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ASSESSING TEACHING STRATEGIES OF STEM COURSES DURING COVID-19 PANDEMIC: A COMPARISON STUDY IN PERFORMANCE AND LEARNING EXPERIENCE BETWEEN SYNCHRONOUS AND ASYNCHRONOUS LEARNING MODE IN HIGHER INSTITUTION

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Abstract: The COVID-19 crisis has forced lecturers around the world to shift from traditional into computer screens classroom. Here, various teaching strategies adopted to support this adhoc virtual learning environment. Despite the various efforts to solve the challenges among the different teaching strategies implemented, the efficiency of the strategies is still questionable. Hence, the aim of this study is to investigate the most suitable teaching strategies for STEM online education. This study presents a comparison of two different learning modes, synchronous and asynchronous mode, in terms of students' performance and learning experience in science, technology, engineering and mathematics (STEM) courses. Two STEM courses were selected: engineering and programming course. The study randomly assigned students to one of two conditions: (i) taking the course in synchronous mode - class conducted in real-time mode with lecturers via online meetings and (ii) taking the same course in asynchronous mode – online materials being provided in advance such as pre-recorded video content. Here, the course content (learning outcomes, course topics required literature and assessment) were identical for all students. Next, all students sit for an (i) assessment to assess their mastery of the course content, (ii) completed an entrance-exit survey and (iii) a self-reported satisfaction questionnaire about their learning experience and satisfaction. Content analysis has been conducted to see the relationship between student scores, learning experience and satisfaction. The results showed that there are differences of a correlation between these

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three factors. This study contributes to identifying the most suitable teaching strategy as well as increasing the efficiency of online learning in the context of STEM education in higher institutions.

Keywords: COVID-19, STEM, teaching methodology, online learning, higher institution

Introduction

Since the devastating COVID-19 pandemic, most schools, colleges, and universities have shifted their paradigm by implementing teaching and learning in digital mode. In this sense, the academic institutions needed to act promptly to ensure the quality and rigour of education were maintained, particularly the active and experiential learning required among undergraduate and graduate courses in science, technology, engineering, and mathematics (STEM).

For many years, higher education in the field of STEM has been in an instability mode. Reform pressures come from factors such as declining STEM student enrolments, high STEM curriculum attrition rates, and the emergence of effective alternative teaching strategies that, according to cognitive science and educational research, are more effective in promoting learning and curricular retention than conventional teaching methods. Additionally, studies have shown that hybrid courses—which integrate the best aspects of both face-to-face and online learning—produce learning outcomes that are equivalent to those of traditional face-to-face and online courses on average. Besides, students must become self-regulated learners by establishing productive study habits in order to have meaningful learning experiences in online classrooms.

In this paper we posit that the teaching strategies used during the online classroom are of high importance of which its incorporation might affect the teaching and learning process. We argue that despite the various efforts to solve the challenges among the different teaching strategies implemented, the efficiency of the strategies is still questionable. We intend to make a contribution to a better understanding of the most suitable teaching strategy as well as increasing the efficiency of online learning in the context of STEM education in higher institutions.

The paper is organized as follows. We begin by reviewing teaching strategies used during online classes. We then give a particular focus on comparing two different learning modes, synchronous and asynchronous mode, in terms of students' performance and learning experience in science, technology, engineering and mathematics (STEM) courses. This ensues with our methods, analysis, and the conclusion.

Previous Studies

Online Distance Learning

Over the past ten years, the commercialization of the Internet in education has given rise to a brand-new teaching strategy known as electronic learning (e-learning). It is one of the technologies that is widely used nowadays, especially in higher learning institutions (Juhaida et al, 2019; Nayak et al, 2020; Kant, 2020). E-learning goes beyond digital technologies. Gradually, the technologies are becoming more integrated as an invisible and ubiquitous part of a global education system (Juhaida et al, 2019). Due to its rapid expansion, e-learning has increased its functionality and changed the name into open and distance learning (ODL). This adoption of technology has enriched the popularity of online learning in educational industries as it offers limitless potential in terms of flexibility and accessibility.

