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The Development of a Hybrid Training Module for Laboratory Practice of Engineering Courses During the Pandemic

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Abstract

The World Health Organization's announcement in May 2023 declared that COVID-19 no longer meets the criteria for a global emergency. However, the pandemic is not over and remains a global health threat, with the potential for new variants to emerge. The impact of the coronavirus on teaching and student learning has been significant. Consequently, nearly all educational institutions have begun integrating remote education technology to varying degrees in response to the COVID pandemic. In study sectors like engineering, program outcomes emphasize the importance of developing both theoretical and practical aspects. Although virtual laboratories cannot entirely replace physical experiments conducted in traditional labs, a combination of online and physical laboratories can mutually enhance academic environments. This study presents the development of a low-cost training module that provides the option of traditional onsite training kits that can be used for engineering courses such as microcontrollers, basic computer programming, and sensors, along with online simulations using Tinkercad and Proteus software. Detailed instructions in the form of lab sheets and videos are included for both versions. By utilizing this module, students can practice wiring sensors as inputs to microcontrollers and control outputs (such as motors and LEDs) using C language programming, in the lab or online. Preliminary results from the implementation of the hybrid training module indicate positive student feedback regarding the effectiveness and usefulness of the approach. Assessment trials show that both methods can be used interchangeably and will benefit students in the same way.

Keywords: Pandemic, Hybrid Learning, Training Module, Proteus, Tinkercad

Introduction

The COVID-19 pandemic has brought about significant changes to the landscape of education globally. At the beginning of the pandemic, all education models around the world collapsed (Huck et al.,2021; Zierer, 2021). Nevertheless, the practitioners in the field responded swiftly and quickly adapted to the situation. Schools and universities around the world had to transition to online teaching and learning methods to ensure continuity of education during periods of lockdown and social distancing measures. However, at that stage, the education system still lacking in trying to cover the practical component of the syllabus. This is especially true in engineering education and skill-based courses where practical work is usually conducted in labs and workshops.

The pandemic has disrupted traditional practical sessions in engineering education, limiting hands-on learning opportunities for students. Practical sessions are crucial to engineering education because they provide an opportunity for students to apply the theoretical knowledge they have acquired. By working in a practical setting, students can see how the concepts and principles they have learned are put into practice. In most of the undergraduate syllabi, practical sessions are part of assessment tools. Without physical sessions, this is not possible. In response, numerous efforts have been made to create virtual labs and make use of online platforms that can simulate the practical work (Diaz, 2021; Azlan, 2020; Jiang et al.,2021; Asgari et al., 2021; Soh, 2021; Wijenayake et al.,2021). The pandemic also prompted a revaluation of assessment methods. Traditional exams and assessments requiring physical presence were replaced or supplemented with online assessments, project-based evaluations, and alternative forms of evaluation. Educators explored creative ways to assess students' learning outcomes in a remote setting and placed a greater emphasis on continuous assessment and feedback.

After the lockdown, by stages, most of the learning systems around the world were back to physical classes. World Health Organisation (WHO) in May 2023 declared that COVID-19 no longer meets the criteria for a global emergency; however, the pandemic is not over and remains a global health threat, with the potential for new variants to emerge. In Malaysia, regulations regarding the isolation of COVID-19 patients are still being enforced. This means that infected students will miss the practical work held in labs and workshops, and the session must be rescheduled if the tutors or instructors get infected. Unfortunately, virtual labs that have been used during fully online classes cannot be used interchangeably with the physical labs' sessions because both modes were not created to offer the same learning outcome or assessment methods. Therefore, there is a need for a hybrid training module that has online and face-to-face components that can be used interchangeably yet yield the same learning experience, and functioning as an assessment tool.

Hybrid Approach

Hybrid learning is part of blended learning. In a blended learning environment, students engage in both in-person and online components as part of their learning experience (Graham, 2006). The online elements can include digital resources, multimedia materials, interactive exercises, discussion boards, and online assessments. The goal of blended learning is to leverage the advantages of both face-to-face and online learning modalities to enhance the educational experience and promote flexibility.

Hybrid learning, on the other hand, is a broader term that encompasses various instructional models combining different learning modalities, including face-to-face instruction and online learning. In a hybrid learning environment, students have the flexibility to engage in learning activities through different modes based on their needs and preferences. This can involve a combination of in-person classroom sessions, virtual classes, online discussions, collaborative projects, and independent study. Hybrid learning often provides more flexibility in terms of time and location compared to traditional classroom-only approaches.

