Assessing the efficacy of embedding online laboratories in e-learning tutorials to enhance student engagement and satisfaction

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SESSION

C1: Integration of theory and practice in the learning and teaching process

CONTEXT

The ever-changing landscape of online learning presents inherent technical and pedagogical challenges regarding student engagement, satisfaction and the application of knowledge, skills and abilities. The lack of face-to-face delivery defines the need for e-learning strategies to foster student engagement and supply industrial credibility. This e-presence is conventionally achieved via the use of synchronous online tutorial sessions (using web and video conferencing) or online laboratories.

PURPOSE

The purpose of this work is to examine an identifiable gap in the current research; the efficacy of embedding these remote and virtual laboratories into contextualised online synchronous tutorial sessions.

APPROACH

The impact of this strategy is evaluated by studying educators and students undertaking online engineering programs at The Engineering Institute of Technology (EIT). The study uses three different research methodologies to determine the student and educator reaction, the effect on learning and the technical challenges in implementation.

RESULTS

The key results indicate a strong preference (greater than 73% of students surveyed) in favour of embedding labs in tutorials as opposed to having tutorials without embedded laboratories. In addition there is a basis indicating an overall improvement in performance of students who received tutorials with embedded laboratories as opposed to those that did not.

CONCLUSIONS

This paper concludes that the use of remote and virtual laboratories during live online tutorial presentations improves the reaction of students and measurable learning outcomes. The majority of students found significant educational benefits in attending these sessions as compared to tutorial sessions without embedded remote laboratories; verified by subsequent grade improvements. This was expected; relational learning and student engagement increased and was accompanied by a reduction in the uncertainty and unfamiliarity with remote and virtual laboratories.

KEYWORDS

E-learning; online learning; remote laboratories; virtual laboratories; interactive tutorials.

Introduction

Over the past decade, there has been a proliferation of remote or distance learning using the internet (often referred to as e-learning or online education) in the engineering education areas (E. Allen & Seaman, 2006; Bersin, 2004; Bonk & Graham, 2006; Ma & Nickerson, 2006; Rossett, 2001). Typical approaches for e-learning are web-based (asynchronous) and streaming of video (synchronous) over the internet (Rossett, 2001). The two forms of learning are illustrated in figure 1.