ODL concept that assists in handling many students from different parts of the world is considered a cost-effective teaching method (Botham and Mason, 2007). For students, ODL offers tremendous advantages including the flexibility of the learning pace. ODL offers students the opportunity to study at their own pace in which students have the opportunity to learn at any time, from anywhere in their own stride. In addition to that, ODL offers opportunities to promote interaction between students and lecturers as well as with experts in ODL. According to Croxto (2014) online courses with high levels of interactivity lead to higher levels of student motivation, improved learning outcomes, and satisfaction over less interactive learning environments. This results in higher-order thinking skills among students.

Based on the study conducted in order to understand students' perception and readiness for ODL, the results indicate that majority of students gave a positive response towards ODL and are ready to follow the university's demands in using it (Lasi, 2021). It is believed that their learning performance can be increased by adopting this online learning process if the students are well-prepared.

Teaching Strategies for STEM and Other Courses

The term "teaching strategies" refers to the fundamental ideas, pedagogy, and management methods used in the educational process (Filiz & Konukman, 2020). The preferred teaching approach will rely on the institution's objective, the subject(s), and the students in class. Whether an instructor teaches a seminar, a lecture, or another type of course, they have a few tried-and-true strategies for facilitating classroom discussions, improving lectures, encouraging collaborative learning, and teaching large groups (Senthamarai, 2018). They might consider active learning, a strategy with academic backing that might produce fruitful learning results. They could also think about team-based and online learning methods. Educators can encourage their students to participate in the learning process through engaging in lectures, discussions, group projects, and other activities (Senthamarai, 2018; Zhao et.al, 2020).

Over the past ten years, STEM education has gained international attention. This is motivated by the shifting nature of the global economy and the projected lack of STEM-trained professionals and instructors globally. According to Kennedy and Odell (2014), in emerging markets, developed nations, and long-established economies like the US and Europe, improving STEM education teaching and learning has taken on economic importance.

STEM education has developed into a meta-discipline, an integrated effort that eliminates the conventional barriers between these subjects and instead focuses on innovation and the practical process of designing solutions to challenging contextual problems using the most recent tools and technologies (Benabentos et. Al, 2021). For programs to effectively engage students in high-quality STEM education, they must incorporate rigorous curriculum, instruction, and assessment methods, integrate technology and engineering into the teaching of science and mathematics and foster scientific inquiry and the engineering design process (Kennedy and Odell, 2014; Sedaghatjou et. al, 2021).

STEM-focused curricula encourage instructional practices that push students to explore and invent. This shows that in order to solve an engineering problem, students must apply what they have learned about science, math, and technology. Brent et al., (2021) found that, students are expected to use this method to demonstrate their comprehension of STEM subjects in a real-world setting. Teachers must be able to provide STEM programs that are standards-based and use cutting-edge teaching methods in order to do this.

In other words, STEM may encourage applied and collaborative learning if teachers are ready and equipped with the necessary resources. In order to increase the learning relevancy, technology must be incorporated into the culture, curriculum, instructional practices, and daily activities of classrooms. At this point, STEM transforms into a meta-discipline that must be taught to students in an interdisciplinary manner while adhering to national/state course requirements.

Synchronous and Asynchronous Teaching Mode

There are two categories of teaching modes in e-learning which is synchronous and asynchronous (Jaimee et.al, 2022; Rehman and Fatima, 2021). Synchronous e-learning mode is a learning process that occurs in real-time (Rehman and Fatima, 2021; Jaimee et.al, 2022). In synchronous e-learning mode, students and teachers are all online at the same time and communicate from different locations. They distribute and receive learning materials through telephone, video conference, the Internet, or talk. Participants can share their thoughts and communicate with other participants during the learning session, and they receive specific questions and solutions. Synchronous e-learning mode is becoming more common as technology and Internet bandwidth capabilities increase.

