Novel use of video technology to enhance the use of marine simulators to link knowledge and practical skills

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Structured Abstract

BACKGROUND
Education programmes for marine engineering students require a strong link between the theoretical and practical components to ensure they gain the required underpinning knowledge as well as the hands-on skills to operate, troubleshoot, and maintain complex machinery on modern ships out at sea. This is exemplified by the growing use of machinery simulators within marine engineering programmes across the world. Given the complexities of the machinery on ships coupled with the need to work within a simulated environment, students need proper and structured guidance to gain the full benefit of simulator based learning.

PURPOSE
Past experience shows that many students found the simulator exercises intimidating, difficult to engage with, and lacked sufficient information or knowledge to make full use of the facility. These issues were compounded by the limited time available on the equipment and the required high staff-to-student ratios. Therefore, it is essential that the students are provided with sufficient background information to navigate through the simulation activities.

DESIGN/METHOD
To address the above, online video/virtual laboratories were developed incorporating the required knowledge-based components. These were supplemented using instructions on relevant simulator exercises to introduce concepts and provide training to achieve the required competencies. This paper focuses on these aspects for understanding the theory and the practice of using the marine process control simulators in higher education institutions. The use of video-based learning allows students to plan and prepare for the simulation exercises.

RESULTS
The videos gave students the opportunity to connect and map the knowledge gained from their classroom work to the practical skills required for the simulator exercises. Once provided with a problem, students researched the required information assisted by prompts in the related videos. This allowed them to develop solutions and processes to achieve the specified unit learning outcomes. Feedback from students including their unit results showed a marked improvement in motivation and achievement. Students indicated that they were able to link the relevant knowledge to the practical exercises.

CONCLUSIONS
It was observed that students were better prepared for the exercises and were willing to undertake much more complex tasks than in the past. Anecdotally, teaching staff found that students were better able to link the relevant knowledge to solve problems on machinery and equipment on ships. An unexpected outcome was the enthusiasm of the students for partaking in the pre-laboratory preparation sessions.

KEYWORDS
Instructional videos, virtual laboratory, marine engineering control simulations, enhanced learning

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Introduction

Engineering is an application of scientific principles for the creation of technology, energy, materials, and information. The goal of any engineering education programme is to prepare students to practice and apply their relevant discipline of engineering within society (Feisel et al., 2005). The Bachelor of Applied Science in Marine Engineering at the Australian Maritime College is aimed at individuals who wish to work as engineers on merchant ships within the international shipping industry. The programme has to meet not only the academic standards stipulated by the university and the Australian Qualifications Framework (AQF), but also the seafarer competencies as stipulated by the International Maritime Organisation (IMO) in the Standards of Training, Certification and Watchkeeping Convention (STCW code) (IMO, 2010).

The use of instructional laboratories has been a cornerstone in the delivery of engineering programmes since the early days of engineering education, ranging from basic engineering workshops to highly sophisticated simulators. The trend is similar in marine engineering, with traditional marine machinery laboratories increasingly supplemented by machinery simulators (Sun et al., 2011). The operation and maintenance of the marine machineries is becoming more complex, as they are designed to meet the increasing demands and requirements of the shipping industry and the global community. Thus, it is important that marine engineering programmes are properly structured to take advantage of new technology, such as simulators and e-learning, ensuring students are provided with the required guidance to make full use of the technology and tools (Ayres & Paas, 2007).

Traditionally, educators have been reluctant to include new technologies in marine engineering curricula. The conventional 'chalk and talk' remains as one of the dominant teaching modality in many engineering departments. With increasing student numbers and insufficient resources for these larger cohorts, the need to critically review teaching practices is of paramount importance (Radcliffe, 1990). Moreover, as stated by Loui (2005), education technologies must support both conventional and online teaching practices. These technologies should provide a bridge between the ideas of instructors and students. Recent observations made by Jackson et al. (2013) suggest that the use of videos in engineering education is one way of assisting students to achieve the desired learning outcomes and student engagement.

An advanced third year unit within the Bachelor of Applied Science (Marine Engineering) programme is Advanced Marine Control Systems and Automation. This unit provides the students with both theoretical and practical knowledge and skills to operate, troubleshoot, and maintain complex automation and control machinery in accordance with manufacturer instructions, industry practice, and statutory requirements,. This requires a well-developed understanding of the theory and concepts coupled with hands-on practical skills. This paper outlines the authors' experience with the use of video technology to enhance the student learning on a marine process control simulator utilised within this unit.

