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Enhancing Student Engagement through Scaffolding Strategy in Active Learning Environment

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ABSTRACT

This paper introduces the implementation of various interactive activities in an active learning environment using the scaffolding strategy, which aims to enhance student engagement in Engineering Mathematics and Statistics course, offered to second year Electrical and Electronic Engineering students. Over the years, students have been struggling to master solving complex engineering problems in the curriculum. The paper suggests that various interactive activities in which course lecturer assumes specific roles, through scaffolding strategy, can enhance students' ability to acquire skills to analyse fundamental theorems related to probability and information theory, and probability and statistical method for engineering problems. This approach involves lecturer assuming specific role in the designed activities using the scaffolding strategy. This paper explores how this approach can be customized to suit the learning needs in both learning modes; face-to-face (pre-pandemic) and online learning (during pandemic). Data collected was based on students' performance and course feedback survey. Improved student performance was observed using this scaffolding strategy, which can also be implemented in both in-person and online teaching.

1. Introduction

Engineering Mathematics and Statistics is a course offered to second year Electrical and Electronic Engineering students, in which they learn probability concepts, elements of information theory, statistical models and methods. While most of the programme courses consist of theoretical and practical (such as lab) component, this course comprises tests and written assignments. Lacking the lab or other hands-on task like other typical engineering courses does pose a persistent need to enhance the student engagement for the course, since student engagement serves as a crucial component of construct in terms of student achievement and quality of educational programme [1-3].

Students are to acquire the ability to develop critical thinking through the analytical reasoning when solving questions in this course, which serves as a foundation when they progress to their third-year study in individual or group projects that are hands-on in solving 'real life' challenges. One

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observation obtained from previous results showed that students were struggling to grasp the mastery of solving complex engineering problems in the curriculum. In alignment with the university teaching philosophy of 'learning by doing,' various interactive activities are introduced in this course to promote student-centered active learning environment through scaffolding strategy [4].

Scaffolding can be defined as 'instructional devices that enable students to complete tasks they would be unable to master without assistance [5]. Scaffolding is a means of providing students with guidance or instructions in the beginning of the learning itself, after which students are gradually given more responsibilities to develop their understanding in the topics. Vygotsky [4] has contributed significantly to the scaffolding construct, who suggested that learning of materials require a certain degree of development through the mediation by others who are ahead in their own development [6]. It was suggested that one actually learns through a process of digesting the information based on interaction with others who had already previously grasped the learning. This kind of support enables the students to eventually demonstrate the learning successfully. The course lecturer's role here is to provide the learning support through 'scaffolding' in terms of interactive activities implemented within each topic of the course.

While the scaffolding (incorporated in the activities designed for the course) is aimed at developing mastery of solving complex engineering problems, the approach in which these activities are designed is also factored in. As Vygotsky also considered social interaction to be a central part of all human learning, the designed activities involve interaction among the course lecturers and students in the process of enabling effective learning [6]. Engaging in the interaction will encourage the learners to gradually take the ownership of knowledge through the support given by the course lecturer, therefore the requirement for learning to happen also relies on the course lecturer's role in providing the appropriate level of development that can allow students to leap from mastery of one topic to the other. For instance, course lecturer may implement coaching and prompting, dialogue with students and discussion, based on the role of the course lecturer in the learning activities [5]. This can be incorporated in both face-to-face classroom setting and online learning.

Inspired by Beichner *et al.,* [7], this paper introduces a mechanism that incorporates interactive activities using scaffolding strategy. Each activity caters to specific role assumed by the course lecturer. This paper aims to analyse the effectiveness of the scaffolding strategy on enhancing student engagement, measured by students' performance and course survey feedback, in both face-to-face and online delivery. This paper explores how the approach was first implemented during pre-pandemic when face-to-face classes were allowed, and subsequently the customisation of the flow of designed activities to meet the learning needs during the pandemic via online learning.

1.1 Research Questions

The research aims to analyse the effectiveness of the scaffolding strategy on students' performance in both face-to-face and online delivery, with the following research question:

"What is impact of the scaffolding strategy on students' performance in face-to-face and online delivery?".

1.2 Research Objective

The research aims to analyse the effectiveness of the scaffolding strategy on students' performance in both face-to-face and online delivery.