Asynchronous e-learning in the other hand is a form of learning that allows you to pause and resume at any time (Rehman and Fatima, 2021; Jaimee et.al, 2022). The learner and the instructor are not necessarily both be online at the same time in this form of e-learning. Email, blogs, discussion boards, eBooks, CDs, DVDs, and other technologies can be used in asynchronous e-learning. Learners can learn at their own pace, download documents, and communicate with teachers and co-learners. Many students prefer asynchronous learning over synchronous learning because they can take online classes at their leisure and avoid disrupting their regular schedules Asynchronous gives flexibility for students, which makes it a very pleasant alternative for a modern student who works in addition to attending to school, unlike other rigid type online learning. Indeed, studies showed that students prefer asynchronous communications (Yamagata-Lynch, L.C., 2014).

Learning Experience During ODL

ODL is an education system wherein lecturers and students need not be present either at the same place or same time but is flexible in regard to modalities and timing of teaching and learning. This adoption of technology has enriched the popularity of online learning in educational industries as it offers limitless potential in terms of flexibility and accessibility. In theory, it can be said that ODL is more effective than traditional learning since it has made learning more efficient, personalized, and accessible to the learners. Some of the reasons are using less time commitment, social learning collaboration, and demand for digital content (Baht,S., 2020).

However, the learning experience for students while using ODL is different compared to the predictable traditional face-to-face classroom approach (Maqableh & Alia, 2021). Research by Maqableh & Alia (2021) showed that more than a third of the surveyed students are dissatisfied with the online learning experience due to distraction and reduced focus, psychological issues, and management issues.

Apart from the aforesaid issues, the extent of interaction and collaborative learning opportunities available in ODL could also influence students' learning experience. Effective interaction has long been stressed in the research on ODL as being essential to students' success in their learning. According to Muirhead and Juwah (2004), interaction is an event that can take the shape of any type of communication between two subjects and objects. The research specifically acknowledges the three typical forms of interactions are student-content, student-student, and student-teacher (Muirhead and Juwah, 2004). Nevertheless, through ODL, interaction opportunities may be reduced due to many reasons that will lead to a sense of isolation, which can be detrimental to student success (McInnerney and Roberts, 2004). Therefore, integration of social interaction into pedagogy for online learning is essential, especially at times when students do not actually know each other or have communication and collaboration skills underdeveloped (Garrison et al., 2010).

Besides all the unfortunate indications, there are various studies that proved the virtuous effect of ODL on students learning experience. Through the years, researchers have outlined numerous propositions in ensuring the effectiveness of ODL hence improving the students' learning experience. This requires participation and collaboration from all parties involved. A study conducted proved that the readiness of a student for ODL was at a premium level when the instructors used ARP initiative (Attention, Recognition, Pressure less) for best academic performance and to drive excellent achievement (Allam et al., 2020).

Method and Analysis

Participant

96 diploma (computer science and civil engineering) students of UiTM Pahang Campus were the participants of this study as shown in Table 1.

Table 1: Descriptive statistics of Student Demographics

Variable	Factors	N	%
Gender	Male	58	61.41
	Female	38	39.58
Program	Programming		56.25
	synchronous	27	
	asynchronous	27	
	Engineering		43.75

	synchronous	26	
	asynchronous	16	
Part	Part 1	42	43.75
	Part 6	54	56.25
TOTAL		96	100%

Procedure

Two STEM courses have been identified and selected (engineering and programming course). Next, the study assigns group of students to one of two conditions; (i) synchronous mode - lectures conducted in real-time mode via online meetings (Google Meet & Ms Teams) and (ii) asynchronous mode - lecture materials being provided in advance (pre-recorded video). All students filled up the entrance-exit survey, sit for an assessment to assess their mastery of the course content and completed a questionnaire about their course experience and satisfaction.

