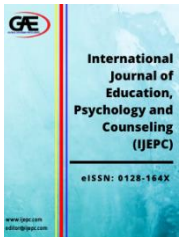
International Journal of Education, Psychology and Counseling
IJEPC
EISSN : 0128-164X
Volume 6 Issue 42 (September 2021) PP. 145-154
DOI 10.35631/IJEPC.642012



INTERNATIONAL JOURNAL OF EDUCATION, PSYCHOLOGY AND COUNSELLING (IJEPC)
www.ijepc.com

A SCOPE REVIEW ON THE IMPLEMENTATION OF REMOTE TEACHING FOR ENGINEERING LABORATORY COURSES DURING THE PANDEMIC COVID-19

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Article Info:

Article history:
Received date: 06.07.2021
Revised date: 30.07.2021
Accepted date: 04.08.2021
Published date: 05.09.2021

To cite this document:

Tukiar, M. A., & Kassim, N. F. (2021). A Scope Review on the Implementation of Remote Teaching for Engineering Laboratory Courses During the Pandemic COVID-19. *International Journal of Education, Psychology and Counselling*, *6* (42), 145-154.

DOI: 10.35631/IJEPC.642012.

Abstract:

This article aims to carry out a scoping review of the implementation of remote teaching for engineering laboratory courses in higher learning institutions during the pandemic COVID-19. Outcome-Based Education (OBE) implementation has required the graduate to attain a minimum of twelve skills and attributes upon graduating from the engineering program; it includes the psychomotor skill involved in laboratory courses. The finding shows that it has various implementations in conducting laboratory courses during the pandemic. The implementation includes recording a video, conducting an online simulation to replace the experimental work, and transforming face-to-face activity into a virtual lecture, modelling, and simulation. The approach for the laboratory that uses software also has recorded videos, using open-source software similar to the software listed in the syllabus, and some institutions allow students to access the computers lab remotely. There are no physical experimental works carried out in the laboratory during the pandemic due to non-access to the lab. Students then are expected to learn from the video to grasp the knowledge and concept. This 'scope review' also found that they have not discussed the suitable assessment in evaluating the psychomotor skill during the pandemic. Therefore, this paper recommends conducting a study to determine the implementation of a laboratory course and investigate the effectiveness of the assessment conduct during the pandemic COVID-19 to obtain the course learning outcome and evaluate its psychomotor skill.

Keywords:

Scope Review, Remote Teaching, Laboratory Courses, Outcome-Based Education

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Introduction

Outcomes-Based Education (OBE) has been widely implemented in a higher learning institution, including for engineering programs, and to be recognized as an accredited engineering program, a broad implementation of OBE is compulsory. The Engineering Accreditation Council (EAC) is responsible for evaluating the OBE implementation for engineering courses in higher learning institutions in Malaysia. The OBE implementation has required the graduate to attain a minimum of twelve skills and attributes upon graduating from the engineering program (Engineering Accreditation Council (EAC), 2020). The twelve skills and attributes listed in Engineering Program Accreditation Standard 2020 as shown in Table 1.

The cognitive domain assesses engineering knowledge, problem analysis, design, development of solutions, and investigation skills and attributes. The curriculum design for the cognitive domain is to develop the students' mental skills and knowledge (Malaysian Qualifications Agency (MQA), 2014). In comparison, the affective domain assesses the ethic, teamwork, communication, management and life-long learning skills and attributes. The curriculum design for the affective domain is to exhibit the students' feelings, emotions, and attitudes (MQA, 2014). Then, the psychomotor domain assesses the students' ability to operate for the modern tool and the curriculum design for the psychomotor domain to enable the students to utilize motor skills and coordinate them (MQA, 2014).

