Emergency transition to remote learning: DoIt@Home Lab in engineering

Nitin Bhaurao Raut
Department of Chemical Engineering, Sohar University, Sohar, Oman, and
Gweneth Gorman
Department of Institutional Planning and Effectiveness, Sohar University, Sohar, Oman

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Abstract

Purpose – The interruption of on-campus teaching and learning, due to the COVID-19 pandemic, forced universities around the globe to rethink their pedagogical models and adopt innovative strategies and approaches that enabled continuity of learning. Engineering schools and faculties were faced with the challenge of how to continue to engage students with the practical component of coursework, especially in terms of lab work and experimentation, which are mandatory requirements for degree awards.

Design/methodology/approach – This study documents how the Faculty of Engineering in a university in Oman engaged students with the practical component of their course during the pandemic by launching the remote DoIt@Home Lab. The DoIt@Home Lab approach included the design and development of video recorded labs, virtual labs, simulation exercises and DoIt@Home experiments which were provided to students as teaching tools and guides to conducting home experiments remotely.

Findings – This study presents the DoIt@Home Lab approach introduced to Year 2 Chemistry for engineering students. Students' grades improved by 11% over the previous year when the course was delivered face-to-face. Failure rates dropped by 8% while the number of students earning a 3.25 grade point average (GPA) or higher increased by 18%.

Originality/value – The DoIt@Home Lab for engineering courses could enhance students' learning experience and create an effective remote learning environment. While the DoIt@Home Lab was created to supplement on-campus activity in the event of a temporary disruption, it can also be used to supplement regular face-to-face program delivery.

Keywords Learning outcomes, DoIt@Home Lab, Quality assurance, Simulated experiments, Chemistry lab, Chemical engineering

Paper type Research paper

Introduction

The transition to the "new normal" during the Covid-19 pandemic saw all higher education institutions in the Sultanate of Oman going virtual, under the guidance of the Ministry of Higher Education, and all course offerings being delivered off-campus through a variety of online modes and tools. This study documents one university's response to the pandemic

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crisis, which was to work with faculty to develop an innovative, new approach to teaching and learning and to create a learning environment, which would provide a holistic support system for students to help them achieve their educational goals. During the pandemic lockdown, the directed remote learning (DRL) approach was implemented as an emergency response to transition students to virtually guided teaching, learning and assessment.

Under the directives from the Ministry of Higher Education, the university, where this study was conducted, designed a hybrid, blended learning approach. Course delivery was adapted, and a range of different activities were designed to support and encourage students to think and learn more independently in remote, virtual settings. In addition to the access to a variety of online resources and course learning materials, the teaching and learning was supported by the delivery of live online synchronous sessions with students, online tutorials, student forums and discussion rooms on Moodle and MS Teams. Training continued to be the linchpin to the success of the new teaching and learning approach.

Despite the overall successful transition to remote and blended learning, one significant challenge remained for the engineering faculty: how to effectively deliver the practical component of coursework, in particular lab experiments and research, which are intrinsically embedded in engineering disciplines and are key to the attainment of the course and program learning outcomes.

Effective learning occurs when a person goes through a cycle of four stages: having a concrete experience, observing and reflecting on that experience, forming abstract concepts (analysis) and generalizations (conclusions), and using those abstract concepts and generalizations to test a hypothesis in future situations, resulting in new experiences (McLeod, 2017). Engineering course curricula are designed in such a way that the lab-based component complements the theoretical principles and concepts learned and enables students to develop the requisite cognitive and psychomotor skills (Rajibussalim, Rahmayani, & Irwandi, 2018). Therefore, devising innovative methods and techniques to cover the lab-based component of engineering coursework in a virtual setting was crucial to the continued successful delivery of the program.

The second-tier challenge was how best to adapt traditional curricula and create new study and working environments that would ensure adequate digital pedagogy and effective learning in remote individual settings. In the case of the Faculty of Engineering, where the lab-based component of the course work is embedded in the weekly course delivery, the challenge was how to continue incorporating the lab-based and research component of the course through the new virtual learning mode. Students not having access to the practical, hands-on experience of conducting experiments in controlled settings would pose an obvious impediment to learning and their ability to demonstrate effective achievement of the course learning outcomes and the required employability skills. The dilemma was how to provide students access to specialized equipment and chemical reagents found in all modern laboratories (Abdulwahed & Nagy, 2009) and how to find ways to supplement these with substitutes that are fit for purpose and are easily accessible in a typical home environment.

Virtual labs are nothing new. Indeed, they have become more sophisticated and advanced over time with the evolution of the internet and artificial intelligence (Scruggs, Leamy, Cravens, & Siegel, 2020). Remote and online simulation labs have proven to be an excellent way to make the students' educational experience engaging, exciting and stimulating, irrespective of geographical location. Moreover, they afford educational institutions with the opportunity to continue to provide guided learning opportunities in situations where on-campus teaching and learning is interrupted and/or not feasible. In addition, free online simulation labs mean no extra costs are incurred over the regular expenses of running on-campus labs.

