protective equipment is kept (eye goggles, lab coats etc.) and finally where they can collect a lab manual and how to sign into the lab class.	4:40
02—Fermenter (Part 1)	Background on the fermenter controls, calibration, and setting.	15:26
03—Fermenter (Part 2)		15:16
04—Sampling	Description of the sampling methods to use during the practical lab activity.	3:34
05—Preparing the bench	Demonstration of the aseptic techniques to use before starting the experiments.	0:57
06–Serial Dilution	Demonstration of how to perform the serial dilution of bacterial culture and subsequently inoculate onto a solid media for colony count.	5:28
07—Optical density (OD)	Demonstration of how to measure OD using a spectrophotometer to determine the fermentation stage.	4:44
08—Glucose concentration	Demonstration of how to quantify the glucose in the fermentation media during bacterial growth.	2:54
09—Dry cell weight	Demonstration of how to prepare dried bacterial samples from the fermentation media.	2:13
10—Leaving the lab	Goodbye video and good practices before leaving the lab.	0:28

(Table 2: correct answers are in bold) prior to their attendance at the lab session. The quiz was designed with questions that were easy to answer after viewing the videos. This was done to maximize the link between watching the videos and answering the questions correctly. The same information could be found in other sources, but not without a considerable amount of additional effort. The answers were marked automatically, and feedback was given online at the end of the quiz. The students had unlimited attempts at the quiz; however, only the first attempt was used to analyze the outcome. Even though the answers could be correctly given from reading or watching other sources apart from the pre-lab videos, all the information required to answer the questions correctly was clearly and specifically addressed in the videos. Therefore, the quiz only served as a formative assessment and did not count towards the final marks of the fermentation session of the RET module.

2.3 | Laboratory experience

The fermentation laboratory is essentially divided into four interconnected activities. Particularly, students have to analyze an *Escherichia coli* culture using a set of techniques including serial dilution, bacterial plating, measuring the dry cell weight, and monitoring the growth via measuring light absorbance and the level of glucose dissolved in the media. Students had occasions to familiarize themselves with pipettes, scales, pH meter, spectrophotometer and other basic lab equipment during this laboratory session.

2.4 | Summative assessment

At the end of the laboratory sessions, the students turned in their reports for summative assessment. The laboratory reports written by the students were marked and accompanied with detailed feedback to the students. This summative assessment accounts for 20% of the final mark for the entire RET module.

2.5 | Online survey

A survey was designed and provided to students through SurveyMonkey® (https://www.surveymonkey.co.uk); questions are shown in Table 3. The survey aimed to evaluate the learning experience of the pre-lab videos. The student survey responses were collected anonymously during the academic years 2017 and 2019. The link to the online survey was sent out after the laboratory class session. Changes made to the 2019 survey are indicated in parentheses.

3 | RESULTS AND DISCUSSION

3.1 | Pre-lab quiz

Prior to the fermentation lab, students had to study the material provided and complete the pre-lab online quiz. The overall pre-lab quiz outcome for each of the 10 questions was recorded and plotted using an independent bar chart per academic year to visualize the performances of

