ACTION RESEARCH ON PEDAGOGICAL PRACTICES IN ENGINEERING MATHEMATICS

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Received: 10.12.2025 Accepted: 2.2.2026
Revised: 31.3.2026 Published: 8 April 2026
DOI: https://doi.org/10.51200/ijelp.v9i1.7019

Abstract

Action research explores and improves pedagogy in an engineering mathematics unit through iterative inquiry and reflection. Compared to the traditional teacher-centred approach, learner-centred pedagogy fosters a more collaborative learning environment. However, limited studies have examined reflective practice in learner-centred pedagogy within higher education, particularly in engineering. This paper presents a reflective practice and action research approach implemented in an engineering mathematics unit, emphasising scholarly teaching, constructive alignment, and active collaborative learning to enhance student engagement. In 2024, a spaced retrieval practice was introduced to improve assessment pass rates. Fisher's Exact Test results indicated no statistically significant differences in midterm test pass rates between Semester 1 2024, Semester 1 2023, and Semester 2 2023 at the 5% significance level. However, statistically significant differences were observed in final exam pass rates. The findings highlight that integrating reflective practice with three key elements, scholarly teaching strategies grounded in constructive alignment for effective lesson planning, collaborative learning methods to promote engagement and inclusivity, and intentional development of a cohesive teaching style combining these frameworks, can improve both instructor effectiveness and student outcomes. This study contributes to the understanding of learner-centred pedagogy in engineering education and demonstrates the value of iterative inquiry and evidence-based reflection in enhancing learning experiences and academic performance.

Keywords: *Pedagogy, learning and teaching, constructive alignment, engineering mathematics education, planning for teaching.*

INTRODUCTION

Pedagogy was initially considered the art of teaching for children, while the term 'andragogy' was made to recognise the different needs and capabilities of adult learners and construct a suitable art and science of teaching matched to these learners (Hägg & Kurczewska, 2020). Previously, the term 'andragogy' was employed by Alexander Kapp (1833), Kapp (1833b), and Kapp (1833a) for the concept of adult learners, which was then expanded and promoted by Knowles (1975). Andragogy can be defined as the art and science of adult learning; hence, andragogy refers to any form of adult learning (Kearsley, 2010). Figure 1 illustrates the difference between pedagogy and andragogy approaches. Compared to the pedagogy approach, the andragogy approach for

adult learners is more capable of self-directed learning. However, the pedagogy approach focuses on the teacher and the activity of teaching, and it is a learner-centred approach to learning and teaching.

On the other hand, the pedagogy approach can be categorised into teacher-centred and learner-centred, or student-centred, pedagogy approaches (du Plessis, 2016). This teacher-centred pedagogy approach concentrates on how the teacher teaches, where the teacher acts as the content expert who delivers knowledge to the learner (Valtonen et al., 2006). In the past, the teacher-centred pedagogy approach was the standard lecture style in educational institutes where the exchange of knowledge was done by the teacher, who holds the knowledge, and then knowledge was transferred to the learner, who is the recipient. Nevertheless, this teacher-centred pedagogy approach could make it difficult to meet the diverse needs of contemporary learners who have different learning levels (Freire, 1970). As compared to the conventional teacher-centred pedagogy approach, the learner-centred pedagogy approach facilitates a more collaborative way for learners to learn. Hence, the traditional teacher-centred pedagogy approach can be shifted to the learner-centred pedagogy approach that works towards learners' interests with the things they learn in the educational institutes.