A recent study on the use of online, simulated laboratory activity in teaching and learning cited in the literature highlighted the use of a "remote laboratory for a second year fluid mechanics course" (Adedoyin & Soykan, 2020, p. 3). This inspired the faculty to explore various alternatives and found the open educational resources, which allow access to "teaching, learning and research materials in any medium, digital or otherwise that reside in the public domain or have been released under an open license that permits no-cost access, use, adaptation and redistribution by others with no or limited restrictions" (Garrison, 2016, p. 362). Appropriate measures needed to be taken to ensure students could access these labs and be ready to conduct controlled/monitored lab experiments remotely in the safety of their home.

The faculty decided to pilot the initiative and embed access to online simulation labs in the design and delivery of a second-year chemical engineering course. The pilot was designed in a way that would enable students to have authentic learning experiences observing and simulating scientifically developed lab experiments in real lab settings. Students would be given the opportunity to experiment with variable input data and generate results, which could then be further interpreted and analyzed as part of their learning experience.

The Chemical Engineering Faculty were ready to pilot the new approach and introduce the DoIt@Home Lab experiments. This case study discusses and elaborates on the innovative ways adopted by second-year chemical engineering students in one course (Chemistry for Engineers) in a university in Oman. Students were directed to set up remote, home-based virtual laboratories where they would conduct a number of activities and experiments following prescribed safety guidelines.

Literature review

The COVID-19 pandemic posed serious challenges to education systems and prompted necessary procedural changes to be adopted by teachers, institutional leaders and officials to mitigate the crisis (Baber, 2021). Reassuring students and parents of the integrity of the program was a vital element of the institutional response (Gonzalez *et al.*, 2020). It was also important to understand the benefits and limitations of online teaching for improving online learning during the lockdown. While online learning is a more sustainable method of learning and online learning modalities are a flexible and effective source of teaching and learning, there are some inherent drawbacks that need to be investigated and addressed (Mukhtar, Javed, Arooj, & Sethi, 2020).

Today, a variety of online teaching tools are used to enhance student presence and learning effectiveness. Students are engaged in their learning through the use of blogs, discussion boards, wikis and 3D virtual worlds (Gregory & Bannister-Tyrrell, 2017), and they "can be anywhere (independent) in these environments to learn and interact with instructors and other students" (Singh & Thurman, 2019, p. 292). Synchronous learning environments are structured in such a way that students attend live lectures, educators and learners interact in real time, and instant feedback is possible, whereas in asynchronous learning environments, content is not delivered via live lectures or classes but rather via a variety of learning systems and forums. Live feedback and instant responses are not possible in an asynchronous online learning environment (Littlefield, 2018).

A detailed, empirically based framework for understanding e-learning in higher education is required. This framework should analyze e-learning in terms of its technological, educational, financial and administrative implications (Gibbs & Gosper, 2006). During the pandemic, the majority of the universities and education institutions adapted their teaching, including laboratory workshops, to an online or blended mode of delivery (Gamage, Silva, & Gunawardhana, 2020). During this difficult period, the question was not whether online teaching and learning methods can provide a high-quality education; rather, the question was how academic institutions would be able to adopt online learning on such a large scale (Carey, 2020).

Amid pandemic situations, virtual classes and online resources serve as a more effective alternative way of learning science from home (Ray & Srivastava, 2020). It is important to understand the e-learning process and e-learners' satisfaction level during this forceful shift away from the traditional laboratory and classroom teaching (Gonzalez *et al.*, 2020). Quality assurance, dependability, responsiveness and website content are important in e-learning (Saxena, Baber, & Kumar, 2020). Implementation of online learning requires innovative and enhanced approaches to learning and adherence to guidelines from reputable organizations, such as the International Society for Technology in Education (Morgan, 2020).

Over the past few years, there has been a continuous increase in the use of online tools for teaching labs (Lewis, 2014). While online teaching and learning has been the subject of research for over two decades, there appears to be a noticeable gap in the literature in terms of effective frameworks and guidelines for designing online or remote methods for teaching off-campus, virtual laboratory courses.

The transition from on-campus learning to a remote learning mode is critical and must be implemented judiciously (Daniel, 2020). A thorough analysis of the potential factors (computer technology, teacher competence, including technological pedagogical knowledge, and opportunities for teacher education to learn about digital teaching and learning) must be conducted. Information and communication technology tools, particularly digital teacher competence and opportunities for teacher education to develop digital competence, are critical in helping teachers to adapt online teaching especially in emergency situations, like the COVID-19 pandemic (Konig, Jager-Biela, & Glutsch, 2020). Research studies emphasize the importance of encouraging students to be active, creative and innovative in an investigative science learning environment (Rahmayani, Irwandi, & Rajibussalim, 2018). According to recent research, classroom interaction, student motivation, course structure, instructor knowledge and facilitation are some of the factors that influence students' perceived learning outcomes and satisfaction with online learning experiences (Baber, 2020).