2. Methodology

Figure 1 illustrates the research methodology employed in introducing scaffolding in the course for the September 2019 student cohort. The design model is based on three questions, namely 'where are we going? (learner and task analysis), how will we get there (instructional strategy and medium), and how will we know we have arrived (assessment and evaluation)' as proposed by Smith and Ragan [8]. The learner and task analysis phase involved course lecturer designing the lesson plan to incorporate the scaffolding strategy, with the objective that students should be able to meet the learning outcome of the topic, which will be measured by the students' ability to solve questions given, as mentioned in Dick *et al.,* [9]. In the instructional strategy and medium, course lecturer determined the best way to teach the topics, alongside the most appropriate media to be used [10,11]. In the last phase, the course lecturer evaluated the students' assessments, after which the continuous quality improvement (CQI) action was suggested, which highlighted the changes that needed to be done to improve the course teaching for the next cohort [12].

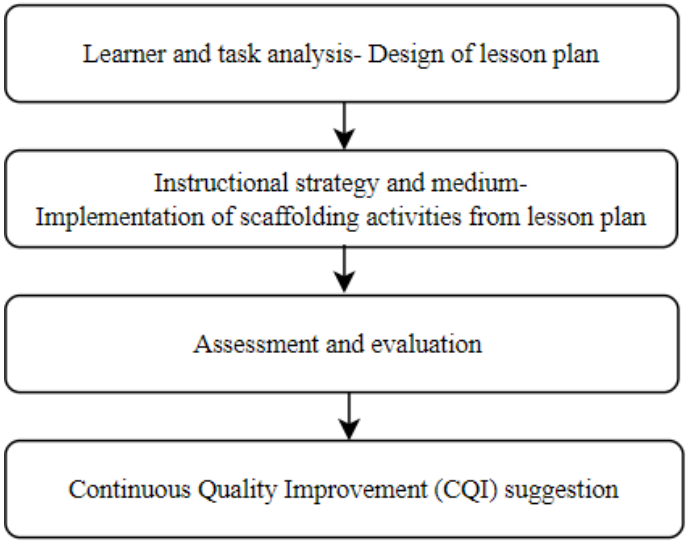

Fig. 1. Implementation of scaffolding strategy

Further details on the instructional strategy and medium are explained in the next section, in terms of the changes incorporated to cater to both face-to-face and online delivery.

2.1 Face-to-Face Delivery

In terms of the 'Implementation of scaffolding activities from the lesson plan' (second item from Figure 1), every topic within the course incorporated the same structure. As mentioned earlier, interaction sets as the core of the learning, in which each activity would involve course lecturer assuming a specific role to facilitate learning. This can be detailed out as illustrated in Figure 2.

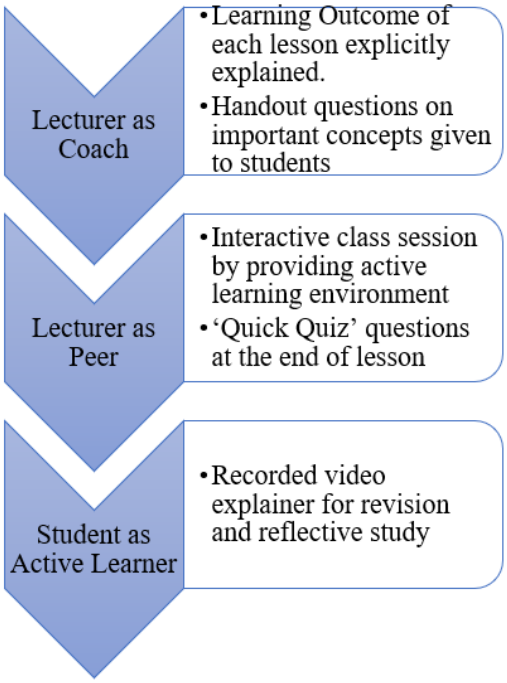

Fig. 2. Implementation of scaffolding activities from the lesson plan: Role of lecturer and students in September 2019 cohort

Key strategies include the lecturer assuming the role as a Coach in the beginning of the lesson; to explicitly explain the intended learning outcome of the lecture to students. As compared to traditional passive teaching, which usually involves course lecturer transferring the knowledge to students and students taking notes without actively engaging with them, handout questions on important concepts are given to the students, to encourage notetaking as the class progresses [13,14]. The handout questions are designed as 'fill in the blanks' and students complete them by providing the phrase, sentence, diagram or paragraph. In the next stage, as a Peer, lecturer creates a safe space for students to ask questions regarding the topic learnt, after which the questions will be then discussed amongst students without the lecturer disclosing any answer. Questions posed to lecturer are always redirected to the students or peers, as part of encouraging collaboration amongst students in the active learning environment. Students are held accountable for each other's learning and get the opportunity to grow their confidence through the discussion. It is observed that the handout questions also probe more meaningful discussion, as this activity requires that students participate in class, compared to conventional one-way communication or teaching. As scaffolding can also be complimented with the support of information and communication technology (ICT), students get the opportunity to answer quick online quiz at the end of the session [15]. These are usually multiple-choice questions through Kahoot platform, in which students are given 20 seconds to select their answers. After each question, the correct answer will be provided. The questions are also designed to reflect the learning outcomes of the topic. Post-class activity involves student as the Active Learner as they are given short videos explainer to reinforce their learning through self-revision. The short videos are of 10-minute duration, which highlights the key concepts of each topic. Compared to the conventional way of revision, where students go through the lecture notes, reference books or free online videos, these supplementary videos are catered specifically to the topics covered, serving as bite-sized learning or resource.