TABLE 2 Pre-lab quiz questions

	Questions	Answers
1	What are the main objectives of this practical?	a. To grow *Escherichia coli* in submerged culture and monitor its growth b. To measure oxygen demand and the solution pH c. To monitor glucose utilization d. **All the above**
2	Which parts listed below control fermenter temperature?	a. **Heating jacket. And cold finger** b. Agitator and sparger c. pH electrode and cold finger d. Sparger aeration. and heating jacket
3	What do you understand by the term calibration?	a. It is an indication to examine the accuracy and performance of instruments b. It is used to eliminate errors in measurements c. **(a) and (b)** d. It is an extra measuring factor with no effect.
4	Why do we recheck the DO2 (dissolved oxygen) probe after the sterilization of the medium?	a. To reach equilibrium b. To dissolved oxygen c. To create stabilization d. **Because the probe can be affected by the autoclaving processes and it needs time to repolarise**
5	Why is the DO2 probe calibrated at 37°C?	a. To kill the bacteria b. **Because that is the temperature at which bacteria will be growing at** c. To dissolved oxygen d. None of the above
6	In the calibration of the pH electrode why it is necessary to adjust pH to 7?	a. To avoid any source of error b. To improve the quality of the solution c. Because that pH is good for bacteria to grow d. **Because 7 is the pH neutral state**
7	Which one of the following substances is not used to prepare the final media solution?	a. KH_2PO_4 b. $MgSO_4$ c. Peptone d. **CO_2**
8	What are the initial setpoints of the fermenter?	a. **$T = 37°C$, Speed = 600 rpm, $DO_2 = 100\%$, heed pressure = 2–3 psi** b. $T = 37°C$, Speed = 900 rpm, $DO_2 = 100\%$, heed pressure = 2–3 psi c. $T = 73°C$, Speed = 600 rpm, $DO_2 = 100\%$, heed pressure = 2–5 psi d. $T = 37°C$, Speed = 600 rpm, $DO_2 = 50\%$, heed pressure = 2–3 psi
9	Why the analysis of a small sample is important?	a. Cold sample b. Large quantity c. **Representative sample** d. Hot sample
10	Which one of the following instruments is used to measure optical density?	a. pH meter b. Glucose meter c. **Spectrophotometer** d. Densitometer

Note: Correct answers are in bold.

TABLE 3 Survey questions

Questions		Response
Section A		
1	After watching the video on what to do coming into the laboratory, were the instructions clear?	Yes/no/not sure
2	Was it easy to follow the instructions from the video on the day of the lab?	Yes/no/not sure
3	Did you feel more confident coming into the laboratory after the video compared to the other laboratory you have been in? (2019)	More confident/slightly confident/Neutral/less confident
Section B		
4	Did you find the videos interesting? (2019) Did you understand the video?	Yes/no
5	Was the video on how to set up the fermenter and sampling clear?	Yes/no
6	Did the videos enable you to answer the quiz correctly	Yes/no
7	Do you think the online prelearning session was beneficial to you?	Yes/no
8	Would you like to have more online prelearning laboratory sessions for your other laboratory practical?	Yes/no
9	Any other comment?	Open answer

Note: NB. The "other" laboratory practical in Question 8 refers to the Reactor lab that took place within the same RET module but was not set up with pre-lab videos.

student groups divided by year for each question. Although the ratio between correct and wrong answers for each question varies every year, most students generally answered correctly. However, questions 4 and 5 seem to be the most challenging of each overall. Additionally, to compare the performance of the students separately on each question, the same dataset was plotted accordingly as shown in Figure 1. Groups of students of different years obtained a similar outcome for all 10 questions. The results of each question and academic year were also averaged to determine the overall student's performances on each question as presented in Figure 1a, while their overall pre-lab quiz score by year is shown in Figure 1b. The pre-lab quiz included general questions on the fermentation lab (Q01, 03, 09, and 10), the fermentation process (Q06 and 07) and the fermenter (Q02, 03, 04, 05, and 08). Most questions were correctly answered by 75%–85% of the students that attended the fermentation lab between 2015 and 2019. However, Q01 was answered correctly by 95% of students, and this is the easiest question of the entire quiz, while, on the other hand, Q04 and Q06 seem to be the most challenging questions of the quiz, correctly answered by 50%–54% of the students, respectively **(**Figure 1a**)**. However, the overall student's performance across the last 5 years is relatively constant, with an average of 75 ± 3% (Figure 1b).

The responses to these questions, which are remarkably above the pass mark for undergraduate (UG) students in this context (40%), show that the students' preparedness for laboratory class has been supported by active engagement with the pre-lab videos. The engagement is termed active as most students watched the pre-lab videos more than twice. This is further reinforced by the responses to question (Q07) on media solution preparation in which approximately 80% of the students from 2015 to 2019 answered correctly after watching the pre-lab video. These responses prove that