Assessment evaluates the level to which course learning outcomes are met and is an important, mandatory element of the teaching and learning environment. Therefore, there is a need to rethink and revitalize online assessment strategies to ensure safety, integrity, validity and reliability (Khan & Jawaid, 2020). There is an opportunity to create a framework to aid in the predictive evaluation of e-learning tools, a framework that could be used by non-tech experts and applied in a variety of learning contexts to help draw their attention to the important aspects of evaluating any e-learning tool (Anstey & Watson, 2018). Appropriate design and delivery strategies, as well as clear assessment criteria for assessment and use, provide an effective learning vehicle for students, assisting them in overcoming language barriers and encouraging them to participate in a nonthreatening learning environment (Sundarasen *et al.*, 2020). This approach expands on the advantages of peer-to-peer learning and case study pedagogy (Seethamraju, 2014).

With this in mind, the current study used an online off-campus mode to deliver the laboratory component of a second-year engineering course through the DoIt@Home Lab. By documenting this process and evaluating its effectiveness, the study attempts to contribute to the building of a framework and guidelines for transitioning traditional face-to-face labs to online environments.

Methodology

The present study is a teaching intervention that piloted a custom-designed second-year engineering course in an online environment.

Participants

A total of 75 second-year students (68 females, 7 males) enrolled in the Chemistry for Engineers course in a university in Oman took part in the study. The students were mostly Omani nationals (67), with four each from Bangladesh and India. For these students who are pursuing a bachelor's degree in chemical engineering, understanding the fundamentals of chemistry and its applications is critical.

It should be stated that the primary objective of the lab-based component in this course is for students to develop a clear understanding of the principles of experimental engineering chemistry and not to strengthen concepts. The course which lies at the center of this investigation, Chemistry for Engineers (CHEM2000), is a two-credit unit (30 credit points) course offered to second-year students in the chemical engineering program of the university where the study took place. The course is taught over 15 weeks and comprises ten notional hours of learning per week. During the transition to remote learning, course delivery transitioned from six hours of traditional weekly lectures, tutorials and lab work on campus to a modular delivery plan.

The program graduate attributes (GA), or transferable generic skills, were also clearly embedded in the teaching, learning and assessment approach as outlined in Table 1.

The original course was assessed through traditional, on-campus, closed book exams and incorporated the requirement for students to conduct a certain number of lab experiments and submit a comprehensive lab report on each experiment for grading. The revised online course required a complementary revision to assessment, in particular a revision of the lab component. Online assessment of learning outcomes required students to conduct home experiments and submit a newly created DoIt@Home Lab report.

The five-stage approach to DoIt@Home Lab

As the Faculty of Engineering looked at how best to adapt teaching and learning to the hybrid blended learning approach for all courses, and the lab-based course components in particular, the chemical engineering team created a five-stage approach to completing lab work through the DoIt@Home Lab model. Figure 1 illustrates the five-stage approach to DoIt@Home experiments for the lab component of the CHEM2000 course. The three key components which are core to all the experimental activities are as follows: the pre-DoIt@Home Lab stage, the DoIt@Home Lab activity and the post-DoIt@Home Lab stage.

Stage 1: Preparation for DoIt@Home Lab. The DoIt@Home Lab for the CHEM2000 second-year course in Chemical Engineering was designed to include six experiments to be done by students at home. At the preparation stage, students were given clear and concise step-by-step procedures for each experiment, which also included an introduction to the relevant safety operating procedures and precautions to be taken. Students were introduced to the chemistry labs that are typically used on-campus through video demonstrations.

Graduate attributes	Description
GA 1. Communication	Communicate effectively to a diverse audience
GA 2. Information technology	Use and analyze a substantial range of information technology
GA 3. Numeracy	Solve abstract complex numeracy problems
GA 4. Creativity and problem solving	Identify and apply methodologies and tools to analyze and complete abstract tasks
GA 5. Teamwork	Collaborate within teams to complete tasks under guidance
GA 6. Critical judgment	Identify and initiate responses to own learning needs
GA 7. Social and ethical responsibility	Manage time effectively to allow for personal development and/or the development of others and use substantial entrepreneurial skills