Laboratory Sessions and Technology

A comprehensive study by Feisel & Rosa (2005) showed that engineers must have knowledge beyond theory, which is traditionally achieved through laboratory work integrated within the units/courses. Krivickas and Krivickas (2007) highlighted the importance of laboratory instructions to develop students' skills in experimental and team work, effective communication, and most importantly to take responsibility for their own results. The educational goal of any laboratory-based study includes the following attributes; conceptual understanding, design skills, social skills, and professional skills. There is a significant amount of research that supports the view that laboratory work can provide significant educational value over the more traditional approaches depending on the context (Oakley et al., 2004). Furthermore, research into the various learning styles clearly indicates a strong student preference for visual over verbal approaches (Boles, 2010). The emphasis on visual methodologies favours hands on demonstrations, laboratory work, and the use of pictures and simulations as part of the teaching armoury.

The use of technology and online resources has increased significantly in engineering education over the past decade. The phrase 'educational technology' currently refers to electronic information technology, which is used to support and complement teaching (Loui, 2005). These technologies support many teaching functions and pedagogies including:

- Communication between students, and between students and instructors;
- Production of documents, drawings, and other artifacts by students and instructors;
- Distribution of these artifacts;
- Archiving of class sessions for revision and future access; and
- Access via the internet to specific resources unique to each unit component. (Loui, 2005, p.436)

An Australian study by Kennedy et al. (2008) of two thousand incoming first year university students gathered data on student access to, and use of, both established and emerging 'living technologies'. Seventy five percent of their study population (94.4% of whom were born on or after 1985) agreed that they wished to use these 'living technologies' as part of their higher education learning experience in the form of 'learning technologies'. Rosen (2009) discussed future trends in engineering education, and on the many related challenges and opportunities open to educators to include current technologies. Feisel & Rosa (2005) made the following comments in relation to the use of simulation technologies for presenting instructional online practical material,

"Clearly, the computer has changed the instructional laboratory greatly over the last few years. It can be used to control experiments; acquire data; and analyze, correlate, and present results. While this level of automation might remove students somewhat from the direct process of the laboratory experience, it can be argued that it has also extended them into areas heretofore impossible to explore. There will undoubtedly be many further developments in this area." (p. 124)

In an online Engineering programme, video is an integral and essential component of the learning activity. Videos in different forms such as communicative, adaptive, interactive, and productive have been developed and successfully used to promote an active learning experience in online engineering course (Jackson, et al., 2013)

Methodology

The Bachelor of Applied Science (Marine Engineering) third year unit Advanced Marine Control Systems and Automation is a core unit within the programme and has a combination of assessment tasks, including a mid-term test, an assignment, a final exam, and laboratory proficiency. The learning outcomes for this unit were;

1. Identify the components of Control System and apply control theory.
2. Analyse and evaluate the operation of the components of control system with different control mediums.
3. Demonstrate knowledge of concepts and operational principles of various sensors, transmitters and final control elements and perform calibration of this equipment.
4. Evaluate the performance of Machinery space monitoring and control system on board ship.
5. Apply theoretical and practical knowledge and analytical techniques to resolve control system problems on-board ship.

The laboratories consist of three sessions worth 20% of the total unit assessments. Short descriptions of each of the laboratory tasks are summarised below:

Practical Task 1 – Calibration - (5%) - Perform the calibration of temperature and level transmitters and produce a technical report explaining the procedures followed during the laboratory practicals and the outcomes of the practical exercise.

Practical Task 2 – PLC - (5%) - Program the Mitsubishi© Programmable Logic Controller (PLC) which controls two hydraulic systems. Instructions will be given during the relevant classroom sessions. Although students work as a team of 6 students in each team to complete the task, each student should demonstrate their ability to program the PLC individually during the practical session and through reports.

Practical Task 3 – Controller Tuning - (10%) - Tune the Process control simulator shown in Figure 1 using Ziegler Nichols Critical oscillation method (Bequette, 2003). Record the data during the process and calculate the relevant parameters, finally checking the system response with the new parameters. Students are required to produce a technical report outlining the process, response of the system and the outcome of the practical exercise. The system consists of an educational board and control module. The board is fitted with a pressurized vessel and a set of sensors and actuators for processes of level, pressure, temperature and flow while the control module contains interface circuits for the sensors and the actuators and the ON/OFF and PID. This process control trainer allows students to study the characteristics of the processes/plants (level, flow, temperature and pressure), characteristics of the sensors and actuators (pump, motor driven valve and solenoid valve) and the performance of the closed loop control of P, PI and PID control actions. The trainer also allows students to develop their own control strategies and algorithm using Data Acquisition (DAQ) card and LabVIEW© programming language.