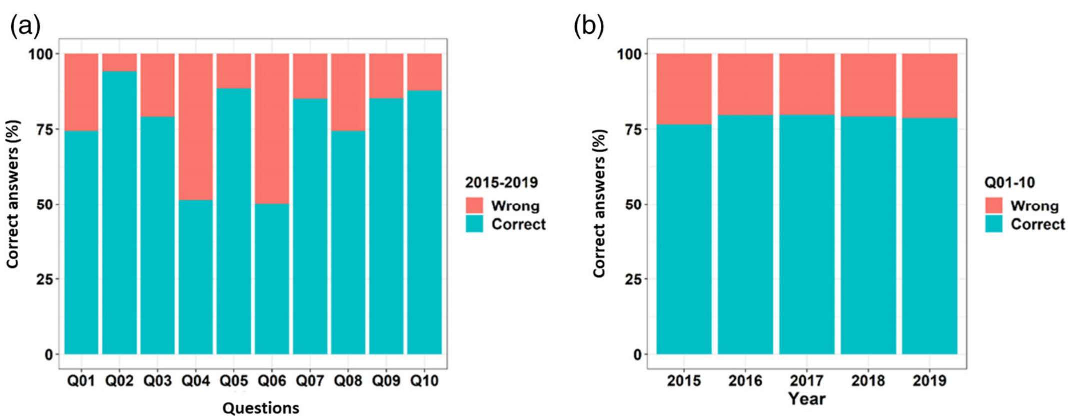

FIGURE 1 Pre-lab online quiz summary: (a) the bar chart shows the ratio between correct and wrong answers for each question. These were obtained via averaging the data collected between 2015 and 2019. (b) The bar chart shows the total yearly scores of the students attending the fermentation lab between 2015 and 2019.

learning occurred as the students engaged with the pre-lab videos. This involves the encountered experience gained by watching the pre-lab videos and relying on the observation and reflecting on that experience to answer the online pre-lab quiz.

On the other hand, question (Q09) aims to demonstrate the students' ability to handle and analyze data. It also reveals the experience and skills gained from the pre-lab videos in regards to data analysis, equipment identification, and controllability. About 80% of the students from 2015 to 2019 answered correctly the importance of analyzing a small sample of data (Q09).

3.2 | Summative assessment

The summative assessment for this part of the course was an individual report on the laboratory work written by each student independently. A statistical analysis of the grades achieved by the students (all of whom had engaged with pre-lab demonstration videos prior to the laboratory) was conducted in order to evaluate the learning that had taken place. The level of performance is an indicator of the extent of learning that took place. The students that failed RET from 2017 to 2019 range between 0% and 3.5%. In contrast, about 27%–57% obtained marks ranging from 70 to 100. The median mark from 50 to 59 was achieved by 9%–19% of the students. This suggests that the majority of the students achieved more than the 50%. This level of performance is evidence of the extent of learning that had occurred as students watched the pre-lab videos supporting material. Notably, most of the students achieved grades in the range of 60–100. Although there was no control group trained without pre-lab videos, the majority of students scored over 70% every year, suggesting that the students can achieve high marks learning from practical experiences combined with digital resources. This is in tandem with the reports[11] that shows progressive improvement in assessment grades of students that engaged more in pre-laboratory videos and previous findings[9] show that 61% of students had a marked improvement in their scores after engaging with digital materials for laboratory sessions.

As a prerequisite to and in preparation for the practical lab session, all students watched the pre-lab videos. The videos, however, were linked to YouTube, so anyone could view them. It is therefore difficult to distinguish between students' views and those of the public, so it is difficult to correlate students' viewing with summative assessments. Even so, the students recognized the importance of pre-lab videos for working through the summative assessment and for preparing for actual lab sessions based on the post-video survey responses. Nevertheless, a study tracking students' views and comparing them with summative assessments would guide further investigation. But for comparison, the same students had to attend and pass both laboratories in RET in the same year, for the year 2018 the average grade for the reactor lab was 55% and for 2019 63%, while for the fermentation lab the average for 2018 was 69.83% and for 2019 was 69.9%. Although the data itself is insufficient to ascertain whether the pre-lab videos produced better performance in the fermentation lab over the reactors lab, the trend seems to be encouraging at least.