Demographic Profile of Respondents

The analysis of this study has been divided into two parts. The first method is by analyzing the student's grades and entrance and exit surveys. For the content analysis, 61.41% of the participants were male students and only 39.58 % were female. This is common in STEM courses where most students are males. Meanwhile, STEM courses chosen for this study are programming (56.25%) and engineering (43.75%). The questionnaire was distributed to the students from selected parts, which were Part 1 and Part 6 students, which represent 4.375% and 56.25%.

Content Analysis of Student Grades and Entrance-Exit Survey

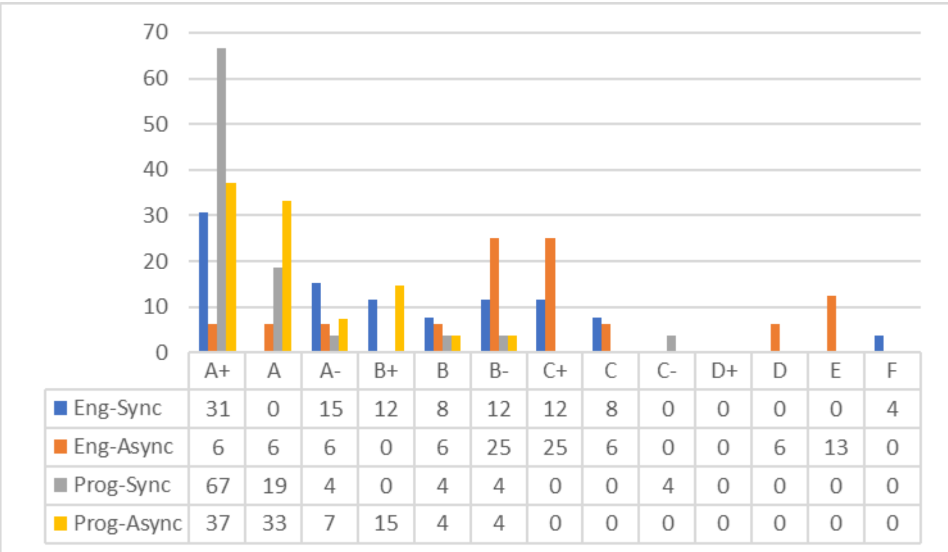

Figure 1: The grade percentage for both programming and engineering students in the asynchronous and synchronous learning mode.

Figure 1 depicts the percentage grades of programming and engineering students in different learning techniques. The figure reveals that many programming students outperformed engineering students regardless of learning modality. This outcome was predicted since the engineering course is more difficult than the programming course. As a result, engineering students have a more difficult time in getting good marks for the quiz. It is also revealed that synchronous learning yielded higher grades for both programming and engineering students than asynchronous learning. This is due to the fact that under synchronous learning, students were taught in a two way basis which enable any questions regarding the course topic could be answered straight away. Meanwhile, during asynchronous learning, the student's questions may not be replied immediately. Additionally, some of the students might not even watch the pre-recorded video in asynchronous learning. As a result, they will struggle to answer the quiz questions. Similar findings were also reported that synchronous learning technique proved to be the most effective in supporting students in gaining knowledge and skills (Saidi, Sharip, Abd Rahim, Zulkifli, and Zain, 2021; Libasin, Azudin, Idris, Rahman, and Umar, 2021; Nsa, Akpan, and William, 2012; Duncan, Kenworthy, and McNamara 2012; Sife, Lwoga, and Sanga 2007; Hrastinski, 2008; and Ruiz, Mintze, and Leipzig, 2006). In contrast, it is reported that there is no statistically substantial difference between the students' results in either synchronous or asynchronous learning (Ogbonna, Ibezim, and Obi, 2019).

Table 2: Entrance and exit survey of programming and engineering students

Variable	p-Value Synchronous vs asynchronous
Entrance -Exit Survey (Programming)	0.5125
Entrance -Exit Survey (Engineering)	0.3115

H01: There is no difference between the entrance exit survey of synchronous and asynchronous students.