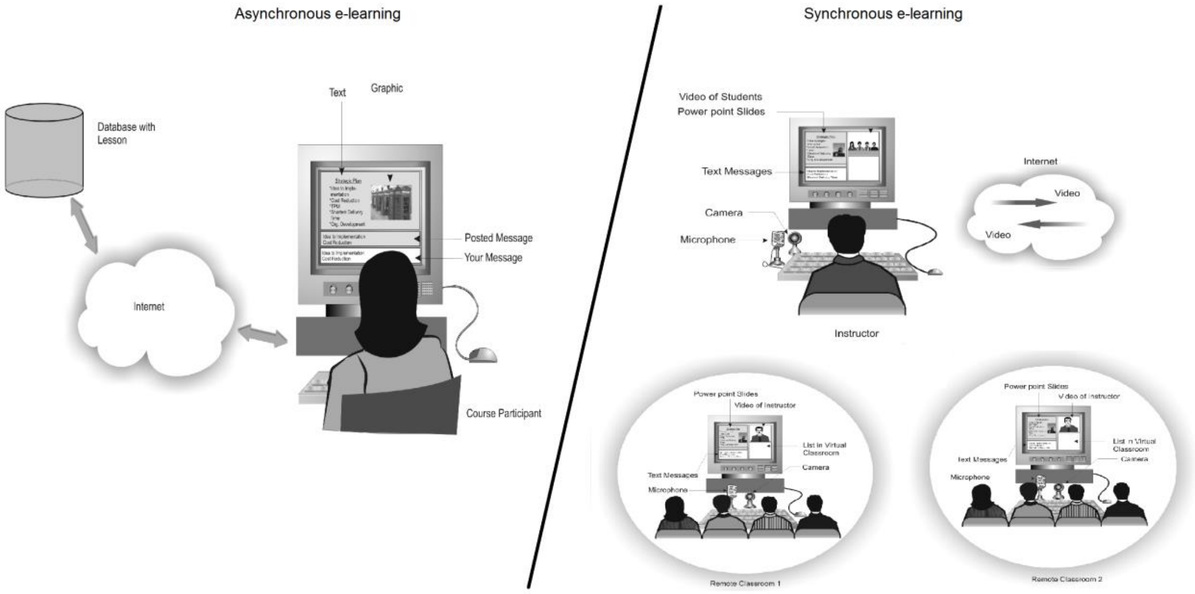

Figure 1: Asynchronous vs Synchronous e-learning

Almgren and Cahow (2005) believed that the factors responsible for improving computer-based engineering education were a desire to increase active and discovery learning, a desire to make lab facilities available to the wider community and to provide students with more meaningful practical experiences. They believed that the appeal for remote (or online, as they termed it) labs is due “to the increasing demand for active learning and flexible education, and for the appeal of implementing techniques of learning via discovery” (Almgren & Cahow, 2005, p. 3). These comments are supported by the research conducted by M. Phillips (2006), where respondents noted the need for more “hands-on” training and concerns that e-learning may not provide it.

Kanyongo (2005) referred to L.J. Smith (2001) who listed the benefits of e-learning as being “accessibility, flexibility, participation, absence of labelling, written communication experience and experience with technology” (p. 1). On the other hand, L.J. Smith (2001) listed the problems for e-learning being that of “team building, security of online examinations, absence of oral presentation opportunities and technical problems” (p. 1). Brown and Lahoud (2005) noted the remarks of Moore and Kearsley (1996) that courses delivered at a distance can be as good as that of traditional classroom instruction. The synchronous form of e-learning – being live and thus perhaps more interactive will be the focus of this research.

One of the areas of increasing interest in e-learning is the use of remote laboratories or simulation software; an interactive hands-on approach to improve the learning experience. There are generally two challenges with e-learning, the lack of interaction with the instructor and the difficulty of providing real tools for practical exercises and to facilitate applied learning (Cooper, 2000; Cooper et al., 2003). These two issues are addressed in this research.

Schank (2002) pointed out that many users commented on the poor quality of e-learning. Although Shank (2002) was thinking along more general lines, he stated that learning by doing was an essential part of the learning experience to enhance the absorption of material.

Learning by doing works because it strikes at the heart of the basic memory processes that humans rely upon. We learn how to do things by assessing the efficacy of our efforts. We learn when the rules apply and when they must be modified. We learn when our rules can be generalised and when exceptional cases must be noted. We learn when our rules are domain bound or when they can be used independently. We learn all this by doing, by integrating these experiences into existing memory structures (Schank, 2002, p. 5).

Huntley, Mathieu, and Schell (2004) defined a laboratory (or lab, as it will be henceforth referred to, for brevity) "as a room or building containing specialised equipment" (p. 398). Lindsay (2005) noted that a typical lab class "comprised a small group of students, and a demonstrator (often a postgraduate student), grouped around a piece of hardware located in a lab. Students typically conduct a series of experimental procedures as outlined in the lab handout, they record the data from the hardware, and they write up a report based on this data and the underlying theory in the week or two subsequent to the session" (p. 44).

Gandole (2005) added to this by remarking that a lab "should aim to encourage students to gain: manipulative skills, observational skills, an ability to interpret experimental data, an ability to plan experiments, interest in the subject, enjoyment of the subject, and a feeling of reality for the phenomena talked about in theory" (p. 49).

Colwell et al. (2002) noted that practical work and executing experiments help those students studying science and engineering subjects. They quoted from Hewson and Hewson (1983) who stated that these students need to engage in knowledge construction; a difficult undertaking as they "need to develop both conceptual and procedural understanding by appropriate actions" (Colwell et al., 2002). Jochheim and Roehrig (1999) noted that experiments with live processes and real equipment provide engineering students with the expertise needed to tackle engineering problems and improves their motivation. He added that many physical phenomena are difficult to understand if written or explained in words; they must be witnessed in action.