Table 1.
Graduate attributes for CHEM2000 DoIt@Home Lab

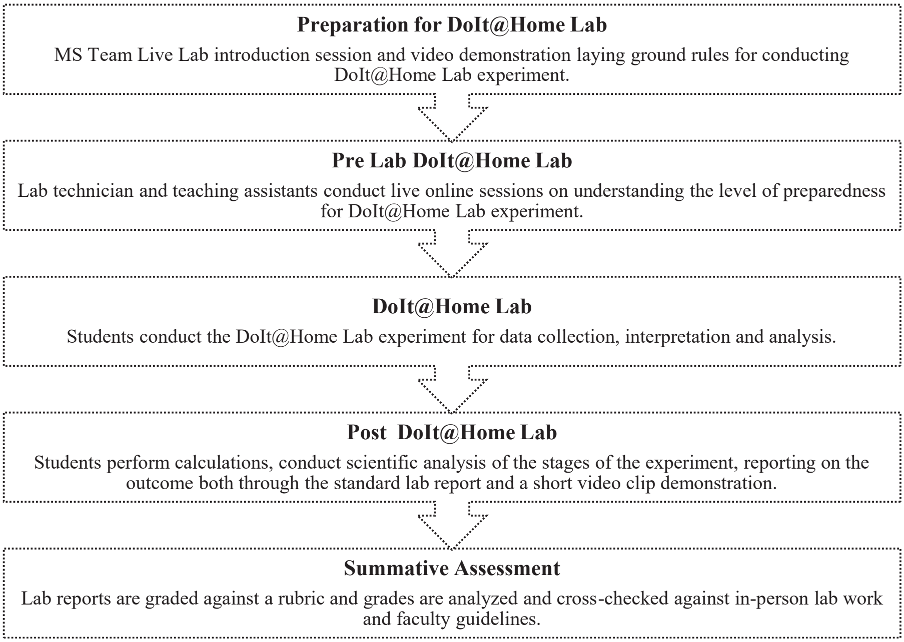

Figure 1.
The five-stage approach to DoIt@Home Lab

Students were encouraged to learn to do all experiments following the same general methods and procedures highlighted in the video demos and described in the Lab Manual that was designed by the teaching team. In addition, students were shown the process and requisite lab reports to be used for recording their own experiments in a clear and concise manner – something that was highlighted as just as important as conducting the experiment itself. The purpose of this was to help students hone their laboratory and reporting skills, which are key to successful and professional integration into industry or research laboratory establishments upon graduation.

Stage 2: Pre-DoIt@Home Lab. This stage in the process was introduced to students during the pre-scheduled MS Teams live session conducted by the course coordinator, teaching assistant and lab technicians. All experiments required for the course had individual video demonstrations and guidelines on how best to conduct each experiment through the DoIt@Home Lab approach. Students were introduced to each experiment to be conducted, outlining the aim and objectives of the experiment; the theoretical principles being put into practice during the experiment; the chemicals and reagents required to complete the experiment; the procedure(s) to be followed; the calculations required, and how observations and analyses were to be conducted and recorded. Students were given an understanding of the expected leaning outcomes to be achieved through the experiment, and again, at this stage, special emphasis was placed on the safety operating procedures to be adopted while conducting the experiments at home. Moreover, this pre-DoIt@Home Lab stage also included a formative assessment to ensure that the students read and understood the content fully before engaging in the formal activity at home.

Stage 3: DoIt@Home Lab. In Stage 3 of the process, students were ready to begin their DoIt@Home Lab experiments. Having completed the previous two stages, students were well equipped with guidelines, knowledge and understanding of the theoretical principles and applications, which prepared them to conduct each lab activity. The guidelines and discussions which had taken place during Stage 2 helped students to determine the workspace and equipment required at home and the designated chemical substitutes needed to perform each experiment. Students were ready to begin experimenting, creating and innovating within the framework of the scientific principles and guidelines shared. They were expected to perform a range of experiments as per the standard prescribed procedures set out. All students were required to complete six experiments: one recorded experiment, one virtual experiment and four DoIt@Home experiments (see Table 2). One of the six experiments, Experiment 5, was a group activity and required the submission of one group lab report. The six experiments were designed to give students an introduction to laboratory procedures for performing experiments in typical chemical engineering labs and to provide students with a deeper understanding of theoretical principles by observing phenomena, measuring physical characteristics and comparing measured vs calculated results. This "hands-on" experience is essential to any engineering student.

Stage 4: Post-DoIt@Home Lab. In Stage 4, students focused on performing calculations, conducting scientific analysis of the stages of the experiment, reporting on the outcome both through the standard lab report and a short video clip demonstration of the experiment they conducted. The data generated were reorganized into readable standard data tables. These data were then plugged into relevant scientific formulas undertaking dimensional analysis. An important section of the lab report was the conclusion where students reiterated procedures followed, restated the results and drew meaningful inferences. The experimental error was computed and compared with the inherent error, and the possible sources of errors were reported. The video clip demonstration of the experiment ensured that students undertook the given experiment following the guidelines in the manual and highlighted the process of learning.