H1: There is a difference between the entrance exit survey of synchronous and asynchronous students.

Table 2 above indicates the difference between entrance and exit surveys for programming and engineering scores. A T-test has been conducted to see the difference between synchronous and asynchronous learning modes. The null hypothesis failed to be rejected as the p-value for both courses is more than 0.05 which is 0.5125 for programming and 0.3115 for engineering. This result is aligned with the student grades referred in to Figure 1. The entrance and exit survey for both courses had designed to measure students' skills before and after completing the subject. Since students were scored in most of their assessments, the result for the entrance-exit survey has aligned with their ability to portray the skills listed at the end of the course taken. Measuring the E-E survey are not referring to the 'values, attitudes, feelings, beliefs, activities, assignments, goals, or grades of the student, thus it is more to student performance that can be measured and observed (Faouzi, Lansari, Al-Rawi, and Abonamah, 2003).

The second part of this study is using a questionnaire to measure the student learning experience. Five variables representing gender, program, part, and student readiness in terms of space and equipment have been asked to understand students' background in facing ODL. Of 96 respondents, 55.21% of the participants in the survey were male and only 44.79 % were female. The two STEM courses chosen for this study are programming (56.25%) and engineering (43.75%). The questionnaire was distributed among students from selected parts, which were from Part 2 and Part 4, which represent 4.375% and 56.25%. In terms of readiness, most students' responses were Yes, with 91.67% for having adequate space and 92.71% for having appropriate equipment.

Table 3: Student learning experience in synchronous and asynchronous

Learning Experience	N	Synchronous VS Asynchronous
Content of material	96	0.000
Interaction with lecturers	96	0.004
Clarification of question	96	0.253
Digital platform orientation	96	0.5
Feels gain new skills	96	0.042
Feels Develop skills	96	0.070
Feels course objectives were met	96	0.433

H01: There is no difference between the learning experience of synchronous and asynchronous students.

H1: There is a difference between the learning experience of synchronous and asynchronous students

Since the students experienced both learning modes throughout the semester, the learning experience survey has been conducted to compare those modes. The t-test result showed that there is a significant difference between synchronous and asynchronous learning experiences in terms of the content of the material, interaction with lecturers, gaining new skills, and course objectives met which a p-value is less than 0.05. Meanwhile, clarification of questions, digital platform orientation, and developing new skills show no significant differences as the p-value is more than 0.05. The results of this study aligned with studies which highlight students tend to choose a synchronous method as they feel it is more practical in terms of the learning experience, positive outcomes, and more efficient (Hrastinski, 2008; Garrison, 2011; Ogbonna, Ibezim, and Obi, 2019). The strengths of the synchronous method do have an impact on the learning experience as the results of this study show the interaction of the lecturer is one of the elements that has been highlighted by the students as it is indirectly followed by other interrelated elements such as the content of the material, gaining new skills, and course objectives. Real-time interpersonal communication, natural language, and direct feedback are the strengths of synchronous methods that have an impact on personalization as they offer the same elements as face-to-face learning environments (Blau, Weiser, and Eshet-Alkalai , 2017).