Although has been in existence for some time now; after the pandemic, the idea of "hybrid courses" has gained popularity and appears to have offered up many alternatives for organizing courses in a variety of activities both on campus and remotely. Many institutions decided to continue the online component of the learning along with the physical session or use it as an alternative. They claimed that the decision resulted in a more effective and better environment for teaching and learning sessions (Triyason et al., 2020; Haningsih & Rohmi, 2022; Kose et al., 2022). One of the reasons is that students and educators have become accustomed to and comfortable with online learning (Kerres & Buchner, 2022). In the case of engineering education, hybrid learning ensures the continuity of practical components, even during challenging circumstances like the pandemic. By incorporating virtual platforms and online resources, practical tasks can still be completed remotely, enabling students to continue their learning journey and progress in their studies without interruption. Hybrid learning also offers flexibility in scheduling practical tasks. This flexibility accommodates various schedules, reduces time conflicts, and provides opportunities for students to balance their academic workload effectively.

1 Hybrid Training Module for Biomedical Sensor and Transducer Course

The developed hybrid module consists of several elements: a traditional training kit, an online circuit simulator using the online platform Tinkercad, circuit interfacing and programming using Proteus (mimicry of the traditional training kit) and instructional videos. There are various possibilities for types of electronics and computer lab work that can be created using this module. However, for the validation purpose of the training module, we created five labs for an undergraduate course: Biomedical Sensors and Transducers. The course introduces students to the basic understanding of the operation and principles of electronic sensor elements used in biomedical measurements. This module covers fundamental knowledge which includes the operating principle, types, parameters, signal conditioning and application of those sensors. The sensors are resistive, capacitive sensors, inductive sensors, electromagnetic sensors, electrochemical sensors, optical sensors, intelligent sensors, and biosensors. Practical works are part of the assessment of this course.

1.1 Low-cost physical training kit

The low-cost training kit developed is specifically tailored to introduce learners to microcontroller circuit wiring and programming, basic types of sensors as inputs and common microcontroller outputs. The kit includes five sensor modules, a microcontroller or development board, outputs in the form of LED / LCD and supporting components such as resistors and jumper wires. Students will be guided through exercises that involve interfacing the sensors with the microcontroller and writing a computer program to perform tasks such as temperature sensing, pressure detection, object detection, colour sense and others. Additionally, students will learn how to calibrate and optimize the performance of the sensors. Figure 1 shows the layout of the training kit. For the course of Biomedical Sensors and Transducers, we created five labs according to the types of sensors; Lab 1: Resistive Sensor, Lab 2: Optical Sensor, Lab 3: Electrochemical Sensor and Lab 4: Capacitive and Inductive Sensor and Lab 5: Biosensor. Each lab is supported with a complete lab sheet accessible physically or in the form of a flipbook.

1.2 Online circuit simulator

Tinkercad's online platform allows students to access the circuit simulator from anywhere with an internet connection, eliminating the need for physical equipment or dedicated laboratory spaces. This accessibility enables students to engage in hands-on circuit design and analysis exercises at their convenience, promoting self-paced learning and accommodating diverse schedules. It also provides a visual representation of the sensors' circuits, allowing students to observe the behaviour of sensors as inputs and the response of the outputs. The simulator provides error-free experiments, wherein in a physical laboratory, mistakes during circuit construction can lead to incorrect results or even damage to equipment. With the simulator, students can experiment freely without the fear of damaging components or making irreparable errors.

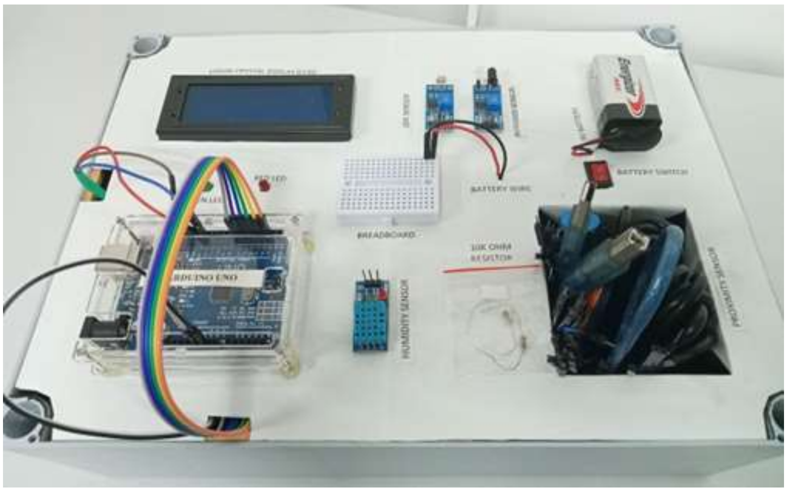

Fig. 1. Layout of the low-cost physical training kit.