3.3 | Online survey

During the practical laboratory sessions and the summative assessment, students acknowledged the importance of pre-lab videos. As a result of the pre-lab demonstration videos, most students arrived at the laboratory session feeling prepared; therefore, the constructivism pedagogy was used during the actual laboratory class to reflect on and build on the experience and knowledge gained from the pre-lab video. In light of this, the pre-lab demonstration videos were clearly valued by students as a means of preparing for the practical lab sessions and summative evaluations. The online survey is limited to a total of 59 students from 2017 and 40 in 2019, who answered the evaluation survey (see above Table 3 for the survey questions). There is a possibility that the results obtained may not be as comprehensive as those from the pre-lab quiz. Nonetheless, the outcome is deemed representative of the year-group in question. The first two questions were on the clarity of the instruction and the ease to follow the instruction on getting into the lab, while the third question has to do with how confident they felt compared to the other lab classes without pre-lab online sessions. The survey results are presented in Figures 2–4.

In the scope of this experiment, the survey indicates that the pre-lab videos and quizzes generally were perceived as helpful and informative. Across the 2 years (2017

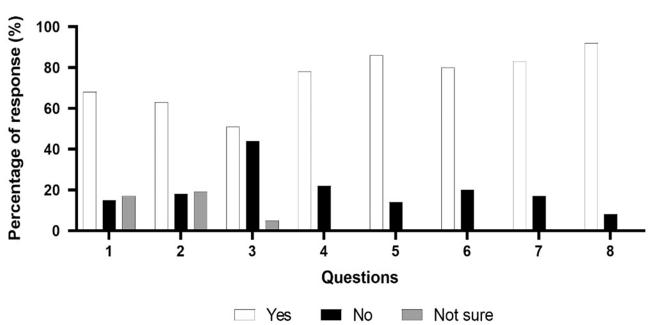

FIGURE 2 Students' online survey results in 2017. This is the students' response to the survey questions shown in Table 3.

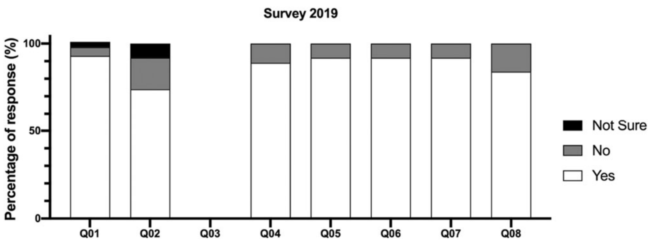

FIGURE 3 Students' online survey results in 2019. This is the students' response to the survey questions shown in Table 3 excluding Q03 in 2019.

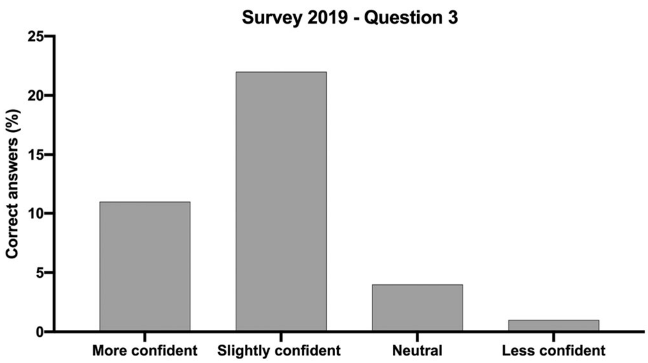

FIGURE 4 Students' online survey results in 2019 in response to the question, did you feel more confident coming into the laboratory after the video compared to the other laboratory you have been in? This is Question 3 in Table 3.

and 2019), the survey shows that 68% (2017) and 92.5% (2019), respectively, of students felt the instruction was very clear (Question 1) while 15% (2017) and 5% (2019) no and 17% (2017) and 2.5% (2019) was not sure (Figures 2 and 3). The percentage of students who considered the instruction from the video on getting to the lab easy to follow (Question 2) was 63% and 74% and those that were unsure were 18% and 19% for 2017 and 18% and 7% for 2019. Moreover, 83% and 92% of the students agree that these videos were beneficial to their learning experience (Question 7), with 92% and 84% wishing similar pre-lab content were integrated into other modules (Question 8). In general, there is a positive correlation between the use of technology and measures of students' engagement reported in other researches.[15] Students rated the videos highly on their clarity and detail, with 86% and 92% indicating they were understandable based on response to Question 5 in Table 3 (Figures 2 and 3). More specifically, the students participating in the 2019 survey were asked to evaluate the qualitative impact on their confidence of the pre-lab videos (Figure 4) and while more students (58%) said that they were "slightly confident" and 29% said they were "more confident," this clearly shows that the vast majority of the students perceived an improved quality in their preparation *vis a vis* the lab.