Table 1: Skills and Attribute excerpt from Engineering Program Accreditation Standard 2020

Skills and Attribute	Domain
Engineering Knowledge	Cognitive
Problem Analysis	Cognitive
Design/Development of Solutions	Cognitive
Investigation	Cognitive
Modern Tool Usage	Psychomotor
The Engineer and Society	Affective
Environment and Sustainability	Affective
Ethics	Affective
Individual and Teamwork	Affective
Communication	Affective
Project Management and Finance	Affective
Lifelong Learning	Affective

In the engineering program, the laboratory courses use to assess the student's psychomotor skill. For example, in a structural engineering laboratory course, the student needs to conduct experimental work in the heavy structure laboratory. The activities including casting for the structural elements such as a beam and testing the casted beam to determine the structural strength and the mechanical properties. During the process, the students must present their ability to conduct the experiments, and they will be assessed for the psychomotor skill through the Practical Test.

Malaysia has discovered the first case of COVID-19 on 25th January 2020 and followed by the first fatal case on 17th March 2020 (Shah et al., 2020). With the increasing number of people infected with the virus, the Government of Malaysia enforced a Movement Control Order (MCO) on 18th March 2020 to break the chain of COVID-19. The enforcement of MCO has

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affected all educational institutions, including schools and higher learning institutions. All the academic premises are closed due to MCO. Activities of teaching and learning are not allowed to be conducted face-to-face (Shah et al., 2020). This enforcement includes laboratory courses that primarily assess psychomotor skill. The courses that assess cognitive and affective skills are not significantly impacted since they have an alternative for online teaching, and the learning activities can be conducted effectively using web 2.0 tools. The assessment also can be conduct online without compromising the quality, validity, and reliability of the assessment. In contrast, the courses that assess psychomotor skills significantly impact teaching, learning activities, and assessment. With the enforcement of MCO, the students are not allowed to enter the laboratory to conduct experimental work; hence, the assessment to assess students' psychomotor ability cannot be done. This article aims to review remote teaching for engineering laboratory courses during the pandemic COVID-19 in the other higher learning institution. The review will lead by the following research question:

How does the implementation of engineering laboratory courses in other higher learning institution during the pandemic COVID-19?

The implementation in the question is including the teaching method, learning activities and assessment.

Methodology

Accordance to Munn et al. (2018), the purpose of conducting scope review is including to identify the available evidence in each area, to identify and analyze of knowledge gaps and as a precursor to the systematic review. Hence, in selecting of the article to review, the systematic approach is adopted to ensure the article reviewed is focusing on the research question and confirmed the quality of the article. This review focuses on the implementation of remote teaching for engineering laboratory courses during pandemic COVID-19. Article journal selected from the Scopus, ScienceDirect and Web of Science (WoS) database. The Scopus and WoS database chose because it has the most extensive abstract and citation database consisting of diverse subject areas and documents such as journals, books, and conference proceedings. ScienceDirect database chose because it has full-text articles from journals and books, primarily published by Elsevier. Most importantly, these three databases chose because it provides a quality article to use in this review. The review process conducted as per below:

Identification

The first phase in the review process is identification. The process involved keywords identification for information searching purposes. The keyword used in searching for the documents in databases also referred to the thesaurus to find the word with similar meaning to enrich its finding. The keyword use in advance searching for article in Scopus database are ***Article Title-Abstract-Keyword (("Remote" OR "Online" OR "Distant") AND ("Laboratory" OR "Practical") AND ("Engineering") AND ("COVID"))***. This process yielded a result of 39 documents. The same keyword applied in searching for the Web of Science database document and the process yield for 18 documents. For the ScienceDirect database, the keyword used in advance searching the documents is ***"online" "remote" "distant" "laboratory" "engineering" "covid"*** and its yield for 26 documents.

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Screening

Screening is a process to include or exclude articles according to the selected criteria with the database's assistance. In the screening process, for Scopus database's criteria limited to ***Document type: Article, Source Type: Journal and publication year: 2020 – 2021*** and resulted in 18 documents. For the ScienceDirect database, the criteria limited to ***Article types: Research Article, Review Article, and publication year: 2020 – 2021*** and resulted in 13 documents. For Web of Science, the criteria are limited to ***Document Type: Article, and publication year: 2020-2021*** and it is resulted in 12 documents. The total numbers of documents from three databases after limiting the searching criteria are n=43. The process continues with merging the findings to exclude redundant articles from the three databases. The process has left 33 numbers of articles.