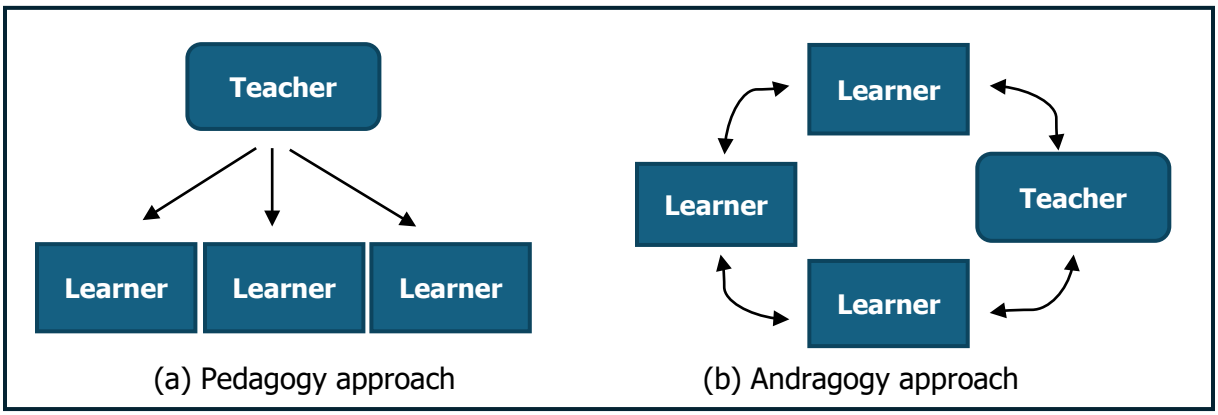

Figure 1: The difference between (a) pedagogy and (b) andragogy approaches.

The learner-centred pedagogy approach concentrates on how learners learn to meet their learning needs (Li et al., 2021). This approach coaches the learners to become active and collaborative participants in real-time reactions to bring with them the knowledge and experience that can contribute to the development of their learning. For instance, having a flipped classroom using Kahoot quizzes is a fun, interactive, and game-style learning activity in the class. Moreover, this approach allows the learners to be recognised as associating with knowledge and experience when they share it with their peers in the class, which will boost their learning experience (Briggs, 2007). Learner-centred pedagogy is essential because it transforms students into active learners, enhances engagement, improves academic outcomes, fosters essential life skills, and adapts to diverse learning preferences (Msonde, 2023). Therefore, the learner-centred pedagogy approach should be implemented in the education programme that provides interactive learning experiences.

Besides, constructive alignment is a learner-centred pedagogy approach to curriculum design and teaching planning that is the process of developing lessons, assignments, units, and projects to teach learners knowledge and skills (Biggs & Tang, 2011). In the context of designing a

programme of study, constructive alignment refers to preparing with the graduate capabilities that focus on what the learner will know or do at the end of their programme of study, as well as scaffolding backward thinking about the skills, knowledge, or capabilities that the learners require to build at each point in their study journey. Hence, the core of constructive alignment and the learner-centred teaching pedagogy approach is that the teacher often thinks about the next step in the pathway for the learners to complete their study, and creates space for creativity and innovation. Moreover, the focus of the teaching and learning activities practising constructive alignment is on engaging learners and developing their skills to be able to solve problems for themselves. On the other hand, the existing studies on the learner-centred pedagogy approach, such as Oyelana, Olson, and Caine (2022); Khadka, Joshi, Adhikari, and Khanal (2022); and Tambak, Sukenti, Hanafi, Rianawati, and Amril (2022), lack the action-research perspective. The action-research perspective enables lecturers to adjust and respond to issues, helping them become aware of their underlying beliefs and assumptions about learning and teaching. On the other hand, Donkoh et al. (2024) conducted a perspective study on the use and challenges of learner-centred pedagogy, but their study focused on primary school education, and the teaching subjects or units were not specifically mentioned.

Furthermore, it was found that a very limited study was focusing on an action-research perspective of the pedagogy in higher education, including engineering studies. This action-research perspective of the pedagogy that involves action, evaluation, and reflection helps to improve the educational practice of engineering study. Therefore, this study aims to present the pedagogy of the learning and teaching of an action-research perspective in an engineering mathematics unit. This study presents the rationale behind the practice of scholarly approaches for the pedagogy of learning and teaching, the constructive alignment linked to planning for teaching engineering students, and collaborative learning in facilitating a positive and engaging learning experience. The action-research perspective that is used to develop a teaching style to get an idea of the teaching and learning approaches is also recommended. Also, Fisher's Exact Test was implemented to carry out the analysis of the difference between the passing rates of the mid-term tests and final exams in Semester 1 (S1) 2024, S1 2023, and Semester 2 (S2) 2023, before and after the newly developed spaced retrieval practices in this engineering unit.