In the open-ended questions, a multitude of positive comments about the videos were made, such as "interesting content," "informative," "clear," "they showed all the equipment clearly": this last comment certainly represents a strong point of the pre-lab videos. On the negative side, the students expressed a strong preference for short and to the point videos and mentioned the need for captions to support understanding. A few students felt that the videos were still not enough for them to come to the lab fully prepared and that the link to the actual practical work was not strong enough. As a result of our surveys, students provided generally positive feedback, which is in agreement with Peteroy-Kelly, who noted that an effective preparation for the laboratory would make the students more engaged, reduce anxiety, and enhance confidence.[16] This is also consistent with an observation on virtual labs in online biology courses,[9] in which 61% of the students agreed that virtual laboratories were effective in promoting learning. However, the extent of learning contributed by the pre-lab demonstration videos to complement and supplement laboratory teaching and learning needs further investigation. Overall, students were also able to learn through repeated engagement with the pre-lab videos and make good use of their time during the laboratory sessions.[2,12,17] This is due to the familiarization with equipment and techniques, which reduced help-seeking behavior during the laboratory session, as students demonstrated a better understanding of laboratory protocols, confirming the learning that took place by engaging in the pre-lab video and quizzes. Thus, the pre-lab videos provided students with a cognitive structure that assisted them in constructing their understandings and knowledge in the laboratory. Students learned from the pre-lab videos by paying attention, observing, interpreting and memorizing.[18] Although there seemed to have been numerous gains associated with the use of pre-lab demonstration videos prior to the laboratory session proper, some level of disconnect between the information in the videos and the requirements on the day was perceived. As highlighted above, it was argued that the pre-lab material did not fully describe the procedures to be followed by the students on the day of the actual activities and some students were unable to autonomously conduct the lab, rather relying on the help of the technicians when it came to the more practical aspects of the experimental methods (e.g., OD measurements, sample handling, pipette use, etc.). This lack of synergy between the video and the technicalities of lab work curtailed some students from developing an in-depth understanding of the experiment. Thus, there is room for improvement by building into the pre-lab videos synergy between practice, knowledge of the equipment and actual implementation of lessons in the lab work. Therefore, to improve students' preparation for the lab, more information about the technical and practical aspects of the lab would be integrated into the videos. This could be achieved in various forms, for example, preparing a list of steps required during the lab, asking the students to research these methods, providing external links or documents describing the experimental procedure in detail or another pre-lab video outlining the procedure behind every step necessary in the analysis of the samples. Other aspects that need improvement include an in-depth explanation of laboratory apparatus and their operations in the pre-lab videos, steps taken before the laboratory such as sample collection by the technicians and more details about the experimental layout such as assessing the student's understating of parameters critical to the operation of the fermenter. Also, investigating the correlation between summative assessments and pre-lab video views.

4 | CONCLUSIONS AND FURTHER RESEARCH

Visual demonstration of laboratory procedures is a key element in teaching pedagogy. The main goals of the study were to create videos explaining and demonstrating a variety of lab techniques, basic safety in the lab that would serve as teaching tools for undergraduate lab courses and assess the impact of these videos on student learning. Data obtained from the pre-lab quiz and survey of two cohorts indicate that using videos to supplement laboratory skills supports knowledge acquisition, confidence, and experience.

The next step will be to develop a fully virtual laboratory that will allow students to practice experiments more frequently, particularly those that are difficult to replicate due to time, resources, and safety concerns. Since contact laboratory hours are limited, students can use virtual laboratories to reinforce their classroom learning.

The current COVID-19 crisis has demonstrated not only the limits of classroom-based teaching and learning activities but also, and most importantly, the potential of blended and eLearning in bringing together cohorts of learners and their instructors across space and time restrictions.