Eligibility

Eligibility is a process to excludes the articles manually according to the specific criteria set by the author. The articles are thoroughly reviewed from the abstract, and those are not meet; the criteria excluded. In this review, the selected article's criteria must directly discuss related to remote teaching for engineering laboratory courses during the pandemic Covid-19. After reading through the 33 articles abstract, it is found out that 11 numbers of the article have fulfilled the criteria.

Data Abstraction and Analysis

The remaining articles were evaluated, reviewed, and analyzed after the eligibility process; the results discussed in detail in this article—the reviews based on specific subjects that matched the research question. Table 2 shows the list of articles selected after the eligibility process.

Table 2: Details of Selected Article from Eligibility Process

Article Title, Author/s, Publication Year	Journal Name	Journal Quartile
A guide to student-active online learning in engineering. (Kyrkjebø, 2020).	Modeling, Identification and Control	Q3
A student primer on how to thrive in engineering education during and beyond COVID-19. (Qadir & Al-Fuqaha, 2020).	Education Sciences	Q2
COVID-19 outbreak: Insights about teaching tasks in a chemical engineering laboratory. (Nogales-Delgado et al., 2020).	Education Sciences	Q2
Delivering remote food engineering labs in COVID-19 time. (Debacq et al., 2021).	Education for Chemical Engineers	Q1
Designing a Hybrid Biopharmaceutical Laboratory Course to Enhance Content Flexibility and Access. (Peng et al., 2020).	Journal of Chemical Education	Q1
Remote knowledge acquisition and assessment during the covid-19 pandemic. (Jacques et al., 2020).	International Journal of Engineering Pedagogy	Q2
Remote practical in the time of coronavirus, a multidisciplinary approach. (Bangert et al., 2020).	International Journal of Mechanical Engineering Education	Q2

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Remote teaching of building information modelling during the COVID-19 pandemic: A case study. (Boton, 2020).	Sustainability	Q1
The Impact of COVID-19 on the Academic Plans and Career Intentions of Future STEM Professionals. (Forakis et al., 2020).	Journal of Chemical Education	Q1
The impact of the COVID-19 pandemic in 2020 on the quality of STEM higher education. (Pintarič et al., 2020).	Chemical Engineering Transaction	Q3
Virtual Laboratory: A Boon to the Mechanical Engineering Education During Covid-19 Pandemic. (Kapilan et al., 2020).	Higher Education for the Future	Q4

Note. The information on journal quartile referred to Scopus CiteScore.

Findings

This part will list the finding from the selected articles related to the implementation of remote teaching for engineering laboratory courses during the pandemic COVID-19. The finding is to answer the following research question: How does the implementation of engineering laboratory courses in other institutions?

The selected articles show two different types of laboratories conducted in engineering courses; the laboratory involved with the software used to carry out the simulation, and the laboratory involved with experimental work that uses machinery and tools. Each article has reported a different approach to conduct laboratory activities during the pandemic.

Implementation of Laboratory Involved with Usage of The Software

Kyrkjebø (2020) has proposed a guideline using a previous researcher model to design active online learning courses. In this case, the mobile robotic course is taken as an example. The course uses online simulation as part of laboratory activities. The guideline does not state any method in conducting experimental work using tools in the laboratory to replace the face-to-face activities except that the student must do the practical experiment in the physical lab. Some of the researchers are also in line with Kyrkjebø (2020). Ma and Nickerson (2006), Balamuralithara and Woods (2009), Jong et al. (2013) and Potkonjaket al. (2016), as stated in Qadir and Fuqaha (2020), has also promoted online simulation for laboratory activities in computer education courses.

Other courses that involved simulation also providing similar solutions in conducting laboratory activities. Jacques et al. (2020) has outlined the implementation of four electronic and electrical engineering courses, including two courses that required tools and apparatus in the laboratory, which are Numerical Analysis and Project. For the course Numerical Analysis, Jacques et al. (2020) mentioned that the students had used open-source software as an alternative for the MATLAB software application and the Project part, the students are limited to carrying out the functional analysis for the teacher's electronic audio system and provided task organization using the Gantt chart. During the pandemic, no experimental works were carried out due to non-access to the lab, and there are no alternative activities to replace the practical work stated in the article.