Context and Method

Context of an Engineering Mathematics Unit

The context of this study is a first-year engineering unit with 25 credit hours in a semester that has 12 teaching weeks and 1 or 2 tuition-free weeks. In each teaching week, there are 3 hours of lecture time, 2 hours of workshop, and 1 hour of lab session for this unit. The participants in this unit during the teaching weeks are a lecturer or teacher and students from different countries, including Malaysia, Pakistan, Myanmar, Thailand, Indonesia, Brunei, Bangladesh, etc., but most of the students are Malaysian. The ages of students are between 19 and 25 years old, with a mix of boys and girls, where the total student number could be in the range of 16 to 192 students per class. Moreover, the teacher, who is also one of the participants in this study, has been teaching this engineering first-year unit for 8 years, from 2017 to 2024. This study discusses pedagogies that are currently used in this engineering unit in higher education in Malaysia. This teacher has the intention to share the educational experience from which perspective best informs the teaching and learning practices. Meanwhile, the application of scholarly active learning

activities and the development of a teaching statement that clearly articulates the rationale behind the pedagogical and curriculum design choices for engineering students are also presented.

Fisher's Exact Test Analysis

Fisher's Exact Test is a statistical method used to determine if there is a significant association between two categorical variables in a contingency table, particularly when sample sizes are small (e.g., <100 students) (Alam et al., 2025). Fisher's Exact Test calculates the exact probability of observing the data (or more extreme outcomes) under the null hypothesis that there is no association between the two variables. It does not rely on approximations, unlike the chi-square test, making it more accurate for small datasets. **Equation (1)** shows the p-value calculation using Fisher's Exact Test.

$$p = \frac{(a+b)!\times(c+d)!\times(a+c)!\times(b+d)!}{N!\times a!\times b!\times c!\times d!} \quad (1)$$

where a and b are the number of students who passed and failed the unit after the spaced retrieval practice, respectively, while c and d are the number of students who passed and failed the unit before the spaced retrieval practice, respectively. N is the total number of students before and after the spaced retrieval practice. When the p-value is less than 0.05 (< 0.05), the null hypothesis is rejected. There is a significant difference in passing rates between the groups. On the other hand, when the p-value is equal to or greater than 0.05 (≥ 0.05), the null hypothesis fails to be rejected, which means there is no significant difference.

Percentage Error Analysis

Besides, in this study, the percentage error, PE, was used to measure the difference between an observed/reference value and the measured value, and it is expressed as a percentage (%). A smaller PE indicates the measured value is closer to the true observed/reference value, while a larger percentage error suggests a greater discrepancy. **Equation (2)** displays the PE formula, where it is calculated by dividing the difference between observed/reference and measured values by the observed/reference value, multiplied by 100%

$$PE = \left|\frac{V_1 - V_2}{V_1}\right| \times 100\% \quad (2)$$

where V_1 is the observed/reference value, while V_2 is the measured value.

RESULTS AND DISCUSSIONS

In this section, the pedagogy for teaching and learning the rationale behind the practice is presented first, and the constructive alignment follows it in planning for teaching. Then, active and collaborative learning in facilitating a positive and engaging learning experience is also illustrated.