Stage 5: Summative assessment. Stage 5 required students to reflect on the outcome of their activities. This stage followed students' completion of the DoIt@Home Lab and required students to record their observations and readings in line with procedures. Stage 5 was closely tied in with the traditional on-campus lab component of the coursework, as students were required to submit a lab report, through Turnitin, on the university Moodle LMS system. The lab report invariably set out the criteria required to complete the assignment. Each lab report carried a summative weight of 5% and was closely aligned with the respective GA to be achieved (see Table 3). Students were also provided with model moderated sample reports to enable them to identify expectations and examples of good practice.

The experiments

The first DoIt@Home Lab experiment, i.e. determination of the boiling point elevation of a solution, required each student to visualize, understand and interpret a recorded experiment, simulated in a similar environment, which aligned fully with what students would have done in an on-campus lab setting. This experiment was designed to demonstrate the effect of solute concentrations on the boiling point solution. During the Pre-DoIt@Home Lab Session (Stage 2), students were shown three videos of instructors performing this same experiment in the university chemistry lab. After watching the two videos (a video of the experiment and a video of the specific lab instructions to be clearly followed), students were required to work through the readings and data given to them for different operating parameters and systems. Students were then required to compile an individual lab report in the prescribed format, which was to be submitted through Turnitin. It should be noted that all theory related to this component of the course had previously been introduced to students and reinforced through a number of Live MS Teams sessions during the first three weeks of the course.

The DoIt@Home experiments required students to substitute the chemicals and reagents typically used in the on-campus chemistry lab with alternate materials and chemicals locally

Table 2.
Activities in the DoIt@Home Lab

Experiment	Video demonstration	Video instructions	Simulations	Assignment quiz	Data analysis interpretations	Group experiment	Individual experiment	Video clip submission
1. Boiling point elevation	☑	☑		☑	☑		☑	☑
2. Surface tension	☑	☑		☑	☑		☑	☑
3. Viscosity of liquids	☑	☑	☑	☑	☑		☑	☑
4. Polar and non-polar substances	☑			☑	☑		☑	☑
5. Synthesis of polymers	☑	☑		☑	☑	☑		☑
6. Detection of functional groups		☑	☑	☑	☑	☑		

available to thus conduct the experiments in their home lab setup. The following four experiments were split into three individual experiments (Experiments 2, 3 and 4) and one group experiment (Experiment 5). Based on the video demonstrations and instructions given to students during Stages 1 and 2, each student was required to design and fabricate the experimental setup and perform the scientific measurements.

The objective of the DoIt@Home Lab Experiment 2 was to enable students to explore and understand the surface tension phenomenon. A dishwashing soap was added to the liquid with food coloring on the surface, and the observations were duly recorded.

The DoIt@Home Lab Experiment 3 objective was to determine the viscosity index of liquid. Students were requested to set up a viscometer where a cylindrical bottle with a regulator cap was inverted over another cylindrical bottle, both bottles were joined, and molding clay and sealing tape were used to secure the home-styled viscometer. The bottom of the inverted bottle was cut to allow the liquid under experimentation to be poured. The base cylindrical bottom was graduated with proper markings. The liquid under experimentation flowed through the graduated cylindrical bottle at a controlled flow rate. The increase in the level of liquid in the bottom cylindrical bottle was recorded with respect to time. The flow rate of water was calculated, and the viscosity index was estimated with reference to water.

The DoIt@Home Lab Experiment 4 focused on polar and nonpolar compounds. A glass rod, fur and a woolen/silk cloth were used to understand the deviation of a fine stream of liquid through a nozzle. The degree of solubility of different solutes (sugar, salt, vitamin tablets, pharmaceutical tablets, etc.) in solvents (oil, fruit juice, water, dishwashing liquid, etc.) was visually observed.

The DoIt@Home Lab Experiment 5 was conducted on the synthesis of polymers and required students to produce a polymer spherical ball using locally available Elmer glue, borax powder, starch, distilled water and food color. This experiment was conducted as a group activity where a group of students would decide the composition of the polymer blend to be synthesized varying the composition of the three main ingredients. Once the polymer molded balls were produced, students were asked to determine the height to which each would bounce back when dropped. The height was to be determined and demonstrated through the recording of a video in slow motion. Furthermore, students were asked to characterize the polymer blend based on their compositions.

Finally, the DoIt@Home Lab Experiment 6 was a virtual experiment on the identification of the functional groups, and it was conducted through the open access online labs. The virtual lab introduced the students, through a theory procedure video demonstration, to how the lab is conducted in an on-campus mode and using a simulator. Students were given instructions on a particular set of variables which they needed to explore in the online simulator to generate data and, using standard methods, to analyze the data using the required calculations. This was followed by the interpretation of results.