Lahoud and Tang (2006) pointed out that many distance learning students found that traditional lab experiments were not an option due to geographical separation. They suggested offering some form of virtual or remote lab environment for distance learning students. They described the two possible solutions:

- Virtual labs comprising simulation software running on a host machine. (They point out two issues: students may struggle to achieve the required skills and practice and servers which are powerful and expensive are often required to make the simulations as realistic as possible).
- Remote labs are equivalent to the traditional lab environment as they involve real equipment, (An issue was noted; the labs are situated at a significant distance from the learner).

Ma and Nickerson (2006) referred to the impact of information technology with the creation of simulated labs and remote labs as useful alternatives to the traditional conventional labs. They pointed out that the effectiveness of these two new lab approaches, as compared with the traditional hands-on labs, was not examined in much detail in the research literature. They felt, however, that the remote and simulated labs were an excellent way to share specialized skills and resources over a wide geographical area by reducing overall costs and improving the educational experience. Azimopoulos, Nathanail and Mpatzakis (2007) concurred with this and emphasised the need for practical work as an important adjunct to the theoretical study.

Esche (2005) listed the benefits of the remote labs for students, suggesting that they: offer a more comprehensive experimental experience, offer a more accurate representation of a hands-on experience, optimise the students' imagination and enthusiasm, allow for more flexibility; instructors and students are not required at the same time, promote self-learning, and allow for a more integrated self-assessment approach. Insofar as the instructors (and their institutions) are concerned, the benefits include: easily adding lab demonstrations into their instruction, monitoring the lab performance of students more rigorously, fewer scheduling problems with large student numbers and fewer lab personnel required, more flexible financial planning for expensive equipment, and greater levels of safety.

A slightly more negative perspective was provided by Albu, Holbert, Heydt, Grigorescu and Trusca (2004). They suggested that remote labs were not as effective for training engineering students for the following reasons: the handling of real equipment is limited; there are fewer real world problems such as loose wiring and electrical contacts and students are shielded from connecting equipment incorrectly. They suggested using remote labs as a prelude to real laboratories.

This research investigates the impact on learning when synchronous e-learning is used and is combined with remote and virtual laboratories.

Purpose

The purpose of this work is to examine and address the following research questions regarding the student experience of live web and video conferencing supplemented by remote and virtual lab exposure:

- What are the reactions of student and educator when this approach is used?
- What is the effect of the strategy on student learning?
- What are the technical challenges when implementing this strategy and can they be remedied?

Approach

Various research approaches and methodologies, such as paired T test and analysis of variance were considered. For Method 1, similar to Tuysuz (2010), a two-tailed paired samples T-test was used to analyse student grades between control and experimental groups, to determine any significant difference to a 95% confidence interval. The Tuysuz (2010) study also focused on both knowledge and attitude metrics (measured here in Method 3), regarding virtual laboratories. Other papers, such as Alghazo (2010), have similarly used final grades as a metric for determining significant differences in teaching styles, in the case of Alghazo, determining “no significant differences in the effectiveness of distance education and traditional classroom education”.

In Method 2, due to the small sample size and number of questions, the confidence interval method was not used and instead, the performance of each group was divided into sets using question 1 and question 2 and the mean results compared.

For Method 3, in a similar approach to Tisdell (2016), the confidence interval was applied to the Likert scale test in evaluating perceived student engagement.

Method 1

The first method is to determine if the use of live lab demonstrations impacts on student grades. This method aims to compare student grades, for one unit in particular, by looking at individual assessments and total unit grade averages over two cohort intakes. The same unit is compared over two different cohorts of known delivery methodology. The content is kept the same in both cohorts to ensure consistency of content being delivered. The difference: one delivery cycle did not have embedded online lab demonstrations in tutorial sessions, while the other more recent delivery cycle included live embedded online lab demonstrations.

The unit used for this comparison is titled - “Industrial Process Control Systems” and is at the Coursework Master Degree level.

The first delivery cycle, without embedded online labs, was delivered in 2015, 2nd semester. The tutorials mainly consisted of theoretical and image based explanation of the various control concepts EIT, 2015). Tutorials were one hour in length and delivered once per week over 12 consecutive weeks.

