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Enhancing Engineering Electromagnetics Education: A Comparative Analysis of Synchronous and Asynchronous Learning Environments

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Abstract

This study evaluates implementation of asynchronous learning in teaching engineering electromagnetics module. A group of first-year engineering students participated in the study. The instruction was divided into two periods, with the first period using asynchronous online mode and the second period using synchronous face-to-face mode. The performance evaluation was based on essay questions on class tests, and the data variances were statistically analysed. In addition, student feedback was gathered through interviews conducted at the end of the semester. In terms of overall performance, the results indicate that synchronous and asynchronous learning methods were equally effective, as no significant difference was found. However, individual student grades revealed a variety of outcomes for the asynchronous learning method, suggesting that students have different learning preferences and levels of adaptability. Positive feedback for asynchronous learning included the ability to adjust the pace of learning and conveniently access course materials. Students valued the availability of recorded lectures for reviewing difficult subject matter. Students with lower study motivation or limited experience with independent learning were negatively affected by the absence of scaffolding and immediate feedback in the asynchronous learning approach. Some students emphasized the importance of face-to-face interaction with the instructor, especially in a subject like electromagnetics that requires intuitive thought and elaboration.

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INTRODUCTION

Engineering Electromagnetics is a fundamental subject that forms the backbone of various engineering disciplines, including telecommunications, electronics, and power systems. Its significance lies in understanding the interaction between electric and magnetic fields, which is crucial for the design and analysis of modern engineering systems (Mikki & Antar, 2016). However, teaching and learning Engineering Electromagnetics can pose significant challenges for both educators and students. The complex nature of the subject, coupled with the need for intuitive thinking and conceptual understanding, demands innovative teaching methodologies to enhance student comprehension and engagement.

Traditional face-to-face instruction has been the primary mode of teaching Engineering Electromagnetics. While this method provides opportunities for immediate interaction and feedback, it may not cater to the diverse learning styles and busy schedules of first-year engineering students. As technology continues to reshape the educational landscape, asynchronous online learning emerges as a potential solution to address these challenges (Roman & Uttamchandani, 2018; Rüde et al., 2018).

As technology continues to revolutionize the educational landscape, traditional approaches to teaching and learning are gradually giving way to innovative methodologies. One such paradigm shift in engineering education is the adoption of asynchronous learning, a pedagogical approach that allows students to access educational materials and engage with course content at their own pace and convenience (Beldarrain, 2006; Rogers, 2000). The concept of asynchronous learning, also known as self-paced or on-demand learning, has gained traction in recent years as advancements in digital technologies have made it more accessible and effective.

Engineering education has traditionally relied on synchronous methods, where students attend in-person lectures and adhere to a fixed timetable. However, this rigid structure can pose challenges for learners with diverse schedules, geographical locations, or commitments outside of academia. Asynchronous learning emerges as a promising alternative to overcome these constraints, providing flexibility and autonomy to engineering students (Gelles et al., 2020, 2020). By leveraging online platforms and resources, educators can deliver course materials, lectures, and assessments that students can access and complete at their preferred time and pace. This adaptability addresses the individual needs and learning styles of students, enhancing their engagement and overall learning experience (Li & Wong, 2021; Ratten, 2023).

Asynchronous learning in engineering education is based on a few fundamental principles. To begin with, course materials, such as lectures, readings, and multimedia content, are made available online and structured on a learning management system. Students can access these resources whenever they want, allowing them to study and review topics multiple times for better understanding. Asynchronous learning, on the other hand, emphasizes self-directed and independent learning. Students take charge of their educational journey, determining their own study schedules and rate of progress. Instructors serve as facilitators, guiding and supporting students as needed, resulting in a more personalized learning experience.

The use of asynchronous learning in engineering education has several benefits (Baukal, 2010; G. Splitt, 2003; Jorgensen, 2003). One of the primary advantages is the removal of temporal and spatial barriers. Students from different geographical areas or with different time constraints can receive the same high-quality education as their peers, fostering inclusivity and diversity in the engineering classroom. Furthermore, asynchronous learning allows students to replay and review course materials, which helps students retain complex engineering concepts. The ability to access content 24 hours a day, seven days a week encourages students to balance their academic pursuits with work, family, or personal obligations, reducing stress and improving overall well-being.

Despite its merits, asynchronous learning also presents challenges (Baukal, 2010; G. Splitt, 2003; Jorgensen, 2003). Maintaining a sense of community and collaboration among students is one of the most important considerations. The lack of synchronous interactions can stymie group discussions and peer-to-peer learning, both of which are essential components of engineering education. It is critical for comprehensive skill development to strike a balance between individualized learning and collaborative experiences. Furthermore, access to reliable internet connectivity and technological infrastructure must be ensured to support the seamless delivery of online content. Institutions must also invest in faculty professional development so that they can adapt their teaching methods and implement effective asynchronous learning strategies.