Therefore, the capacity and capability to provide an effective information management system (creating, gathering, and disseminating quality information) are vital to the transformation of higher education provision in this era of target-driven learning outcomes. This is the basis for competition between universities, and the future sustainability of university education will be determined by how effective they are at building and maintaining an effective Managed Learning Environment (MLE).

AUTHOR CONTRIBUTIONS

All authors were involved in the preparation of the manuscript. Helen Onyeaka conceptualized and wrote the initial draft. Paolo Passaretti and Phillip Robbins were involved in the methodology design and data curation. Taghi Miri, Claudia Favero, Abarasi Hart, and Christian K. Anumudu were involved in reviewing and editing the manuscript.

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CONFLICT OF INTEREST

There are no conflicts to declare.

DATA AVAILABILITY STATEMENT

Data in this paper are available free of charge via http://edata.bham.ac.uk/.

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REFERENCES

1. Chan C, Fok W. Evaluating learning experiences in virtual laboratory training through student perceptions: a case study in electrical and electronic engineering at the University of Hong Kong. Eng Educ. 2009;4(2):70–5.
2. Jolley DF, Wilson SR, Kelso C, O'Brien G, Mason CE. Analytical thinking, analytical action: using prelab video demonstrations and e-quizzes to improve undergraduate preparedness for analytical chemistry practical classes. J Chem Educ. 2016;93(11):1855–62.
3. Agustian HY, Seery MK. Reasserting the role of pre-laboratory activities in chemistry education: a proposed framework for their design. Chem Educ Res Pract. 2017;18(4):518–32.
4. AIChE. (2017). *AIChE Education and Accreditation Committee*. https://www.aiche.org/sites/default/files/docs/pages/pevprogram-guidelines-v2_10-31-17.pdf
5. Broadbent O, McCann E. Experience-led learning for engineers–a good practice guide. Royal Acad Eng. 2016;19:2018.
6. Ouyang SG, Wang G, Yao JY, Zhu GHW, Liu ZY, Feng C. A Unity3D-based interactive three-dimensional virtual practice platform for chemical engineering. Comput Appl Eng Educ. 2018;26(1):91–100.
7. Hashemi J, Austin KA, Anderson EE, Chandrasekhar N, Majkowski A. Elements of a realistic virtual laboratory experience in materials science: development and evaluation. Int J Eng Educ. 2005;21(3):534–45.

8. Sorensen E. Implementation and student perceptions of e-assessment in a chemical engineering module. Eur J Eng Educ. 2013;38(2):172–85.
9. Stuckey-Mickell TA, Stuckey-Danner BD. Virtual labs in the online biology course: student perceptions of effectiveness and usability. MERLOT J Online Learn Teach. 2007;3(2):105–11.
10. Zaneldin E, Ahmed W, El-Ariss B. Video-based e-learning for an undergraduate engineering course. E-Learn Digit Med. 2019;16(6):475–96.
11. Rodgers T, Cheema N, Vasanth S, Jamshed A, Alfutimie A, Scully P. Developing pre-laboratory videos for enhancing student preparedness. Eur J Eng Educ. 2020;45(2):292–304.
12. Stieff M, Werner SM, Fink B, Meador D. Online prelaboratory videos improve student performance in the general chemistry laboratory. J Chem Educ. 2018;95(8):1260–6.
13. Sherer P, Shea T. Using online video to support student learning and engagement. Coll Teach. 2011;59(2):56–9.
14. Mitra B, Lewin-Jones J, Barrett H, Williamson S. The use of video to enable deep learning. Res Post-Compulsory Educ. 2010;15(4):405–14.
15. Chen P-SD, Lambert AD, Guidry KR. Engaging online learners: the impact of web-based learning technology on college student engagement. Comput Educ. 2010;54(4):1222–32.
16. Peteroy-Kelly M. Online pre-laboratory modules enhance introductory biology students' preparedness and performance in the laboratory. J Microbiol Biol Educ. 2010;11(1):5–13.
17. Gautam S, Qin Z, Loh KC. Enhancing laboratory experience through e-lessons. Educ Chem Eng. 2016;15:19–22.
18. Ashman AF, Ashman A, Conway RN. An introduction to cognitive education: theory and applications. England, UK : Psychology Press; 1997.

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