Table 3. Mapping CHEM2000 DoIt@Home Lab to GAs

	Graduate attributes						
Experiment	GA 1	GA 2	GA 3	GA 4	GA 5	GA 6	GA 7
1	☑	☑	☑				☑
2	☑					☑	☑
3	☑		☑	☑			☑
4	☑	☑		☑			☑
5	☑		☑	☑	☑	☑	☑
6	☑	☑					☑

In all DoIt@Home Lab experiments and simulations, students were required to analyze and interpret their observations and record data following standard procedures. All findings were to be reported and submitted through Turnitin.

Instructor interactions

The 75 students enrolled in the CHEM2000 course were divided into three sections with each section having one scheduled live session per week dedicated exclusively to the DoIt@Home Lab. These live sessions were delivered by the course coordinator while teaching assistants and lab technicians typically summarized the concepts and equipment functions at the beginning of each lab and provided support and assistance to students during the lab, as needed. The interaction between students and academicians was facilitated mainly through MS Teams and the Moodle discussion forum and complemented by regular exchange of emails.

The principal purpose of the live sessions on MS Teams was to reinforce the key concepts, principles and procedures required for the experimentation stage; to guide students in choosing, designing and creating their experimental setup and familiarizing them with the working of online simulators. Throughout the delivery and instruction of the DoIt@Home Lab, students were directed to relate their experiments to the respective module learning materials available on Moodle and to use the MS Teams live session platform for discussion and clarification.

Assessment and evaluation

The assessment strategy for the DoIt@Home Lab focused more on the assessment of the process of learning rather than exclusively on the product of learning. This was ensured through direct observation of the video clips students submitted of their experiments; the way each student conducted the experiments (both individual and as part of a group); the planning and preparation stages prior to conducting the experiment and the time management factor required for all three stages of the process: preparation, execution and reporting.

The assessment of DoIt@Home experiments was continuous with feedback provided on each experiment. Every three weeks, students were assessed on their participation and performance in the DoIt@Home Lab through a lab report submitted in standard format. The points earned each week were totaled and added together to determine the overall grade for the lab component. Students' reports were graded against predefined criteria in the rubrics shown in Table 4.

Evaluation of the DoIt@Home Lab

Student and staff evaluations of this new approach to teaching and learning were collected. An online survey approved by the university Institutional Planning and Development committee was written and administered in English to students enrolled in the CHEM2000 course at the end of the semester. The evaluation survey was designed to monitor how effectively the course's aims and objectives, teaching and study plans, learning outcomes, delivery, resources and student experience were achieved (see Table 5). In the first section of the survey, students were asked about the course's broad objectives and how strongly they agreed or disagreed that those objectives were met in the DoIt@Home Lab mode. The final two questions in the survey asked students if the course made them more competitive professionally and increased their understanding of the discipline. Students provided open-ended written feedback on the DoIt@Home Lab in the second section of the survey. The survey was piloted with 12 respondents, and their feedback was used to design the final survey.

The results of the survey were recorded in Google Forms, and the responses of the students were collected in an Excel spreadsheet. Learning perception was assessed using a

Criterion	Video recorded	Virtual	Experiments
Introduction Information section is clearly introduced. There are strong links to relevant theory. Excellent definitions of subject-specific terminology	☑ 10 points	☑ 10 points	☑ 5 points
Scientific method A wide range of factors are analyzed that relate to the key understandings of the topic. It includes excellent written purpose, hypothesis, materials, procedures, observations and a well-explained conclusion	☑ 15 points	☑ 15 points	☑ 15 points
Instructions Clear, concise and detailed explanation of appropriate method; procedure very clearly outlined	☑ 10 points	☑ 5 points	☑ 5 points
Interactive simulators and tools High speed, high performance tools and simulators capable of producing high quality print work. Perform complex calculations and simulations simultaneously. Ability to post, respond to and assess work online	–	☑ 10 points	☑ 10 points
Experimentation Excellent technique was used throughout the lab procedure. Procedures were well-planned and well-executed. Data and observations were recorded accurately, descriptively and completely, with no serious errors	–	–	☑ 20 points
Charts/graphs/results Interactive graphics and charts. Well-presented high-quality presentations, assessments and discussion boards available	☑ 15points	☑ 15 points	☑ 10 points
Interpret and analyze data Process and analyze data and information using a wide range of representations, including tables and graphs, to represent and describe observations	☑ 25 points	☑ 20 points	☑ 15 points
Conclusions and evaluation Conclusion is comprehensive and succinct, showing significant depth of thought and strong evidence of successful learning. Activity suggests high student engagement High level evaluation functions	☑ 15 points	☑ 15 points	☑ 10 points
Lab report format (spelling, punctuation, grammar and diagrams) Standard format, well-written and free of grammatical errors, clear and accurate diagrams	☑ 10 points	☑ 10 points	☑ 10 points
Total	100	100	100

Table 4. Evaluation criteria for students' DoIt@Home Lab reports

five-point Likert scale (from 1 – strongly disagree to 5 – strongly agree). In addition, students' summative assessment scores were compared to the previous cohort using a *t*-test.