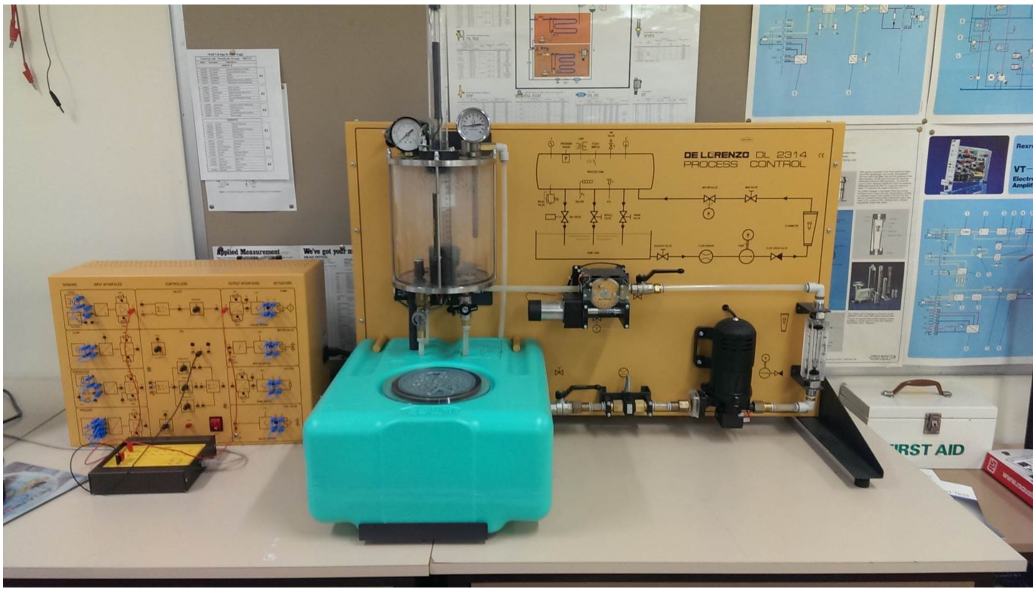

Figure 1: Process control simulator

The laboratory tasks and sessions were structured to emphasise relevant concepts and principles aligned with the unit learning outcomes (Biggs & Tang, 2011; Brown, Collins & Duguid, 1989; Crowe, Dirks & Wenderoth, 2008). Learning is a hierarchical multifaceted and multipart process (Gagne, 1977). Merrienboer, Clark, & Croock (2002), using Gagne's learning hierarchy, argued that complex learning requires the co-ordination and integration of structural progression through progressive skills. Harden and Stamper's (1999) research showed that where students recognise that there are increasing complexity and integration between stages, the students increased their learning outcomes. They also discussed the change from the traditional view of each part of the curriculum considered as disparate and separate entities, to a curriculum where there is "continuity from one stage of the curriculum to the next and vertical integration between the different stages" (p. 142). In addition, in using proven design principles for the laboratory sessions Gandole, Khandewale & Mishra (2006) showed that the following engineering competency skills and standards were addressed.

The ability to:

- work from first principles;
- design and conduct experiments;
- perceive sources of error and to quantify them;
- test systems in a laboratory setting;
- think ahead, troubleshoot, and to develop contingency plans when necessary;
- translate laboratory test data into the external applied environment; and
- work cooperatively as a team member.

The merits of teamwork during the laboratory sessions were of high importance. Research from Kennedy et al. (2008) and Krivickas & Krivickas (2007) showed that:

- students working in teams are more likely to achieve their goals rather than when working individually;
- assigning work to student teams can lead to benefits and improved student satisfaction;
- cooperative learning leads to improved academic success, enhanced quality of relationships with peers and university staff, and in turn a more positive attitude towards the university experience;
- student satisfaction is strongly related to active and sensitive guidance of the teams by the instructor; and
- the three key aspects of the teamwork vital for a positive student experience were satisfaction with the team experience, an acceptable level of guidance, and there being no slackers in the team.