The second delivery cycle, with embedded online labs, was delivered in 2016, 2nd semester. In this unit, the tutorials consisted of embedded lab demonstrations. These lab demonstrations were delivered in tutorial sessions by means of in session screen- or lab-share, with the lecturer detailing and demonstrating various real-time aspects of advanced control theory. At least half of the tutorial lectures included embedded online labs and these were included early on in the unit delivery (EIT, 2016). Tutorials were one hour in length and delivered once per week over 12 consecutive weeks.

At the end of both units, students were required to complete two major assessments. These assessments were report-based, but they also required students to use lab software. This lab was merely explained in the first delivery cycle, but embedded in the second delivery cycle. The resulting grades for each of these cohorts was then derived and compared in order to ascertain whether the changes to the tutorial delivery had any impact.

A second unit was selected as a control variable; to calibrate the study unit results and account for the differences in student ability. This unit was delivered in parallel with the study unit “Industrial Process Control Systems” in each of 2015 and 2016 respectively. The control unit was delivered to each cohort identically and did not include embedded online lab demonstrations in its tutorial sessions. The grades for the same students in each respective cohort were then compared and used to determine whether there was any significant difference in average student ability between the cohorts which would impact the study unit results.

Method 2

The second method assessed students and educators across a range of cohorts and engineering disciplines based on the content of a custom 30 minute live tutorial on the subject of robotics and autonomous vehicles. The attendees were split into two groups.

Group A received a live tutorial without any remote or virtual lab demonstrations that covered topics ranging from the basics of robots and control theory to simultaneous localization and mapping (SLAM) and the D star search algorithm.

Group B would receive a live tutorial covering the same content with the same basic slides; however the second-half of the webinar was abridged and the additional free time was dedicated to illustrating the concepts through the use of remote and virtual lab demonstrations which included a Lidar/SLAM robot navigating around obstacles and a graphical representation of the D star search algorithm using a C# program.

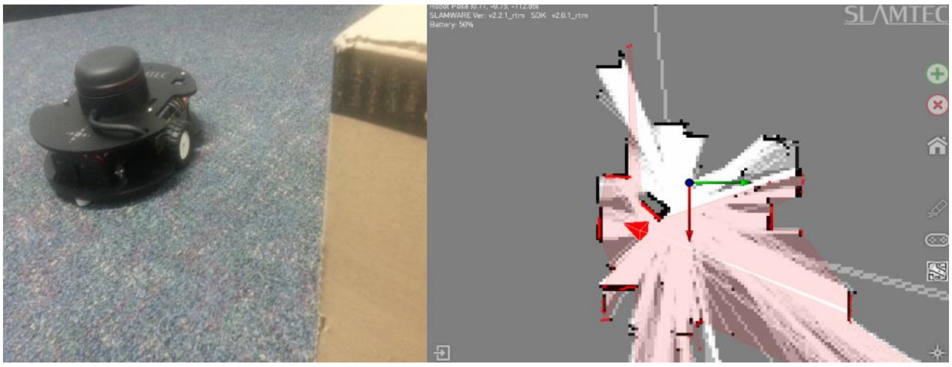

Figure 2: Lidar/SLAM robot lab demonstration

Following each live tutorial, each individual was assessed on what they had learned using an identical multiple-choice quiz with two questions (each with four options). The quiz for both Group A and Group B was structured as follows:

- Question 1: A question to select the correct statement, for which the options are based on the content delivered in the identical first half of each group's tutorial. This was used as the control variable for the experiment as students from each group had received the exact same material needed to answer this.
- Question 2: A question to select the correctly depicted scenario given the following: "A robot toy car (shown in red) can move horizontally or vertically to crosses on the grid. The robot has assigned costs to each of these crosses (nodes) on the map including the brown walls but it is not aware of the grey wall, which has just been introduced. Its goal is to move to the blue circle following a path shown in green. Using the D* (D star) algorithm, which of the below shows its most likely initial guess at a path?" Four different illustrations were given, each showing a different path that the robot could take. This was based on the second half of each tutorial where, although both Group A and Group B had been taught how the D star search algorithm works using examples, Group A was limited to explanations and slide illustrations whereas Group B had online lab demonstrations in addition to the abridged explanations and slide depictions delivered to Group A.

The tutorial attendance was captured and used to verify the quiz submissions, administered and collected using SurveyMonkey. The quiz results were then compared between the two groups (EIT, 2017).