Asynchronous learning is reshaping the landscape of engineering education and has the potential to become a critical component of learning's future. The incorporation of emerging technologies such as artificial intelligence, virtual reality, and gamification can improve the efficacy of self-paced learning even further (Alexander et al., 2019; Almeïda & Sïmoes, 2019; Pappas et al., 2022; "The Core Components of Education 4.0 in Higher Education," 2021). Institutions must foster a culture of continuous improvement by soliciting feedback from students and instructors in order to constantly improve asynchronous learning methodologies. Engineering education can use asynchronous learning to produce a new generation of agile and adaptable engineers ready to face the challenges of an ever-changing world by embracing the principles of flexibility, inclusivity, and self-directed learning. This study compares student learning performance under synchronous and asynchronous learning environments for subject of engineering electromagnetic. Data from one semester teaching cycle were compared and analysed. To identify the effectiveness of both teaching delivery methods.

METHOD

Learning Process

The study was carried out in the Faculty of Integrated Technologies at Universiti Brunei Darussalam during the second semester of the 2021/2022 academic year. Twelve first-year General Engineering students were enrolled in the Engineering Electromagnetics module. The module was taught over two periods by two different lecturers. The first half of the learning was done online in an asynchronous mode, and the second half was done in a face-to-face synchronous mode.

There was no direct face-to-face interaction in the asynchronous online mode. The online briefing was given once at the beginning of the semester to brief the student on the method and assessment. The students then spent six weeks learning from pre-recorded lecture and tutorial videos organized in the Canvas learning system. The videos have been uploaded to YouTube and are now available. The first mid-semester evaluation was given as a class test in a physical class. The lecturer stood by and was contacted directly by the students when necessary to resolve some issues encountered by the students.

All teaching delivery in the synchronous face-to-face mode was done in physical class, according to the class schedule, just like in the traditional learning method. After completing the online method, the students learned for six weeks. The second mid-semester evaluation was given as a class test in a physical class. Because of the nature of the learning method, issues that arose during the delivery class could be resolved directly by the lecturer.

Performance evaluation and analysis

The results of the class tests were used to evaluate the students' performance. Essay questions were used in the tests. The summaries of the students' grades were compared and analyzed using the ANOVA method. Individual student marks were plotted to understand the effect of individual learning characteristics on performance. Finally, at the end of the semester, students' feedback was gathered through an interview.

RESULTS AND DISCUSSION

Student Performance

Figure 1 shows that the online asynchronous method can be used to teach the engineering electromagnetics module to first-year engineering students. The asynchronous and synchronous learning methods received 10.43.4 and 11.42.0 out of 15 points, respectively. It demonstrates that the synchronous face-to-face method outperformed the synchronous online method. However, the p-value (0.3837) corresponding to the F-statistic (0.7901) of one-way ANOVA for the two group samples is greater than 0.05, indicating that the treatments are not significantly different at that level of significance.

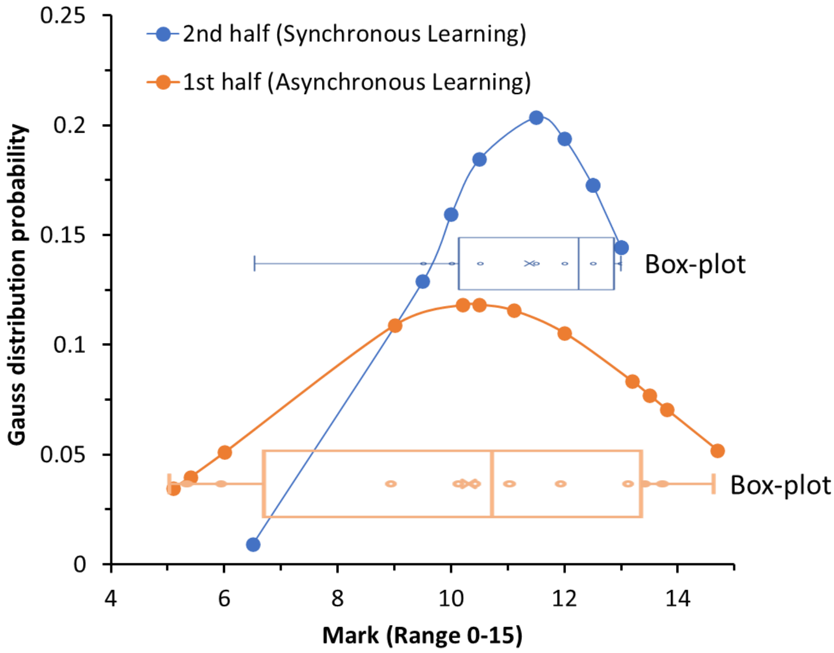

Figure 1. The summary of the students' performance results evaluated based on the results of the tests at the end of the learning periods.