Pedagogy for Teaching and Learning: The Rationale Behind the Practice

Aligning Pedagogy to the Learning and Teaching Approach

Compared with andragogy, I am more interested in pedagogy because I am using it for a teaching unit in the Engineering First Year department. As far as I know, pedagogy focuses on how teachers teach the contents of the syllabus in a unit, teacher intentions, instructional strategies, knowledge, and student reactions (Cess-Newsome, 1999; Shing et al., 2018; Smith & Neale, 1989). So, students can gain a deeper grasp of fundamental material from the syllabus. It is what I am doing now that needs meaningful classroom interactions between the lecturer and students to deliver the content within a semester. Pedagogy aims to present a course that can enhance students' involvement in their learning to develop skills and attitudes (Cotton et al., 2007; Magolda, 1992). Meanwhile, I usually gather the students' feedback on the teaching delivery and adjust my teaching techniques to meet their requirements.

On the other hand, the students are being questioned instead of answering their questions directly to cultivate their critical thinking skills. Understandably, all students are future engineers who need to solve real-world engineering problems that engage them in higher-order thinking skills (Živkovič, 2016). Moreover, I often link the course's content with engineering-related matters to gain their interest and curiosity toward learning the content. To develop a self-regulated learner, students should be advised to know how to pinpoint the issue, collect information, decide what's relevant, have self-evaluations, conclude, etc. (Graham et al., 1992; Wallin & Adawi, 2018). It can be said that pedagogy affects learning by leading the students with the skills necessary to develop their ideas. Hence, aside from what they learnt, they should also have known how they learnt. Lastly, I will continue to implement pedagogical approaches as well as discover new pedagogical teaching styles that suit my classroom.

Key Beliefs and Values Associated with the Pedagogy Concerning the Teacher, Learner, and the Relationship Between Learners

In my opinion, the key beliefs and values associated with the pedagogy I identified with the teacher, learner, and the relationship between learners are integrity, fairness, mutual respect, and responsibility. These beliefs and values are required to achieve my teaching and learning philosophy since I aim to convey teaching values, beliefs, and goals to students and then gather judgment on the quality of teaching and evidence of my teaching effectiveness (Kumaravadivelu, 2012). Besides professional skills, practices, and expertise in disciplinary knowledge, a lecturer needs to have integrity. I need to respect all students regardless of their nationalities, genders, religions, appearances, ages, social standings, abilities, and achievements. With integrity, I can gain the trust of students, engage well with the students, and form a good teacher-student relationship (Gregory et al., 2016). Moreover, as a lecturer, I am required to be fair to every student, including the assessments given and the marks. Furthermore, the marked past assessments and marking schemes are made available and transparent in Moodle and Blackboard. So, students can review them anytime, and they have equal opportunities to score high marks in the teaching unit.

Additionally, both the lecturer and students must have mutual respect and responsibility (Roache & Lewis, 2011; Wolhuter et al., 2020). A lecturer should apply learner-centred pedagogy to respect and understand how students can learn better and meet their learning requirements. For

instance, I adjust my teaching methods to meet students' requirements as well as engage students with fundamental concepts, principles, and connections of the teaching topics. It is an essential task for the students to achieve the unit learning outcomes and concepts of the topics that may relate to the other units to a higher degree. Also, I use the brainstorming method and concept maps, where a summary of all the topics with visual organisation and representation of knowledge is prepared on a piece of A4-sized formula sheet. My efforts have been well acknowledged by the students in my teaching evaluation report. On the other hand, students are responsible for attending the classes and assessments, as well as contacting and informing their lecturers about their problems and needs (Macfarlane, 2016). Besides, students are advised to continue learning and group study with their peers to enhance their learning experience. Lastly, the effectiveness of my learning and teaching philosophy is associated with the abovementioned key beliefs and values to achieve good outcomes. Thus, I will continually build a good relationship with the students, evaluate the quality of learning and teaching, and make necessary amendments if required.