Method 3

The third method comprised of a four question survey in which students were asked to indicate how strongly they agree or disagree with the following statements (as questions) on a 5-point Likert scale rating by selecting one of; Strongly Disagree; Disagree; Neutral; Agree; Strongly Agree:

- Question 1: Online laboratories (software simulations or hardware with webcams) are effective in helping me to understand engineering topics.
- Question 2: Online tutorials that include online laboratory demonstrations are more effective than online tutorials that do not include online laboratory demonstrations.
- Question 3: I would like to see more online laboratory demonstrations in my engineering course.
- Question 4: I feel better equipped to complete my practical assignments when online laboratory demonstrations are included in my course's online tutorial sessions.

The survey was sent to 496 students who have been studying for a period of at least 6 months with EIT and thus have encountered online laboratories. The responses were then collected and tabulated (EIT, 2017).

Results

The results of each method are as follows:

Method 1

For the determination of embedded lab impact on student grades in historic delivery cycles, the results are as follows: The first delivery cycle in 2015 had 32 students in the cohort and the second delivery cycle in 2016 had 9 students in the cohort. The grades of the two major assessments and their unit average are detailed in Table 1 below, where a 95% confidence interval is used to determine whether $p<0.05$, $\bar{x}$ is the mean (%), and σ is the standard deviation:

Table 1: Average grade performance (%) for compared delivery cycles

Experimental Unit	2015 Delivery cycle 1			2016 Delivery cycle 2			t	p
	n	$\bar{x}$	σ	n	$\bar{x}$	σ		
Assessment 1:		74.19±5.17	14.93		81.22±6.63	10.14		
Assessment 2:	32	77.38±2.52	7.27	9	79.78±9.86	15.09	1.08	0.31
Unit Average:		83.38±2.02	2.02		86.56±5.7	8.73		

Table 2: Control unit average grade performance (%) for compared delivery cycles

Control Unit	2015 Delivery cycle 1			2016 Delivery cycle 2			t	p
	n	$\bar{x}$	σ	n	$\bar{x}$	σ		
Unit Average:	32	82.25±5.65	16.32	9	82.63±10.2	17.26	0.06	0.95

Method 2

The results of the post-tutorial quiz are provided in the table below. 14 students/educators attended the Group A session, whereas 22 students/educators attended the Group B session.

Table 3: Post-tutorial quiz results for compared groups

Student Results	Group A	Group B
Q1 correct	11/14 = 78.57%	15/22 = 68.18%
Q2 correct	7/14 = 50%	12/22 = 54.54%
Q1 correct & Q2 correct	5/14 = 35.71%	11/22 = 50%
Q1 correct & Q2 incorrect	6/14 = 42.86%	4/22 = 18.18%
Q1 incorrect & Q2 correct	2/14 = 14.29%	1/22 = 4.54%
Q1 incorrect & Q2 incorrect	1/14 = 7.14%	6/22 = 27.27%

Method 3

Out of 496 students surveyed, 69 responded (13.9%), whose preferences are illustrated below:

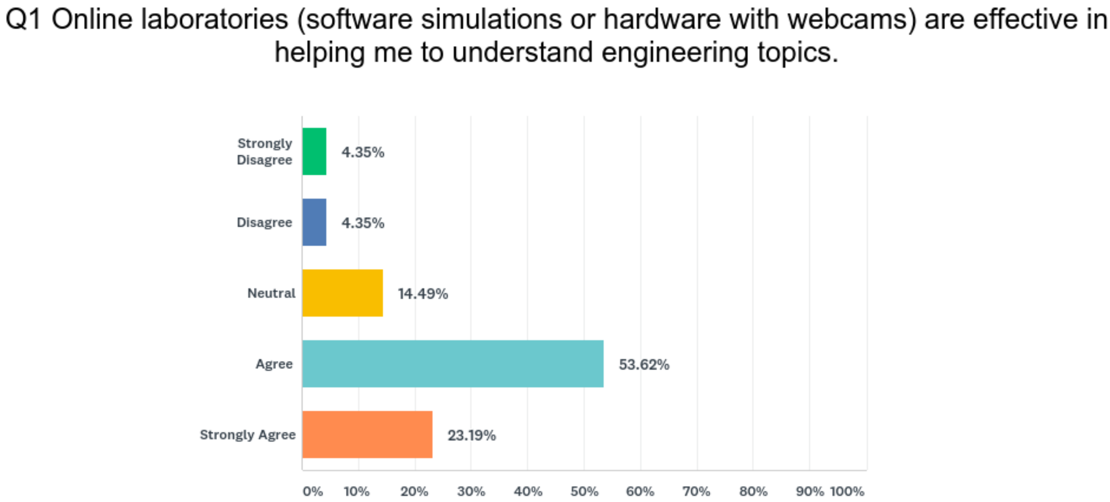

Figure 3a: Q1 Results of the survey for tutorial quality improvement.

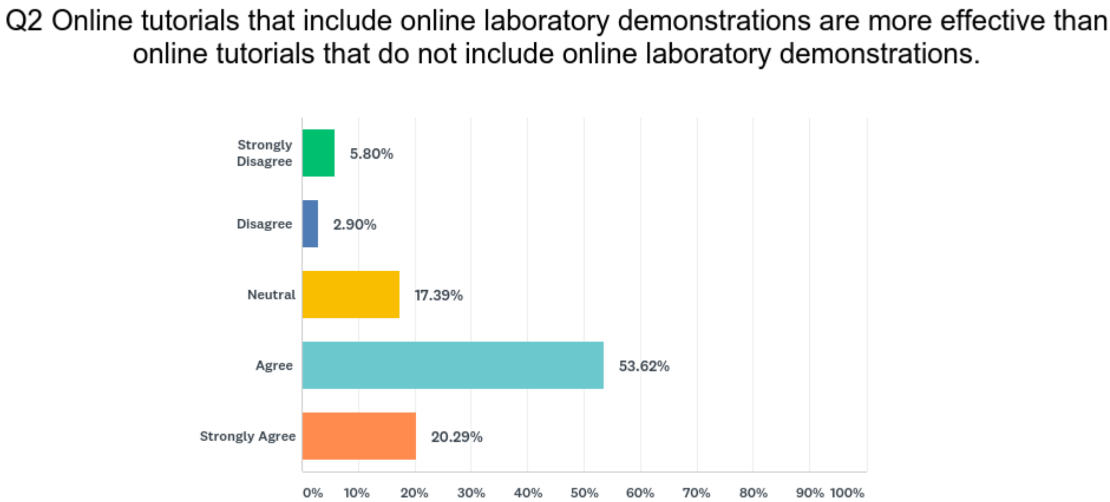

Figure 3b: Q2 Results of the survey for tutorial quality improvement.

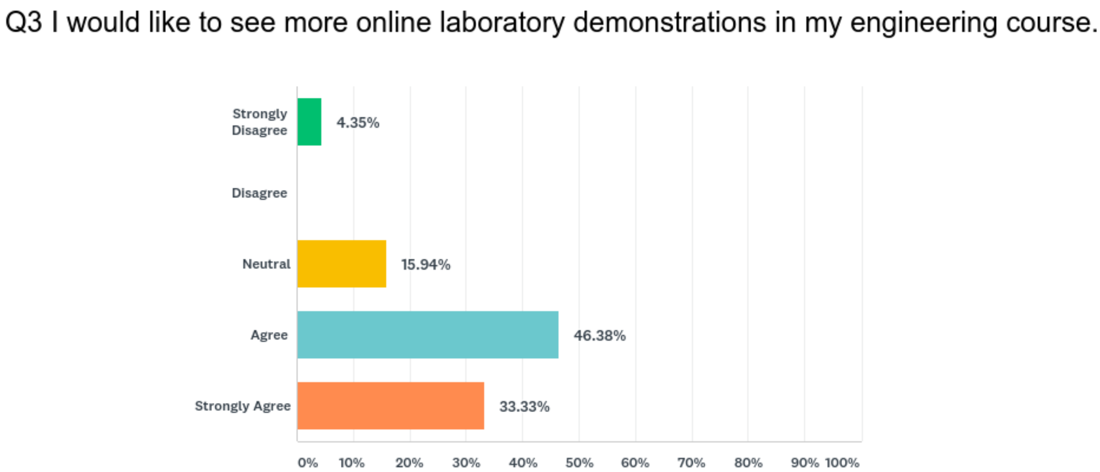

Figure 3c: Q3 Results of the survey for tutorial quality improvement.