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Boton (2020) has written the implementation of a program using Building Information Modeling (BIM) in the École de Technologie Supérieure, Canada. The program balance theoretical and practical learning and most activities carried out in the computer laboratory. Three software utilized in the program; Autodesk Revit, Tekla Structural and Navisworks Manage software. In completing the program during the pandemic, the author mentions 30 videos related to the software produced and given to students. Then another eight videos were produced by filming the teacher explaining the courses' theoretical concept. The author adds that the software can be installed on students' personal computers as the software provided an educational license. Alternatively, the institution also allows students to access the computers lab remotely.

Implementation of Remote Teaching for Laboratory Works Involved with Machinery and Tools

All the conducted activities above for the laboratory involved software for simulation. For the laboratory that involves tools and machinery in conducting experimental work, the different approaches are applied. Bangert et al. (2020) has outlined the implementation of Multidisciplinary Engineering Education in laboratory works. The authors mentioned, they have recorded a laboratory experience and put all the videos, quizzes, and data on online platforms to engage students during the pandemic for the laboratory courses. They believe that this is an effective way for students to interact with actual data and equipment that they cannot access in the lab during the pandemic. They implemented a simulation for robotics courses by using an open-source robots' simulator, Webots. Using the Webots, the authors mentioned that students can still learn to develop the same core robot's behaviour and, in parallel, fulfil the learning outcomes.

The other institution applied a similar approach. Forakis et al. (2020) has shared the chemical laboratory's implementation during the pandemic. The authors have mentioned that graduate teaching assistants provided a video of conducting lab activities, including collecting the data method to students. Students later will produce a weekly laboratory report that includes an analysis and conclusion based on the given data in the video. Pintarič and Kravanja (2020) also had outlined the implementation of laboratory courses for chemical engineering at the University of Maribor. Like Forakis et al. (2020), the technician and lecturers record the experimental work and then disseminate the recorded video to the students. However, in the mid of May 2020, when students are allowed to enter back to the campus, they have physically performed their missing lab in one day to minimize the number of students in the lab due to campus restriction.

Nogales-Delgado et al. (2020), from the University of Extremadura, Spain, also has outlined the chemical engineering laboratory's implementation during the pandemic COVID-19. The assessment, either theoretical or practical, is conducted through online assessment using the virtual campus. However, the final degree project involving lab activities is compulsory to be done in the laboratory. There are no alternative methods to replace the lab's compulsory activities except to increase the working pace to complete the experiment as many as they can within the time. The authors also stated that some students had not completed their work due to time constraints during the pandemic.

Debacq et al. (2021) has outlined the experience in implementing remote teaching for food engineering laboratory for Master students during the pandemic at AgroParis Tech. The

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laboratory's implementation consists of four main activities: Theoretical courses, practical work, report writing, and the final oral exam. The authors mentioned that they had replaced hands-on activities (theoretical courses and practical works) with the various types of virtual tours of equipment, including explaining the detailed description and operation. They also provide the previous data related to the equipment. The authors also mentioned that they had conducted the assessment, individual quizzes, online oral exams, and individual and group reports. The authors also reported that they evaluated the implemented system's effectiveness—the evaluation was conducted through an anonymous survey, observation, and student's performance.

Despite recording experimental work, some institutions transform face-to-face activities into various teaching and learning activities such as modelling, simulation, and virtual lectures to improve students' learning experience. Peng et al. (2020) has outlined the implementation of virtual mode for the Hybrid Biopharmaceutical Laboratory courses at Columbia University during the pandemic. The lab that applies for chemical engineering knowledge comprises theoretical and practical activities, including crystallization, chromatography, and mass transport, requiring an apparatus in the lab. The authors mentioned that they have eventually transformed the face-to-face lab course into a virtual mode during the pandemic. The transformation occurred by introducing various additional elements such as modelling, simulation, and virtual lectures to improve students' learning experience, exposing them to more advanced knowledge. The authors also reported that the assessment conducted through quizzes and lab reports shows the student achievement has remained consistent.