Constructive Alignment: Planning for Teaching

Articulating Learning Outcomes Clearly to Learners

I apply constructive alignment in every teaching unit where planning for teaching focuses on what it is intended that students should learn and how they should express their learning, clearly stated before teaching takes place (Jaiswal, 2019). Thus, I noticed that I briefed students about the learning outcomes stated in the unit outline more often in each lecture, workshop, and lab session. These learning outcomes inform students what they are expected to know, understand, or be able to do to be successful in the learning unit. Also, each assessment of a unit mapped to the unit learning outcomes is developed to test their knowledge. Constructivism assumes that students come to study and bring with them prior knowledge and experiences (Meyer, 2004), which will be valuable for future learning. Hence, it is an essential task, as students need to achieve the unit learning outcomes and concepts of the topics that may relate to the other units to a higher degree.

On the other hand, the brainstorming method and concept maps, which are my strategies, are also discussed by Sim and Pop (2012), Abd Karim et al. (2016), Filgona et al. (2016), and Adeyemi and Adesola (2021). The student commented on it in the full unit report, "My formula sheet is very helpful in my studies." Besides, in class, I also use e-learning programmes such as an e-book, Wikipedia, and YouTube, which can be excellent sources to get extra information about teaching topics. This flipped classroom method is an active and learner-centred technique that can increase the quality of learning delivery (Ozdamli & Asiksoy, 2016). Lastly, the effectiveness of my learning and teaching philosophy depends on the learning and teaching outcomes. Thus, I will continually evaluate the learning and teaching philosophy statements and make necessary amendments when those statements do not work consistently toward those outcomes.

The Significance of Constructive Alignment in Teaching and Learning

A constructive alignment is a student-centred approach to curriculum design and session plan, which is discussed in the context of designing a programme of study (Katawazai, 2021). A proper curriculum design and session plan for new content delivery is important since it allows students to make sense of their learning based on their sense-making or through the co-construction of learning through social interactions with peers and lecturers. These interactions, including sharing ideas and feedback from peers, lecturers, and themselves, can lead students to engage and create opportunities to have higher-order thinking. Meanwhile, a constructive alignment, which is a student-centred method, focuses on how the students learn and the relationship between teaching and learning. It is how a lecturer gives opportunities for students to build the knowledge and skills to allow students to perform the tasks, as well as create a place for creativity and innovation development.

When talking about constructive alignment in the context of designing a programme of study, the graduate capabilities focusing on what the student will know are also important (Spencer et al., 2012). Moreover, student achievement of the graduate capabilities is mastered via the implementation of outcome-focused education. Hence, these graduate capabilities that scaffold backward thinking about the skills, knowledge, or capabilities required to be developed are mapped with the learning outcomes designed for a unit. Besides learning outcomes, constructive alignment also involves the assessment method, teaching, and learning activities, where the assessment method is adjusted to the intended learning outcomes, and students construct knowledge through teaching and learning experiences. The performance of students in the assessments of a unit demonstrated evidence of how they meet the outcomes, where they show the construction of knowledge and skills. Hence, I discuss this constructive alignment that consists of learning outcomes that are mapped to the graduate capabilities, assessment methods, and teaching and learning with my students. Hence, students are aware of the constructive alignment in the assessment, which is transparency and validity. Finally, I will continue applying constructive alignment between the aimed learning outcomes and learning activities and measure the achievement of those outcomes.

Active and Collaborative Learning: Facilitating Positive and Engaging Learning Experience

Learning Activity Links to Learning Outcomes and Assessment

The learning activity that I used is more content-focused and interactive, in which the learning outcomes of a class are included. Moreover, I used constructive alignment in designing the learning activity, and constructive alignment is one example of a pedagogical approach based on constructivism. I often brief students about the learning outcomes stated in the unit outline, as well as explain them to the students in every lecture, workshop, and lab session. This is because these learning outcomes are the foundation of course design and assessment and help students focus on what is essential (Martin et al., 2019). These learning outcomes describe what they are expected to know, understand, or be able to do to be successful in the learning unit. Also, each assessment of a unit mapped to the unit learning outcomes is developed to test their knowledge (Fisher & Walker, 2014). Besides achieving good marks in the assessments, I would emphasise and motivate students to equip themselves with the knowledge that can be used in their future careers. Besides, alignment occurs when the learning activities are engaged with the students,

and engagement involves two-way interaction between the teacher and the students in the classes to help them develop their knowledge, skills, and understanding. Hence, I always try my best to have more engagement with the students as well as align the learning activities with fundamental concepts, principles, and connections of the teaching topics. It is an essential task, as students need to achieve the unit learning outcomes and concepts of the topics that may relate to the other units in higher degrees. Lastly, I will continually attend more workshops to improve my learning activities to enhance the teaching unit deliveries.