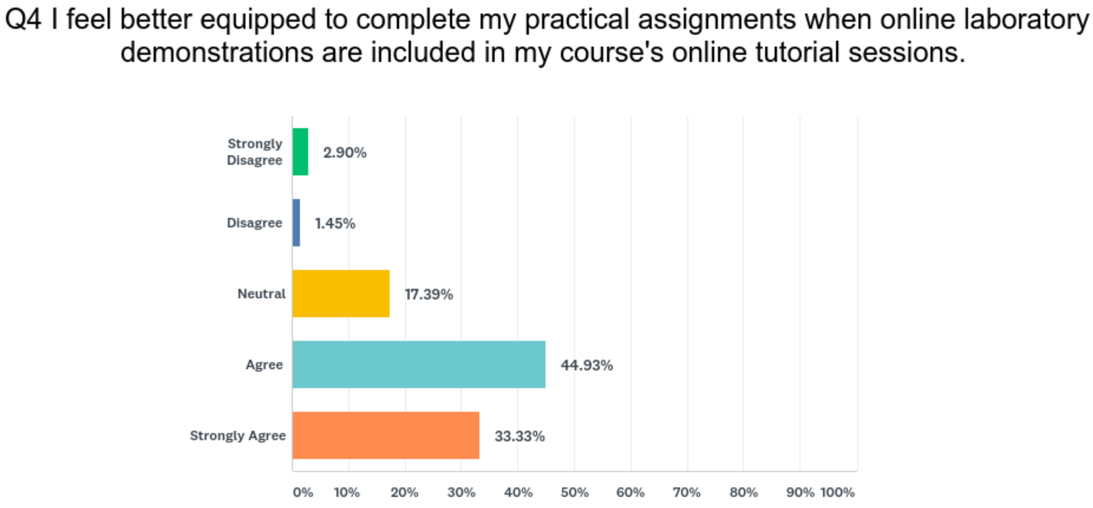

Figure 3d: Q4 Results of the survey for tutorial quality improvement.

Table 4: Table of survey result statistics including 95% confidence interval

Survey Questions	**Survey Results**		
	n	**$\bar{x}$**	**σ**
Q1	69	3.87±0.23	0.96
Q2	69	3.8±0.23	0.99
Q3	69	4.04±0.22	0.94
Q4	69	4.04±0.21	0.91

Discussion

Method 1

Factoring in the control unit; the difference in the average cohort grades between cycle 1 and cycle 2 was less than 0.4%, as depicted in Table 2, indicating a comparable and near-equivalent level of student ability. The p-value is 0.95 showing no significant difference in the ability between the 2015 and 2016 delivery cycles in the control group, thus students from each group are of a similar ability level.

When comparing the experimental unit grades between the two delivery cycles, there is a slight increase of 3% in grades for students who attended sessions with embedded online labs, in delivery cycle 2. What's interesting to note is that students performed better earlier in the course, most likely due to their confidence in using the lab for their assessment. Students without the embedded labs were left to their own devices in figuring out the labs, and this might have an impact on their earlier performance. The grades converge towards the end of the course and might indicate that students have all become more familiar with the labs due to continued use throughout the course. The p-value is 0.31 which suggests a not significant result at the 95% confidence interval, but given the scope of the study it warrants further investigation.

The grade data is also quite low (n<100) for a parametric test. The size of the cohort could influence the outcome, however, in the student surveys (also covered in this paper) for the unit with embedded lab demonstrations; students clearly highlight their perceived value in, and appreciation of, the inclusion of demonstrations for the practical parts of the work, where the unit without the demonstrations had no mention of this in the surveys - arguing that there was indeed a major impact when the labs were embedded. Additional limitations of the study include the limited number of trials as well as the variance between unit types and learning styles.