Results and discussion

The large majority of students (85%) in the DoIt@Home Lab reported they were able to learn how to analyze experimental data and collaborate with peers (see Figure 2). The synchronous MS Team sessions, where students could work in small groups with instructor contact, most likely contributed to these favorable impressions. Along with students' perceptions that the DoIt@Home Lab format met learning objectives, it was also found that student performance on graded assessments was comparable to previous semesters when the course was taught face-to-face.

Only 55% of the students agreed that the DoIt@Home Lab broadened their understanding of the subject (see Figure 3). This appears to be a shortcoming of the

Table 5.
List of survey questions

The DoIt@Home Lab
1. Enabled me to carry out experimental procedures
2. Assisted me in organizing a lab report
3. Helped me with data analysis
4. Promoted teamwork
5. Increased my competitiveness
6. Broadened my understanding of the subject
7. The MS Teams sessions enabled me to meet the course objectives
8. The instructional videos improved my understanding
Open-ended questions
9. How can we make the DoIt@Home Lab better?
10. How can the DoIt@Home Lab be integrated into other courses?
11. How effective is instructor/tutor presence during the MS Team sessions for discussion?

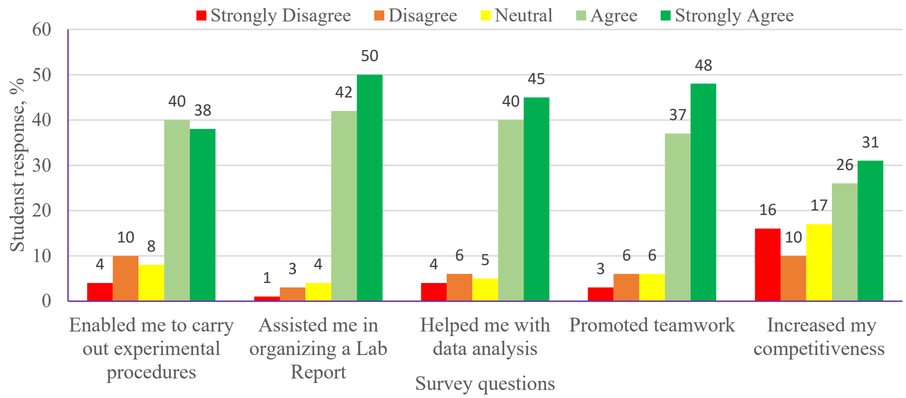

Figure 2.
Summary of responses to survey questions 1–5

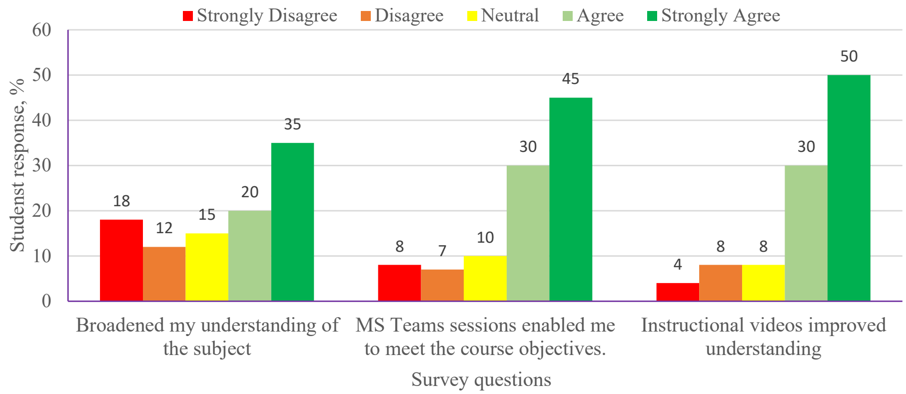

Figure 3.
Summary of responses to survey questions 6–8

DoIt@Home Lab, which is not a substitution for hands-on experience and may be associated with a lack of immersion and a slow acceptance of new teaching and learning approaches. Students proposed that future DoIt@Home Labs include more extensive videos that guide through each stage of the process, as well as more images of the lab setup at different times throughout the experiment. A student said, "[. . .] *in order to fully understand, I would have enjoyed a step-by-step, voiced video tutorial with supporting images."*

The weekly MS Teams sessions where students and instructors could discuss the experiments were found useful by the majority of students (75%) (see Figure 3). With instructors present, students benefited greatly from dedicated lab time for data analysis and discussion. Their written feedback indicated that regular MS Team meetings helped maintain a sense of normalcy and kept students motivated and on task. Most of the students (80%) stated that the instructional videos helped them understand the experiments better (see Figure 3).