The simulator also offers immediate feedback on circuit behaviour, allowing students to identify and understand the impact of changes in component values, circuit topology, or signal input. This real-time feedback promotes a dynamic learning process, as students can observe the consequences of their design choices and adjust accordingly. The usage of Tinkercad as a virtual lab has been proven as the best alternative for electronic circuit and microcontroller programming training (Mohapatra et. al, 2020; Shalannanda, 2020; Juanda & Khairullah, 2021). There is a Tinkercad simulator for each of the physical labs created using the training kit. Figure 2 shows the interface of the Tinkercad simulator of Lab 1: Resistive Sensor.

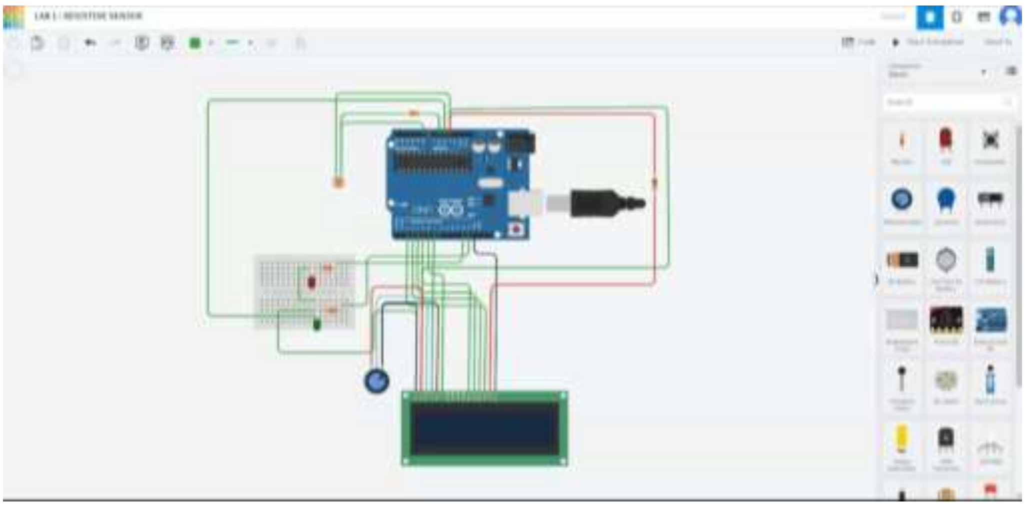

Fig. 2. Tinkercad simulation of Lab 1: Resistive Sensor

Online Circuit Interfacing and Programming

Students also have access to Proteus files that are pre-filled with components the same as the traditional training kit. Every file is the mimicry of the physical training kit labs. Proteus enables students to access the virtual laboratory from anywhere with an internet connection, offering flexibility and convenience. This accessibility promotes self-paced learning, allowing students to engage with the sensor applications at their own pace and revisit experiments as needed, reinforcing their understanding using Proteus software. Proteus software has been used widely for teaching and learning of microcontroller systems and other electronic courses for many years now and the online platform has proven to be very useful during the pandemic. In this training module, using the Proteus files, students have to do the wiring and write the codes exactly as in a face-to-face session (see Figure 3). The online session also acts as an assessment instrument in place of practical sessions using the physical training kit.

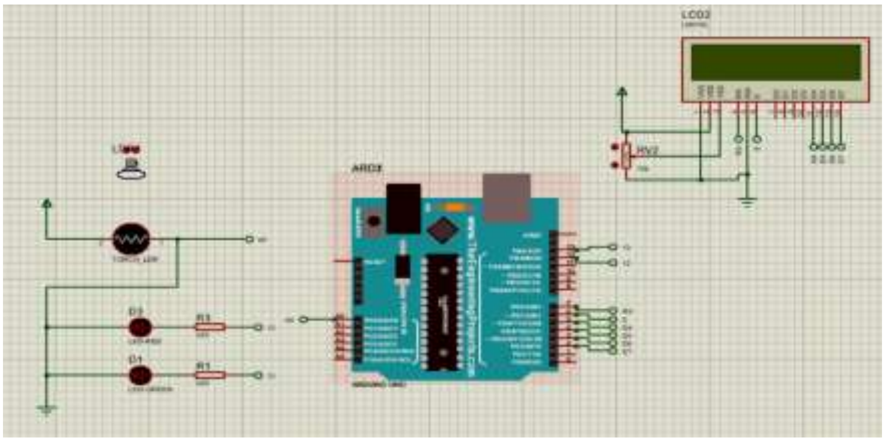

Fig. 3. Proteus online platform for training in sensor wiring and microcontroller programming