Method 2

The following was found when comparing the quiz results of Group A and Group B, detailed in Table 3:

- 27% of Group B had incorrect answers for both Q1 and Q2, as compared to only 7% of Group A. Focussing on Q1, which had identical delivery material between Groups, 79% of Group A had a correct answer, compared to 68% in Group B. This suggests an overall lower ability of Group B when delivered the same material.
- Despite this; 54% of Group B had a correct answer for Q2, as compared to only 50% of Group A. Using Q1 to scale relative expected performance; 79% of Group A were correct for Q1 and 50% for Q2.
- Given only 68% of Group B was correct in Q1, following the trend derived from Group A that would suggest an approximate 36.7% drop in correct responses from Q1 to Q2; Group B would be projected to have only 43% correct responses for Q2; yet they achieved 54% correct responses; 11% above the projection.

It would seem this increase in correct responses is due to the change in tutorial mode upon which Q2 is assessed. The limitations influencing this conclusion are however, many, including but not limited to the following considerations: technical differences in the delivery between groups contingent upon the individuals internet connection and hardware; the limited, diverse and asymmetric group sizes; the scale of the study; the method by which tutorial time was re-allocated to remote and virtual labs as well as the type of labs themselves; the types, nature and number of questions assessing tutorial content; ongoing and long-term assessment of group performance; the aptitude of the individuals for the subject; the learning style of individuals; as well as a need to swap the strategy and control group to further calibrate projected grades and determine causality.

Method 3

The survey presumes an equal likelihood of dissatisfied, impartial and satisfied students responding. The responses, detailed in Figures 3a, 3b, 3c and 3d, as well as the summary in Table 4, indicate a strong preference for embedded laboratories. 53.62% of responders agreed with the statement that online laboratories (software simulations or hardware with webcams) are effective in helping them to understand engineering topics, with a further 23.19% strongly agreeing, with a mean score of 3.87. 53.62% of responders agreed and 20.29% strongly agreed that online tutorials that include online laboratory demonstrations are more effective than online tutorials that do not include online laboratory demonstrations; as opposed to 2.9% disagreeing and 5.8% strongly disagreeing, with a mean score of 3.8. 46% agreed and 33.33% strongly agreed that they would like to see more online laboratory demonstrations in their engineering courses, with a mean score of 4.04, and 44.93% agree and 33.33% strongly agree that they feel better equipped to complete their practical assignments when online laboratory demonstrations are included in their course's online tutorial sessions, with a mean score of 4.04.

The responses indicate a perceived benefit to embedding online laboratories in tutorials, with over 73% of responses indicating perceived improvements to engagement and understanding. Although the standard deviations were all < 1 and the confidence intervals < 0.24, the survey data is also quite low (n<100) for a parametric test. The limitations of these results largely fall to: the diligence of the responder in accurately interpreting and answering the questions; the scale of the survey; and a link with demonstrable long and short term performance and understanding. Furthermore, all responders were international engineering students across several levels and disciplines, yet it was not tracked whether these aspects affect the responses, nor the fact that all of the students were undertaking engineering courses under an online delivery mode and blended delivery mode students were not considered.

Conclusions and Recommendations

From the three research methodologies employed, the paper observes that the use of remote and virtual labs during live online tutorial presentations improves the reaction of students and measurable learning outcomes. This strategy holds both a perceived improvement to engagement and relational learning, a reduction in uncertainty regarding online laboratories, as well as some evidence that it can yield net performance improvements across student cohorts when implemented effectively, verified by subsequent grade improvements. As with Tuysuz (2010) “it was identified as a result of this study that the use of virtual lab increased students’ achievement levels and made a positive impact on students’ attitude”. Future work should expand on the size of the study, the evaluation methodologies and the method by which labs are integrated into tutorials.

The general student feedback at EIT holds no shortage of open ended qualitative responses, asking for an even “greater use of labs” or praising “the interaction with labs” for contributing to a career-relevant “practical learning experience”; all points accentuated by the study conclusions contained herein. The recommendation is thus as such; that engineering educators may significantly enhance student engagement and relational learning by embedding remote and virtual laboratories into contextualized online or blended tutorial sessions, technical limitations notwithstanding. Future research will consider: larger sample sizes, the different types of labs and tutorials, and the degree of student-tutorial interactivity.

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