According to the gauss distribution and box-plot curves in Figure 1, there were more students with low marks of 6 (3 with marks of 5.1, 5.4, and 6) for the asynchronous method and none for the synchronous method. Nonetheless, the asynchronous method had more students with the highest scores (4 students) than the synchronous method (none). These findings indicate that the asynchronous method is either highly suitable or not suitable for a particular group of students, as discussed further in the following section.

The wider distribution of test scores reflects the high variability of student preferences in the asynchronous learning method. The lack of scaffolding effort for online learning can explain this finding. The lecturer had the smallest possible channel to observe the learning process and provide adjustments and responses as needed, which is easily accomplished in the face-to-face learning method. For face-to-face synchronous learning, the mark distribution clusters primarily around the mean value. Students who lacked motivation and learning passion were left behind in the nonsynchronous method to deal with the mental issue. Passionate students, on the other hand, can re-learn and perform exercises by rewinding the video lessons, as reported earlier (Hadullo et al., 2018; Lin & Gao, 2020).

Students' Learning Preference

Figure 2 shows a box plot of the percentage change in mark change when switching from asynchronous to synchronous learning methods relative to the average of both methods.

It demonstrates that the majority of the scores are negative, with a few scores dropping by more than 60%. It also shows that the majority of the data were in the first and third quartiles, close to the mean value. The presence of data below the first quartile indicates that students performed poorly in the asynchronous learning method but well in the synchronous learning method. A datum above the third quartile, on the other hand, performed extremely well on the asynchronous learning method but underperformed on the synchronous learning method. The discovery revealed that a group of students either dislikes or enjoys the synchronous learning method.

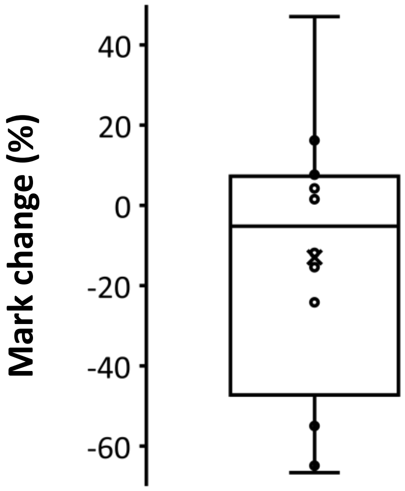

Figure 2. Percentage of mark change of marks by changing the learning method from the asynchronous to the synchronous relative to the average of both methods.

Based on the student categories depicted in Figure 2, the implementation of asynchronous learning necessitates skill training. Students did not adapt well to the new learning method because they were used to face-to-face synchronous learning and required intensive scaffolding and mentoring.

Students Feedback

According to an interview with students at the end of the semester, the majority of them prefer the asynchronous learning method for a variety of reasons. Students value the ability to tailor their learning experience to their individual needs. Students have the freedom to access course materials and lectures whenever they want. This adaptability is especially useful for engineering students, who frequently have hectic schedules due to coursework, projects, and other obligations. They can study electromagnetics without being constrained by fixed class schedules thanks to asynchronous learning, which allows for better time management and work-life balance. They can study at any time and in any location that suits them. This freedom enabled students to bring out the best in themselves by self-motivating to study within the constraints and expectations placed on them (time limit, assessment).

Another positive comment was about the ability to learn and relearn from the pre-prepared videos, which were supplemented with lecture notes and a tutorial solution. Students can revisit complex topics multiple times thanks to the availability of recorded lectures and course resources. Electromagnetics is a fundamental engineering subject, and its concepts can be difficult to grasp at first. Students can review lectures and materials as many times as they need with asynchronous learning, reinforcing their understanding and improving retention.

Asynchronous learning can also accommodate different learning styles. Some students may prefer a slower pace to thoroughly digest the material, whereas others may grasp concepts quickly and wish to progress more quickly. Asynchronous courses can accommodate both types of learners, allowing for a more personalized learning experience that meets the needs of each individual. Furthermore, online asynchronous learning can help engineering students develop a sense of independence and self-motivation. Students develop essential skills such as self-discipline, time management, and critical thinking by taking control of their learning process. These qualities will be invaluable to future engineers who will face real-world challenges that will necessitate self-directed problem solving.