2.2 Online Delivery

As the COVID-19 pandemic has impacted the education sector, the September 2020 cohort experienced the entire course via online delivery. One should also note that the absence of face-to-face contact also brings along some challenges, one of which is the lack of avenue to observe students' facial expression when delivering the materials in class and respond accordingly to enable students grasp the concept within the topic. Fortunately, the concept of scaffolding has become diverse as technology extends learning beyond a classroom setting [16-19].

One of the advantages of the existing strategies prior to the pandemic was the incorporation of ICT as part of the learning technologies, therefore the changes made to cater to online delivery was more dependent on how the course lecturer could establish active learning environment through providing the support (scaffolding) for students in virtual collaborative setting.

Thus, the course lecturer decided to utilise the 'extensive feedback from instructor and peers' in the interaction during the online sessions [20]. To achieve this, the flow of the designed activities was customised as such that the last component of the mechanism in Figure 2 was placed at the beginning instead, as shown in Figure 3 below.

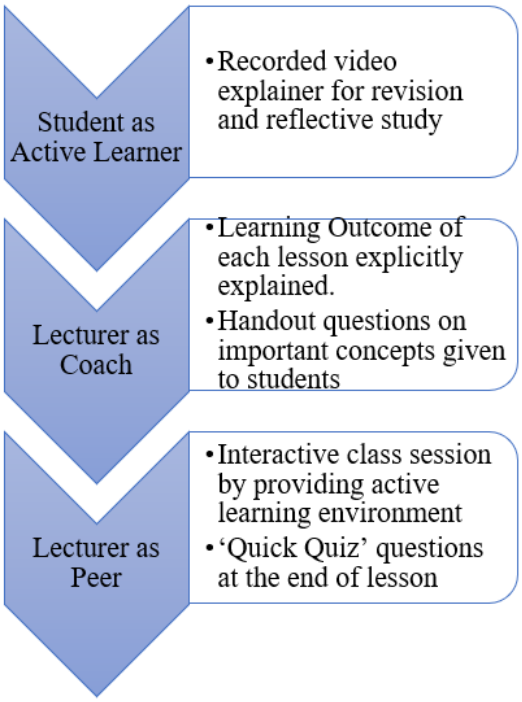

Fig. 3. Implementation of scaffolding activities from the lesson plan: Role of lecturer and students in September 2020 cohort

Instead of replicating the physical lecture during the online sessions, recorded videos were provided to students prior to the class. Students were informed to peruse the materials given before attending the online sessions. The video-based materials have always been part of asynchronous learning in the scaffolding strategies, enabling students to access them anytime and anywhere.

The online sessions started with course lecturer as Coach (in the beginning of the session), in which the learning outcomes were explained, followed by the handout questions for discussion. In the previous practice, students would have had a handout copy and any notetaking based on the discussion would only be accessible individually (on their own). In the online sessions, the course

lecturer utilised various technological tools available that could assist the teaching more effectively, therefore the handout was displayed (via sharescreen) and students were asked to contribute to the answers by noting them down on the 'online screen'. Course lecturer also assumes role as a Peer when there were subsequent questions asked during the class, as the session was focused on student-led discussion by enabling students to capitalise the virtual learning environment to communicate with their peers. Intervention was done only when students required more guidance in answering certain questions. This was also part of the reason behind the watching videos (students as active learner) prior to attending the class, to ensure more meaningful discussions during the session, based on the assumption that students would already have some understanding on the topic to learn, or questions that arise from watching the videos as well.

3. Results and Discussion

This section entails the implementation of the scaffolding strategy in the course, in which students' performance serves as an indicator to evaluate the effectiveness of the strategy. The following section explains the results when face-to-face learning was done, and subsequently the changes made to cater to the online learning.

3.1 Pre- and Post-Scaffolding

The proposed mechanism was first introduced in the September 2019 cohort when all learning and teaching activities were done in face-to-face setting. It observed a great improvement with 100% passing rate compared to the previous cohort, September 2018 at 96%, as tabulated in Table 1. The average marks also increased from 66.2% to 79.2%, with a good range of standard deviation of 14.2 and 11.0, respectively.