Students also provided written feedback in the open-ended survey questions on integrating DoIt@Home Labs into engineering degree studies and the importance of group work and instructor's presence during the MS Team sessions.

> I think it's a fantastic idea for a pre-lab.
>
> [. . .]Once those fundamental concepts are grasped, perhaps DoIt@Home labs are the ideal choice.
>
> It was better to work with a group than to try to figure out how to do it all alone.
>
> [. . .]had reservations regarding the experiment's data and interpretation [. . .] opted for the instructor's and tutors' expertise over the internet.

Students appeared to have an overall positive view of the usefulness of the DoIt@Home Lab component of the course, and their responses further illustrated the critical role of the instructors and the tutors in the learning process as well as the benefits of working in groups.

By and large, the students' feedback on the survey indicated student satisfaction with the levels of engagement and the opportunity to demonstrate creativity and innovation whilst experimenting in the DoIt@Home Lab. The students acknowledged the positive effect of the DoIt@Home Lab approach on their learning and understanding, which was also reflected in the summative assessments. When comparing the cohort of students who completed the CHEM2000 course using the remote learning mode (75 students) to the previous year's cohort who completed the course in the traditional face-to-face mode (75 students), the average student marks in the online mode increased by 10.7%. An independent *t*-test was used to compare the two cohorts, and the results showed that there was a significant difference between the students who had attended the traditional CHEM2000 course in 2020 ($M = 60.5$, $SD = 10.6$) and the students who attended the blended learning CHEM2000 course in 2021 ($M = 71.2$, $SD = 9.68$), ($t\ (148) = -5.9$, $p = 0.001$), and this difference can be primarily attributed to the DoIt@Home Lab component in the blended delivery mode. Furthermore, the failure rate fell by 8%, while the number of students achieving a GPA of 3.25 or more increased by 18%. This is further evidence of the successful completion of the course objectives through an innovative teaching and learning approach that enabled students to demonstrate achievement of the expected learning outcomes in a new setting and in a new way.

Given the positive results of the pilot, once fully developed and further improved, the DoIt@Home Lab approach could be used as a complement to on-campus lab experiments to enable students to reinforce and master key skills and competencies throughout the delivery of a module, course or program. This would not only keep students engaged and focused throughout the course but potentially lead to increased creativity and innovation.

The feedback and findings from the DoIt@Home Lab can provide a valuable insight on how to rethink and redesign traditional on-campus lab experiences in the future. For example, the "identification of functional groups", a fundamental experimentation in any on-campus lab, was conducted as a "virtual lab" through simulation. Based on student feedback and observed performance during the DoIt@Home Lab experiments, the course team concluded that this "virtual lab" could continue to be offered virtually even during traditional on-campus delivery. Indeed, the time spent on campus conducting this elementary or basic experiment could well be dedicated to more advanced experimentation. This could ultimately lead to more effective utilization of lab resources.

Conclusion

The sudden transition to remote teaching and learning during the pandemic compelled the engineering faculty at an Omani university to think creatively when it came to how to provide continuation of learning and how best to successfully deliver the lab component of course work. As all teaching and learning moved online, the faculty response was to pilot the DoIt@Home Lab approach. This was designed to keep students engaged in course work, develop key core skills and competencies, and practice the knowledge component of the course through simulated lab work at home. Various strategies were devised ranging from recorded experiments to virtual labs and DoIt@Home Lab simulations, which were designed to complement the online learning process.

This case study successfully implemented recorded labs, virtual labs and DoIt@Home Lab experiments to support student achievement of the intended learning outcomes in one engineering course. However, in the future, additional tools and techniques should be included in the process to strengthen a blended or hybrid learning approach. Faculty need to explore more innovative and creative methods and approaches to applying the DoIt@Home Lab for higher level engineering courses. A proper segregation of the activities to be accomplished in an on-campus mode of delivery aptly supplemented by a DoIt@Home Lab can be an effective tool for enhancing student understanding. It should be noted the DoIt@Home Lab may not enable successful achievement of all intended learning outcomes at higher level courses or modules; therefore, more in-depth study is required on this. Feedback is critical to improving academic delivery and student experience, including the lab component. A systematic mechanism to record student activity and feedback on the DoIt@Home Lab is essential.

While the on-campus lab experience can never be substituted fully by virtual lab work, the effective implementation of the DoIt@Home Lab for engineering courses could definitely enhance students' learning experience and create a productive remote learning environment. Even though the DoIt@Home Lab was designed as part of an emergency response to the pandemic, it can also be considered an effective complement to the learning process during regular program delivery.

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Corresponding author
Nitin Bhaurao Raut can be contacted at: drnitinraut@gmail.com