Instructional videos

The module provides instructional videos of both experiments using a traditional training kit and Proteus environment. The instructional videos provide a visual demonstration of laboratory procedures, allowing students to observe the correct techniques and steps involved in conducting experiments. By watching the videos, students can better understand the setup, equipment usage, and the sequence of actions required to perform the experiments accurately. Incorporating instructional videos into the hybrid laboratory training provides comprehensive and accessible learning experiences. The instructional videos enhance students' understanding, engagement, and performance in laboratory sessions, contributing to a more effective and enriching hybrid learning environment. Figure 4 shows a snippet of instructional videos to be watched before the physical training kit session for Lab 2: Optical Sensor.

Fig. 4. Instructional video for physical training kit.

Results and Discussion

A training module is not only an educational tool, it is also an assessment tool. Apart from the student's learning experience, before the hybrid training module can be used formally in class; we have to make sure it is a valid assessment tool. This hybrid module was developed with the intention of ensuring the continuity of practical work of the course amidst the pandemic that may hinder the face-to-face sessions. Therefore, it is crucial to confirm that both the physical training kit and the online version can be used interchangeably and will provide the same benefits to learners. A group of undergraduate students from the Biomedical Engineering Course in Politeknik Sultan Salahuddin Abdul Aziz Shah, Shah Alam, Selangor was divided into two groups of 14 students each. Group A was given access to paper lab sheets, an online simulator beforehand and a demonstration by the instructor in class. Students then used the physical training kit to make the connections, write the codes and summarise the results. The session went on for 2 hours. Group B was given access to the flipbook of lab sheets, an online simulator beforehand and instructional videos. Students then used the Proteus platform to do the wiring, write the codes, simulate the circuit and summarise the results

Both groups have to write a lab report after the session. Assessment of the lab results summary and lab reports of students from both groups was done using the same rubric. The marks were given for the results summary, answers to questions in the lab sheets, and the lab report prepared. A simple statistical significance test, a two-tail T-test was done to compare the marks given for Groups A and B (results in Figure 5). The results show that there was no significant difference in the means of the data between the two groups. This means that students gain at-par learning experience and knowledge using physical or online lab sessions. It proves that both modes can be used interchangeably and validated as fair assessment tools. A short survey was distributed to all 28 students using Google Forms to assess their feedback on the learning experience of using the training module. The results of the survey indicate that students reported high satisfaction with the virtual simulations, finding them immersive and effective in reinforcing theoretical concepts. Remote experimentation provided a valuable opportunity for hands-on practice and fostered collaboration between students and instructors despite physical distance. However, challenges related to limited access to equipment and potential technical issues were acknowledged and addressed through clear communication and technical support.

t-Test: Paired Two Sample for Means		
	Group A	*Group B*
Mean	85.38571429	82.18571429
Variance	15.07362637	39.06747253
Observations	14	14
Pearson Correlation	-0.297975921	
Hypothesized Mean Difference	0	
df	13	
t Stat	1.445580226	
P(T<=t) one-tail	0.085984329	
t Critical one-tail	1.770933396	
P(T<=t) two-tail	**0.171969**	
t Critical two-tail	2.160368656	

Fig. 5. Results of the significance test.

Conclusion

In conclusion, the hybrid training module developed offers a flexible and accessible solution to maintain the practical component of the Biomedical Sensors and Transducers course during the pandemic, ensuring that students can continue their learning journey without compromising their safety. Preliminary results from the implementation of the hybrid training module indicate positive student feedback regarding the effectiveness and usefulness of the approach. Students reported improved conceptual understanding, enhanced practical skills, and increased confidence in working with biomedical sensors and transducers. Assessment results show that both methods can be used interchangeably and will benefit students in the same way.

This research contributes to the ongoing efforts to adapt laboratory-based education to unprecedented circumstances. Future work will focus on further improving the module based on student feedback and exploring its applicability to other laboratory-intensive courses in the biomedical engineering curriculum during and beyond the pandemic.

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