In the past, students have used the simulator to reinforce the theoretical knowledge they learned in classroom lectures. This required the students to spend a significant time in the laboratory to familiarise themselves with the simulator itself, with the lecturer required to repeatedly deliver the same material to multiple groups of students. This, in addition to being an ineffective use of the lecturer's time, considerably reduced the time available for the students to use the simulator in the actual task. Students were also having difficulty in managing their laboratory time efficiently and effectively.

To address these issues, a series of videos were developed incorporating the required knowledge based components. These were made to explain and expand upon the theory the students learnt and to demonstrate the features and use of the simulator. Suitably structured videos can present information in a more accessible and engaging format for visual learners (Jackson, et al., 2013). The rationale behind the development of the videos was to enhance students' understanding of the subject matter and to assist students in familiarising with the marine process control simulator. The videos were developed with the following features:

- aim/objective of each laboratory task;
- familiarity with the components of the apparatus;
- process of conducting the tasks;
- instruction on the use of the simulator;
- related knowledge and information; and
- links to the intended learning outcomes.

In making the videos, two cameras were used to record the lecturer's demonstration of the physical changes in the process simulator. Simultaneously, Campteisa© a screen capturing software program, was used to record the information displayed (shown in Figure 2) on the computers connected to the simulators. Subsequently, the videos were edited to demonstrate the processes in the simulator and to supplement the relevant theory. The duration of each of the videos was kept between 15 to 20 minutes in order to maintain the interest of the students while delivering sufficient content to ensure the students can carry out the tasks with minimum supervision. The shorter videos also allowed minimisation of bandwidth and improved download time. Traditional longer lectures were now replaced with edited shorter, scaffolded segments of learning.

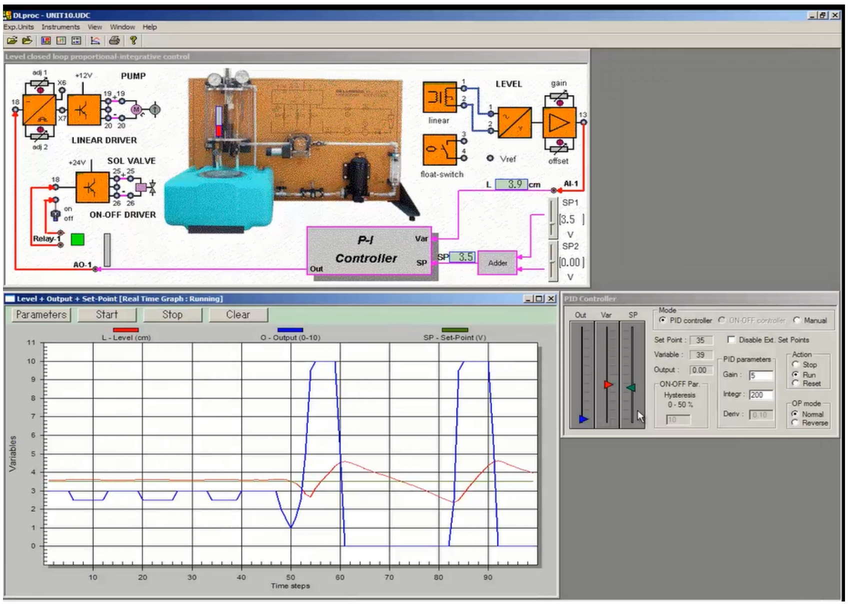

Figure 2: Computer display of the simulator

A subsequent addition was the production of screen captured short lecture summaries with annotations and animations to enhance students' experience. The use of these videos allows students to have individual control over the pace of their learning and the opportunity for repeated viewing. The videos were available for the students from the start of the unit delivery so that students could familiarise themselves with the simulator and link the theory they learnt in the class to practical applications. The videos also provided guidance, prompts, and hints for the students to perform specific tasks, such as the tuning of the process controller to meet the stipulated outcomes.

The students are encouraged to watch the videos before attempting the laboratory sessions. They are also encouraged to carry out research into the underpinning knowledge and theory of each of the tasks, using the information in the videos and their classroom lectures as a foundation. The students are divided into groups of 6, with each group encouraged to spend approximately 2 hours per week linked to the tasks associated with the simulator. As the students gained knowledge and became familiar with the simulator, they were required to perform the final task, which required synthesising the knowledge gained from all the learning tasks throughout the semester. Towards the end of the unit delivery, a student survey was conducted by an independent facilitator. The survey consisted of a questionnaire aimed at determining the students' experience in the laboratory sessions. In particular, students were asked to quantify the extent the videos were useful to attain the required knowledge. The Likert Scale student survey was provided to all 32 students in the class, and although participation was not compulsory, all students responded to the survey. The class consisted of a mix of Australian and overseas students, as well as a mix of school leavers and those who had progressed from a trade background. An analysis of the survey is given in the next section.