The Positive Impact of the Implemented Learning Activity and Action Plan

My learning activity focuses more on the content and interaction that connect to the learning outcomes. To understand how well my learning activity in a class is, after a lecture is delivered, I usually implement the learning activities, including Kahoot, Socrative, and quizzes in Moodle, during and outside the classes. These task-based learning activities work well when most of the students enjoy and try them (Willis, 2021). Also, these activities should enable students to engage with and develop their skills, knowledge, and understanding in different ways. I would let students know the purpose of implementing the learning activities in a teaching unit. Students should know that they are designed to develop learning that supports learning outcomes. Moreover, these activities also help to foster students' curiosity and critical thinking. Most importantly, these activities enable the students to understand and learn from their own experiences since they are practising the learning activities. So, students are willing to participate in the planned and organised learning activities. After that, I will check the results of these activities. If the student's performance in Socrative and Kahoot is poor, additional explanations on the topics and questions are provided in the coming classes.

To meet the diverse learning styles and needs of students, I practice e-learning programmes in teaching and learning, which transform traditional classroom-based learning to digital learning to facilitate inclusive pedagogy and culturally responsive teaching (Germain-Rutherford & Kerr, 2008). For instance, I used technology-based learning, which is an AI-tool-powered platform, namely EdApp, to produce online spaced-retrieval practices in the face-to-face learning mode to support my pedagogical approach and high-quality teaching content and materials, and deliver multiple clinics (revision classes). These spaced-retrieval practices involve learning that takes place over time with rest periods between practice sessions. Students used this EdApp, which provides action plans for each question in the spaced-retrieval practices to serve as feedback to students. These action plans enable students to recap their lectures to have a better understanding of the teaching materials and allow students to focus their study efforts on those weaker areas, improving overall comprehension and knowledge. They experienced the real-time feedback practices that can facilitate their learning, and it is the primary emphasis remaining on student involvement with and driving learning.

As shown in **Table 1**, my approach to using this AI tool has significantly improved the passing rates for the midterm test from 67.86% and 64% in the year 2023 to 80.33% in the year 2024. Notice that the PE values between the passing rates for the midterm test between S1 2024 with S1 2023 and S2 2023 are 15.25% and 20.33%, respectively. These 15.25% and 20.33% of PE values quantify the magnitude of difference among the passing rates of the midterm tests, but do not confirm statistical significance. Hence, Fisher's Exact Test, which is a hypothesis test, is used. The p-value from Fisher's Exact Test for S1 2024 and S1 2023 is 0.257, while for S1 2024 and S2 2023 it is 0.18. Both p-values are greater than 0.05, so the null hypothesis fails to be

rejected. These results indicate that there are no statistically significant differences in passing rates of the midterm tests between S1 2024, S1 2023, and S2 2023 at the 5% significance level. As for the passing rates for the final exam in S1 2024, S1 2023, and S2 2023, their PE values are 44.54% and 32.59%, respectively, where their PE values are higher than the PE values for the midterm tests. From Table 1, the p-values for the final exams in S1 2024, S1 2023, and S2 2023 are 0.0003 and 0.0035, which are lower than 0.05 (<0.05). Therefore, the null hypothesis is rejected, in which there are statistically significant differences in passing rates for the final exam between S1 2024, S1 2023, and S2 2023 at the 5% significance level. It can be concluded that the spaced retrieval practice has positive impacts on the assessments, especially the final exam in S1 2024. Meanwhile, the overall passing rate of this engineering unit in S1 2024 has improved to 95.08% (Wan Sieng et al., 2025). My pedagogical approach of using EdApp was recognised by International Innovation ARSVOT Malaysia 2024 (IAM2024) and received a Gold Award. Moreover, based on the online anonymous questionnaire survey for the spaced retrieval practice, all students fed back that the spaced retrieval practice is effective, and 90.2% of students enjoyed the spaced retrieval practice.