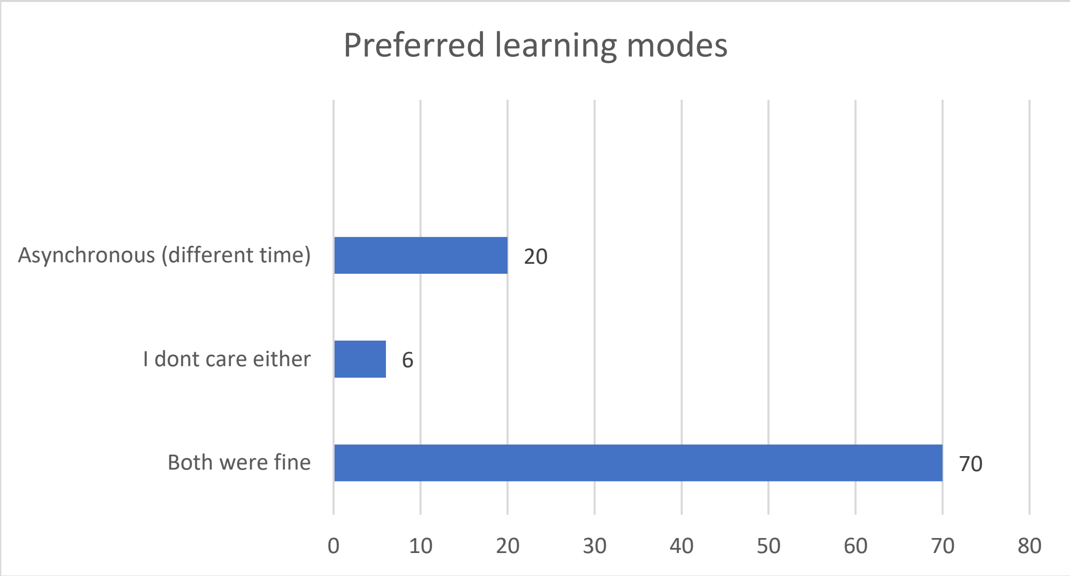

Figure 2: Preferred learning modes

To find the best teaching strategies for online STEM courses, the student has been asked the for their prefered method in online learning. Out of four types of answers, 70 of them were fine with both methods whether it is asynchronous or synchronous. Only 20 of them preferred asynchronous whereby six do not care about either asynchronous or synchronous. This indicates that students prefer both methods. This could be due to the student's readiness for online learning as shown in Table 1 which they have adequate space and appropriate equipment. This also indicates that environments such as space and equipment play important roles to support student learning. Lack of appropriate devices, poor learning space at home, stress among students, and lack of fieldwork and access to laboratories are the challenges that will affect the students learning experience (Day, Chang, Chung, Doolittle, Housel, & McDaniel (2021). As online learning has both advantages and disadvantages, a previous study by Xie, Liu, Bhairma, & Shim (2018) stated that blending both methods is suggested to be applied in online learning environments. Students mostly do prefer asynchronous as it is free to access and suitable for the student who is uncomfortable with direct discussion or immediate feedback. Nevertheless, the presence of a lecturer and prompt feedback is also required to make the learning more effective (Xie et al, 2018).

Conclusion

The paper aims to find the best strategies for STEM online education at Universiti Teknologi MARA Cawangan Pahang. Two selected STEM courses have been chosen as the respondents for this study; engineering and programming. An analysis of student results and student entrance exit survey were used to measure student performance. Meanwhile, a set of questionnaires were distributed to measure the different student learning experiences between synchronous and asynchronous. The result of the study showed that there is no significant difference in student performance whether the learning method is synchronous or asynchronous. This is probably due to the students' adaptation to online learning itself, as they have been experiencing ODL for almost 2 years since the COVID-19 outbreak in early 2020. Nevertheless, the experience of ODL has made these students ready to study in both modes, which makes them more motivated to learn as well as perform better in their assessments.

Thus, this is also supported by the advantages of ODL itself, such as flexibility and accessibility, which have motivated the student to set their own pace of study.

Although there is no difference in student performance, the learning experience shows other differently. The students indicated there is a difference in the learning experience between synchronous and asynchronous delivery in terms of the content of the material, interaction with lecturers, gaining new skills, and meeting the course objectives. As the process of synchronous learning happens at the same time, it provides a unique opportunity for students to discuss the content and communicate directly with the lecturer. The existence of real communication in synchronous learning has supported the student's feeling of gaining new skills and meeting the course objective. To conclude the best strategies for STEM courses, most of the students stated that both methods, whether synchronous or asynchronous, were fine for them. As the online learning courses are widely used and improving, the students are ready to adapt as both have advantages and disadvantages that need to be coped with.

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