Results and Discussion

The results discussed in this section relate to the following questions, which formed the major part of the survey.

1. The laboratory practical sessions addressed the key learning outcomes stated in the unit outline.
2. The laboratory practical sessions enhanced my understanding of the subject.
3. Videos provided sufficient background information to navigate through the simulation activities.
4. Videos provided the opportunity to connect and map the knowledge gained from the classroom lectures.
5. Explanation and demonstration in the videos helped to perform better during simulator exercises.
6. The content of the videos presentation was clear and easily understandable.
7. What were the best aspects of the laboratory practical work?
8. What aspects of the Laboratory practical work could be improved?
9. Any other comment related to the laboratory practical and the video presentation used in the unit.

The statistical analysis of the Likert Scale student survey response is shown in Figure 33.

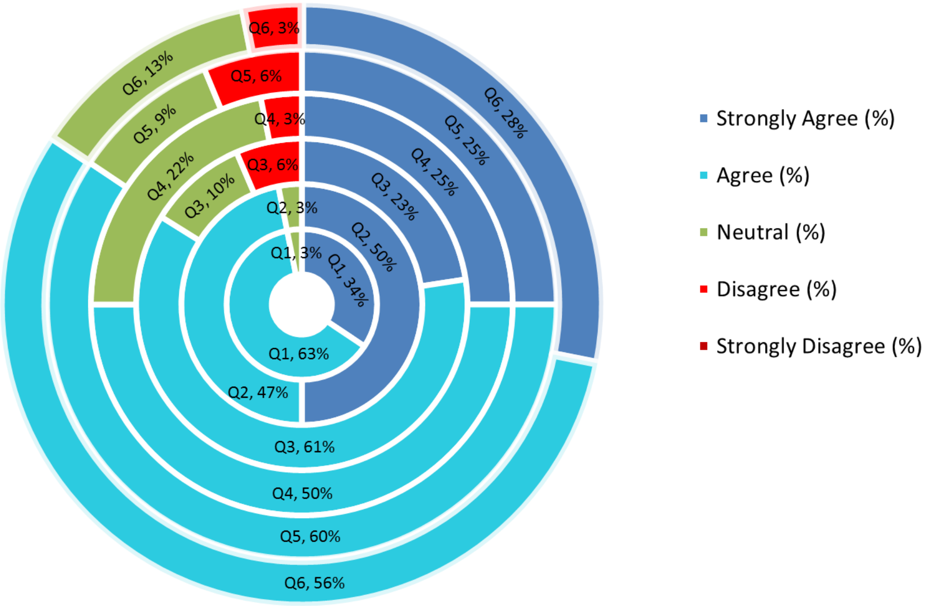

Figure 3: Survey results for the laboratory sessions for the unit Advanced Marine Control Systems and Automation, population size = 32, responses = 32

Questions 1 and 2 are related to the students' experience of the laboratory sessions, while questions 3 to 6 specifically target the use of the videos. As shown in Figure 3, almost 97% agreed that the laboratory sessions using the simulators addressed the key learning outcomes and enhanced their understanding of the subject. This reinforces the need to provide visual learning and hands-on tasks to effectively transfer knowledge to students (Boles, 2010; Oakley, et al., 2004). The descriptive responses from the students were in general also supportive of the sessions, although there were some comments linked to the group size. An example was,

> *"Lab was very good however, classes (groups) too big. Hard to get a go during group exercises."*

However, in general most did enjoy the laboratory sessions, hence the high percentage of satisfaction. The issues of group size will need to be addressed. This may be through reduced group sizes or through a more structured set of procedures that enables students to participate simultaneously in parallel tasks.