Table 1. The obtained results *before and **after the spaced retrieval practice for the mid-semester test and the final exam for an engineering unit

Semester/year	**S1 2024**	*S1 2023	PE (%)	p-value	*S2 2023	PE (%)	p-value
Total number of students	61	28	-	-	25	-	-
Number of students who passed the midterm test	49	19	-	0.257 (>0.05)	16	-	0.18 (>0.05)
Number of students who failed the midterm test	12	9	-		9	-	
Passing rate for the midterm test	80.33%	67.86%	15.25	-	64.00%	20.33	-
Number of students who passed the final exam	55	14	-	0.0003 (<0.05)	17	-	0.0035 (< 0.05)
Number of students who failed the final exam	6	14	-		8	-	
Passing rate for the final exam	90.16%	50.00%	44.54	-	68.00%	32.59	-

*S1 and S2 are Semesters 1 and 2, respectively.

In conclusion, students who have experienced this AI-related e-learning programme that supports their active learning can guide their attitudes and improve their understanding and thinking. Moreover, I would communicate further with the students to get some feedback on the teaching delivery and the learning activities. I will make some adjustments according to the students' comments and suggestions. Lastly, I will continually search for different online platforms or any interactive learning activities for the students to have better engagement and teaching delivery, as well as build a good relationship with the students.

CONCLUSION

This study aims to present the pedagogy of the learning and teaching of an action-research perspective in an engineering mathematics unit. In this study, the rationale behind the practice of scholarly approaches for the pedagogy of learning and teaching, the constructive alignment linked to planning for teaching engineering students, and collaborative learning in facilitating a positive and engaging learning experience were reported. Additionally, the action-research perspective that employs developing a teaching style to get an idea of the teaching and learning approaches was shared. Concerning my teaching style, I have planned programmes of study and designed teaching styles or activities based on constructive alignment, how students learn, both generally and within their subject/disciplinary areas, and the available use and value of appropriate learning technologies. Curtin University has a diverse community, so I have developed learning activities that meet the diverse learning styles of individual learners and use universal design principles to optimise equality of opportunity for learners. By taking into consideration the diversity in learning styles and the value of feedback, I structure the teaching styles or activities as they create an impact on the development of the students' learning in my teaching units. Therefore, efforts are required to know the individual and create a learning environment that can help the learning process and is suitable for students with multiple intelligences and learning styles to improve their learning. I design and provide teaching styles or activities with a structured programme that consists of a competency framework of theories and concepts for the teaching units, as well as demonstrating the application of those theories and concepts in practice. To get the value of feedback, I use online evaluation, in-class evaluation, and discussion with students at the end of the class to evaluate the efficacy of the structured programme. Also, I continue doing self-action-research perspective to think about or reflect on what I do.

Co-Author Contribution

The author declares no conflict of interest. Wan Sieng Yeo conducted this research study, prepared the literature review, handled the research methodology and data entry, performed statistical analysis, and interpreted the results.

Acknowledgements

The author would like to thank Curtin University Malaysia for providing financial support for this project through the Curtin Malaysia Teaching Innovation Project (CMTIP) 2022 and Curtin Malaysia Teaching Support (CMTS) 2024 Round 2 grants.

Ethics Statement

This study was conducted following ethical guidelines. Informed consent was obtained from all participants. This study underwent the Curtin University Low-Risk review process, and ethical approval (Approval Number: HRE2024-0173) was granted.

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