Like Peng et al. (2020), Kapilan et al. (2020) has outlined the implementation of a virtual laboratory for fluid mechanics in Mechanical Engineering. In the virtual laboratory implementation, the student conducting a simulation-based virtual experiment to obtain the result. The simulation conducted was based on the mathematical modelling equation. The lecturers also conducted the actual experiment, and the result from the actual experiment and the student's simulation results were compared and discussed. The students can repeatedly use the experiment until they grasp the concept and the procedure.

Discussion

This part will discuss the findings. The findings found various approaches in conducting the laboratory courses during the pandemic, including recording a video to show the procedure and process to carry out experimental work, conduct an online simulation to replace the experimental work, and transform face-to-face activity into a virtual lecture, modelling, and simulation. The approach for the laboratory that uses software also has recorded videos related to the software produced; some of the plans are using open-source software similar to the software listed in the syllabus, and some institutions allow students to access the computers lab remotely. The listed finding showed all the approaches taken by the other institution to conduct the laboratory courses.

In one of the studies related to the recording video as a material for online teaching, Wang, Antonenko and Dawson (2020) have conducted a study to determine the effect of the instructor present in online video. The study found that the instructor's presence in the online video does not affect the retention of learners, but it can improve learners' performance and outperformed learners who watch an online video without an instructor. The finding stated by Wang et al. (2020) is in line with Kizilcec, Papadopoulos and Sritanyaratana (2014); the instructor's

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EISSN : 0128-164X
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presence did not affect the retention of learners. Wang et al. (2020) also determine the relationship between visual attention behaviour and learner's perception. Wang et al. (2020) stated that the presence of the instructor in the online video had attracted a high level of visual attention, and the finding is similar to the finding from van Wermeskerken, Ravensbergen, and van Gog (2018) and Kizilcec, Bailenson, and Gomez (2015). Many studies show the positive impact on learners to support recording a video to replace face-to-face laboratory activities during the pandemic. Hence it is no doubt that video record can be adopted as a teaching method for laboratory courses during the pandemic.

However, other than teaching methods and learning activities, the curriculum also includes the assessment. In OBE implementation, the assessment is one of the crucial parts. The assessment design must be valid, reliable, and aligned to the course learning outcomes. For the engineering laboratory courses, one of the assessments is to measure the student's psychomotor skills. Before the pandemic COVID-19, the psychomotor skill was evaluated through face-to-face observation in laboratory activities and the Practical Test. However, with MCO enforcement, students are not allowed to enter the laboratory to conduct experimental activities. Hence the assessment of students is impacted and must be redesigned to ensure that it is equivalent to the assessment conducted before the pandemic. Not many articles were found to discuss the suitable assessment in evaluating the psychomotor skill during the pandemic. Hence, it is suggested to conduct a study examining the implementation of laboratory courses and determine the effectiveness of the assessment strategy during the pandemic COVID-19 to achieve the course learning outcome and evaluate students' psychomotor skills.

Conclusion

This article was written to review the implementation of engineering laboratory courses during the pandemic COVID-19. In this review, the research question was "How does the implementation of engineering laboratory courses in other higher learning institution during the pandemic COVID-19?". After selecting the article using a systematic approach, there are various approaches in conducting the laboratory courses during the pandemic, including recording a video, conducting an online simulation to replace the experimental work, and transforming face-to-face activity into a virtual lecture, modelling, and simulation. The approach for the laboratory that uses software also has recorded videos, using open-source software similar to the software listed in the syllabus, and some institutions allow students to access the computers lab remotely. From the current and previous study, it can be concluded that the video record can be adopted for the teaching method for laboratory course during the pandemic. However, in the current and previous study, they have not discussed the suitable assessment in evaluating the psychomotor skill during the pandemic. Hence, it is suggested to conduct a study looking into the implementation of laboratory course and investigate the effectiveness of the assessment conduct during the pandemic COVID-19 to achieve the course learning outcome and evaluate its psychomotor skill.

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