For Question 3, 84% of students agreed that the videos provided sufficient background information to navigate through the simulation activities, with only 6% disagreeing. This latter could be due to the difficulties encountered by some individuals to access the university's online study platform. This was clear from some of the comments such as,

> *"It was very expensive to watch videos at home. Used a lot of download"*

> *"Unable to view videos properly due to poor quality reception".*

Thus, options such as smaller and more accessible videos and alternate methods of distributing the electronic files may warrant investigation. However, the majority agreed that the videos helped them and provided encouraging feedback such as,

> *"Would have been difficult without videos"*

> *"Well done. Great improvement from when I did the course in 1990."*

Around three quarters of the class agreed that the videos provided the opportunity to connect and map the knowledge gained from the classroom lectures (Question 4). However, there was almost 22% who gave a neutral response to this statement showing that in future more in-depth videos were needed. This could be in part due to some technical issues encountered during the viewing of the videos online when students access them via the university's online platform from outside the university. The authors are aware of this issue and are in the process of improving the quality and quantity of the videos to be used in future.

For Question 5 and Question 6, 84% of the students agreed that the explanation and demonstration in the videos helped to perform better during simulator exercises and the content of the videos presentation was clear and easily understandable. Of the 6% who disagreed with the statement in Question 5, none provided any follow up comments with regard to the issues that caused them to disagree.

Questions 7 to 9 were included to enable the students to provide comments and suggestions. The student responses provided valuable feedback, not only on how the videos helped them, but also on how to improve them in future. Their responses captured some of the best aspects of the newly introduced videos with comments such as,

> *"Hands on experience with equipment were great, learning to calibrate and tune will be of great knowledge for me in the future."*

> *"The personal exam of what I understood of PID gave me a clear understanding of my understanding."*

> *"Putting theory into practice and group/peer work/talking."*

From the response to Question 8 where students are asked to comment on how to improve the sessions, it was clear that most students did not like the large group size. This is reflected in the following comments.

> *"Lower number of people in the groups."*

> *"Size of groups could be smaller."*

> *"Smaller group."*

> *"Would have been better with smaller class sizes."*

As discussed earlier, this issue of group size will be addressed in future. A report by Kostulski & Murray (2010) regarding review of the delivery of practical laboratory education in

Australian undergraduate engineering programs showed that the optimum group size in laboratories is a very active discussion topic. The results of the survey showed that ideally most academics (39%) preferred two students per group, followed by 3 students per group (31%). However, the responses declined rapidly after 4 students per group, and no academic responded for more than 5 students per group.

Question 9 allowed the authors to collect additional feedback, which in general showed that the students did find videos useful. Typical comments were,

"Lab and videos were very good and appreciated."
"Great chance to ask further questions brought about by undertaking practicals due to approaching content from different angle (practical application)."

Overall unit results showed a marked improvement in motivation and achievement. In 2013, 21% of the class achieved grades of distinction or above, but in 2014, 40% of the student cohort achieved above distinction grades. Students' enthusiasm and motivation were also apparent in the data collected through the University's online survey tool. In the open ended question: What are the most helpful aspects of this unit? Students responded following answers.

'Practical tasks'

'What little practical we are able to fit in has assisted in gaining some concept of this unit. As the lecturer struggles with the theory side of this unit more practical would be an advantage.'

'Practical lab work.'

'Time in the control labs'

'The lab pracs are OK'.

'Practical experiments in the control lab'

Conclusions

Videos are dynamic learning tools that can be used to provide scaffolded positive learning experiences. This paper outlines the use of a marine process control simulator to enhance the learning process for marine engineers by linking the theory to practical tasks, thus enabling students to take advantage of visual and hands-on learning. These laboratory sessions were enhanced by the use of videos, providing students with instructions and related knowledge, thus improving the efficiency and effectiveness of these sessions.

A survey conducted on the first group of students experiencing the integrated video and simulator sessions showed that the use of video technology to link the theory and practical components of the unit enhanced the students' perception of the knowledge of the practical application of a marine process control simulator. The student's participation and engagement with these dynamic learning tools also gave them advanced preparation and allowed them to optimise their time during the laboratory sessions.

Issues raised by the students, such as technology restrictions on access to the online system and group sizes need to be addressed. The former may require smaller and more accessible videos and alternate methods of distributing the electronic files. As for the group size, although a smaller group size is an easy option, it may result in reduced efficiency due to the need of additional sessions. Thus, it is important to consider other options such as restructuring the tasks to enable simultaneous parallel duties for all students. A reduced group size also works against promoting group work, tasks allocation, interaction, and communication; soft skills that are essential within a learning process. It is also planned to further develop additional videos to focus more on linking the theory to the practical tasks.

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