Table 1
Students' performance for September 2018 (pre-scaffolding) and September 2019 (post-scaffolding) cohort

Assessment Evaluation	September 2018	September 2019
Passing rate	96%	100%
Average	66.2%	79.2%
Standard deviation	14.2	11.0

Another evaluation that was considered is the course feedback survey, as tabulated in Table 2. Since the feedback is based on voluntary participation, the percentage rating given is calculated based on feedback where more than 80% students agree and more than 40% strongly agree, where number of respondents is 5 or more. The improvement of students' perception on lecturer's accessibility increased from 82% to 91%. Since the scaffolding strategy involves some planning ahead in designing the activities (instructional strategy and medium), as explained in the previous section, 82% agreed that materials were well prepared compared to 77% previously. From 77%, 91% felt that they were allowed contribution via questions and discussion, which supports the idea that interaction serves as the core component in each activity. The biggest jump was observed, whereby 91% (from 55%) perceived that the teaching was effective. The observed data implies that the scaffolding activities have provided better structure and effectiveness in learning, thus also improving the lecturer's teaching performance.

Some written comments include "ability to interact with students whilst teaching," "instructor was easy to talk to regarding material in the course," "instructor was always prepared with her own

notes before the lecture, with necessary information that's related to topic," "instructor was approachable and kind, would help students in solving problems. She provided many exercises but need to guide students for solutions".

Table 2
Course feedback for September 2018 and September 2019 cohort

Feedback	September 2018 (%)	September 2019 (%)
Lecturers were accessible to students	82	91
Lecturers were effective in teaching	55	91
Lecturers' materials well prepared and carefully explained	77	82
Lecturers allow student contribution via question and discussion	77	91

Based on the good improvement, the course lecturer continued with the scaffolding strategy in the next September 2020 cohort. It should be noted that the CQI action to improve the course teaching for this cohort also factored in the fact that this cohort would undergo online learning, compared to the previous cohort (face-to-face classes).

3.2 Scaffolding in Online Learning Environment

The results of the students in online learning (September 2020) showed slight decrease in comparison to the previous face-to-face learning (September 2019), as tabulated in Table 3. The result of the September 2020 cohort was also contributed to an outlier data, in which student was absent for the assessments, therefore affecting the passing rate. Exclusion of this data would give a 100% passing rate (as compared to 93%).

Table 3
Students' performance for September 2019 (face-to-face learning) and September 2020 cohort (online learning)

Assessment Evaluation	September 2019	September 2020
Passing rate	100%	93%
Average	79.2%	61.8%
Standard deviation	11.0	20.8

Since this course was streamlined across campuses at different locations in the same institution, the impact of this strategy on online classes was also studied by comparing the academic performance between two campuses. Course contents, materials, assessments and delivery were kept the same for the campuses, and the only difference lies in the scaffolding (proposed mechanism) implementation in the Malaysia campus during the online sessions.

Table 4 tabulates the results between Malaysia campus and the other campus. As compared to the same cohort in other campus, where students went through the same recorded videos and online sessions were conducted for discussions, the passing rate for Malaysia campus was 93%, whereas the other at 90%. The lower average of 61.8% could be justified by the abovementioned outlier data of one student who remained absent for assessments, from which exclusion of this data would then provide average of 64.4% and standard deviation of 18.7. It is suggested that the scaffolding strategy has helped in engaging students to navigate their learning more effectively whilst coping with the online learning, therefore improving the passing rate.

Table 4
September 2020 Students' performance between two campuses

Assessment Evaluation	Malaysia campus	Other campus
Passing rate	93%	90%
Average	61.8%	68.2%
Standard deviation	20.8	18.2

4. Conclusions

This paper proposes a mechanism that incorporates interactive activities using scaffolding strategy for an engineering course. Improved students' performance was observed for both face-to-face and online delivery, alongside positive responses from students in the course feedback survey. It also provides the flexibility in terms of customising the flow of the designed activities to cater to different mode of learning, face-to-face and online. This can be done through utilising the technology tools to meet the learning opportunities of the students where necessary. Since the pandemic may also contribute to other factors that may affect the students' performance, further studies will be required to measure the impact of this strategy on student learning especially in the online delivery. Future work can incorporate the next student cohort performance to gain better insight on how scaffolding could be instrumental in enhancing student engagement in active learning environment. There might also be other underlying factors that affect the students' performance in online delivery during the pandemic, which would require further studies.

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