The students' main challenge was a lack of learning progression milestones. The lack of summative assessment and regular interaction with the lecturer makes learning management extremely difficult, especially for students who lack study motivation and are unable to learn independently (Bennett, 2011; Stiggins & Chappuis, 2005). Online asynchronous learning may necessitate a greater level of self-motivation and discipline on the part of students. Some learners may struggle to stay focused or maintain a consistent study routine without the structure of regular in-person classes, potentially affecting their overall learning outcomes. In the field of electromagnetics, where complex concepts may necessitate clarification or elaboration, the lack of immediate feedback during asynchronous learning can impair students' ability to resolve doubts quickly. The freedom granted to manage their learning at their own pace has become a problem. Some students encountered difficulties as a result of their inexperience with independent learning as fresh graduates from pre-university studies.

Some students mentioned how the module's inherent nature required intuitive thinking. Because video lectures did not cover all concepts, the presence of a lecturer to elaborate and discuss was critical to supporting learning. Due to the abundance of unrelated and untrustworthy information available on the internet, they also had difficulty locating additional resources (online or offline).

Another challenge was the potential decrease in collaborative learning opportunities. In engineering, teamwork is essential, and electromagnetics often involves group projects and discussions. Asynchronous learning may limit the level of peer-to-peer interaction, making it difficult for students to engage in meaningful group collaborations and discussions that enhance their problem-solving and communication skills, as frequently reported early (Beldarrain, 2006; Gelles et al., 2020; Jorgensen, 2003).

CONCLUSION

For the subject of engineering electromagnetics, a comparison of student learning performance in synchronous and asynchronous learning environments yielded interesting insights. After statistically analyzing the data, the study discovered that both teaching delivery methods had comparable effectiveness, as evidenced by the results of the class tests. The synchronous face-to-face method had a slightly higher mean score than the asynchronous online method, but there was no statistically significant difference between the two. However, an examination of individual student grades revealed some intriguing patterns. The asynchronous learning method had a wider range of scores, indicating a wide range of student preferences and outcomes. Some students excelled, while others struggled to adjust to the new learning format. Asynchronous learning presented challenges due to the lack of scaffolding and immediate feedback, particularly for students with low study motivation or inexperience with independent learning. Despite the difficulties, students' reactions to asynchronous learning were generally positive. They appreciated the ability to adjust their learning process to their own pace and the ease with which they could access course materials. Students were able to revisit complex topics, reinforcing their understanding, thanks to the availability of recorded lectures and resources. Overall, the findings support the use of asynchronous learning to teach engineering electromagnetics. Asynchronous learning may be difficult to design due to the extensive preparation required for the video and tutorial lecture. However, once the system is in place, it can be used repeatedly with minimal effort. The system can also be improved over time to improve the learning experience.

RECOMMENDATION

Improving online asynchronous learning necessitates a methodical approach that addresses the challenges while capitalizing on the advantages of this educational format. Improving instructor presence is critical. To foster a supportive learning environment, instructors should actively participate in online discussions, provide timely feedback on assignments, and encourage student interactions. Furthermore, structured course design is required. Students can stay focused and grasp the subject matter more easily if course materials are organized in a clear and logical manner, with well-defined learning objectives, sequential modules, and consistent navigation. Incorporating interactive learning activities such as quizzes, simulations, and group projects can also improve student engagement and understanding, particularly when dealing with difficult concepts taught in the Engineering electromagnetic module. These activities allow students to apply their knowledge, collaborate with peers, and receive immediate feedback, resulting in a better understanding of engineering concepts.

Nonetheless, the issue of learning preference should be resolved through coaching or regular formative assessment, as well as other forms of learning intervention from the lecturer. When students only completed the learning process near the end, when the final exam was approaching, such intervention can address issues related to a lack of motivation. In addition, introducing synchronous elements on occasion, such as live lectures or virtual office hours, can compensate for the lack of real-time interaction in asynchronous learning. Students can interact with the instructor and their peers during these synchronous sessions, creating a sense of connection and fostering a more dynamic learning experience. They can talk about issues that are impeding or impeding their learning. Clear lines of communication between students and instructors are critical for resolving questions and ensuring a positive learning experience. Encouraging students to ask questions via discussion boards or email, and promptly responding to their inquiries, will help to foster a supportive learning community. Furthermore, gathering feedback from students and instructors about the online asynchronous learning experience on a regular basis is critical for identifying areas for improvement.

Author Contributions

The authors have sufficiently contributed to the study, and have read and agreed to the published version of the manuscript.

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Declaration of Interest

The authors declare no conflict of interest.

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