An M-MIAP Learning Model to Develop Engineering Competency of Pre-Engineering Students via Metaverse

Junjiraporn Thongprasit* and Pallop Piriyasurawong

***Abstract*—This research aimed to develop an M-MIAP learning model via Metaverse to develop the engineering competencies of pre-engineering students, and to evaluate the appropriateness of the model. This research is divided into two phases. In the first phase, literature studies of various learning models were conducted to construct the matrix of Metaverse elements and engineering competency for the M-MIAP model. The second phase was the evaluation of the appropriateness of the developed M-MIAP model by various expert stakeholders in the fields of information technology, communication technology, Metaverse, and pre-engineering. It was found that the M-MIAP model consists of input, M-MIAP learning process, engineering competency, and feedback. This research uses Metaverse in the learning process to provide students with a new virtual dimension experience. This collaborative learning process also results in a deeper comprehension of the subject matter and increases educational opportunities for students. The assessment result was rated as "very good", suggesting the suitability of the overall learning model. This indicates that the M-MIAP model can be utilized to cultivate engineering competencies in pre-engineering students, and to prepare for the impending transition to the digital era. It also supports the educational system in achieving the same level of enduring quality.**

***Index Terms*—MIAP learning, Metaverse, engineering competency**

I. INTRODUCTION

Currently, technology, and global economic and social frameworks are rapidly transitioning into the digital age [1, 2]. Many nations worldwide are implementing national reforms for economic and social growth, which include educational aims to develop and enhance educational opportunities at all levels. In addition, currently, technology and global economic and social frameworks are rapidly transitioning into the digital age [1, 2]. Many nations worldwide are implementing national reforms for economic and social growth, which include educational aims to develop and enhance educational opportunities at all levels. In addition, science and engineering is still essential foundation in driving society today because engineers play a significant role in creating new innovations for the future, and because success in science and technology requires an engineering background [3]. Therefore, it is important to develop a teaching curriculum for students to have engineering competencies. Engineering competency means the necessary professional abilities of an engineer [4], including the skills and characteristics necessary for preparing for a career in engineering, and for a successful transition to work, by being able to apply the technical knowledge learned in the industry [5, 6]. In addition, the continuous improvement of all aspects of engineering skills and knowledge is very important for the growth of today's technology [7]. That is why the pre-engineering curriculum has been developed, which is a specific curriculum of the Pre-Engineering School developed to produce students with the skills and characteristics that are ready to become future engineers. It is a course that focuses on students' training in practical skills, builds on technical experience, scientific knowledge, fundamental competencies in engineering, and practical experience in factories to meet the needs of the industry.

A teaching technique that clearly emphasizes learner competency is the MIAP learning process, which is a teaching and learning process that focuses on skill training and development of learner competency. It enables learners to observe and acquire the process of correct procedures and to learn in such a way that knowledge is retained permanently [8–13]. MIAP includes four steps: Motivation, Information, Application, and Progress (Fig. 1). These four elements of the MIAP learning process are each essential to a person's learning, if any one step is missing, the learning will not be as successful as expected. If any one step is missing, the learning will not be as successful as expected at all. As vocational certificate education emphasizes practical competency skills, the MIAP learning process is suitable for teaching and learning at this level. As vocational certificate education emphasizes practical competency skills, the MIAP learning process is suitable for teaching and learning at this level. Because students will learn and observe the correct procedure, after which their behavior will be transformed, they will be able to apply what they learned indefinitely. To prepare the students for internships in the workplace by enabling them to apply the various skills they have acquired to tackle the many challenges encountered in their workplaces.in the workplace, by enabling them to apply various skills, which they have acquired to tackle many challenges encountered in their workplaces [14–16].

The situation of COVID-19 epidemic has greatly affected pre-engineering students as well as courses that emphasize practical training and require students to be placed in external internships. COVID-19 has deprived these students of the opportunity to develop practical skills or experience real-world situations to prepare them for future careers. One of the best solutions is to use technology to overcome those challenges by using Metaverse to transform traditional teaching and learning into a modern technology-enabled education system.

The Metaverse is a virtual shared space that is created by

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Junjiraporn Thongprasit and Pallop Piriyasurawong are with Department of Technological Education and Information, Faculty of Technical Education, King Mongkut's University of Technology North Bangkok, Bangkok, Thailand.

*Correspondence: junjiraporn.t@op.kmutnb.ac.th (J.T.)

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the convergence of physical and virtual reality [17]. It has the potential to revolutionize the way we learn and develop competencies, particularly in engineering [18]. By integrating Metaverse with learning processes, we can create immersive and interactive environments that allow learners to develop and apply engineering competencies in a dynamic and engaging way [19, 20]. One of the key benefits of integrating Metaverse with learning processes is that it provides a platform for experiential learning [21]. Learners can engage in simulations, virtual experiments, and collaborative projects that allow them to practice and refine their engineering competencies in a risk-free environment. This approach to learning can be particularly valuable for developing competencies that are difficult or dangerous to practice in real-life situations [22]. Another benefit of integrating Metaverse with learning processes is that it can provide learners with access to an expanded range of resources and expertise [23]. Through Metaverse, learners can connect with other learners, experts, and resources from different locations and backgrounds, allowing them to broaden their perspectives and knowledge base [24, 25]. This approach to learning can be particularly valuable for developing competencies that require interdisciplinary knowledge and collaboration.

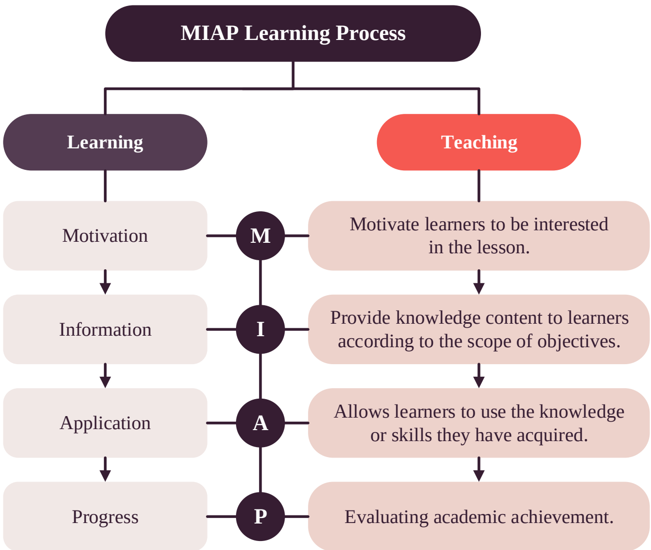

Fig. 1. MIAP learning process.

Moreover, integrating Metaverse with learning processes can also provide learners with opportunities for personalized and self-directed learning. Learners can customize their learning experiences based on their individual needs, preferences, and learning styles. This approach to learning can be particularly valuable for developing competencies that require creativity, critical thinking, and problem-solving skills [26, 27].

In conclusion, integrating Metaverse with learning processes can be a powerful tool for developing engineering competencies. It can provide learners with experiential, collaborative, interdisciplinary, personalized, and self-directed learning opportunities that can enhance their competencies and prepare them for the complex and rapidly changing engineering landscape [18].

In this research, the present M-MIAP model combines Metaverse technology with the MIAP learning process to develop pre-engineering students' competencies, readying them to advance to be proficient engineers. In order to ensure that the developed learning model is appropriate and can be used for the greatest benefit, this learning model will be evaluated by experts before it is implemented.

A. *Objectives of the Research*

1) To develop the M-MIAP learning model via Metaverse to develop the engineering competency of the pre-engineering students.
2) To evaluate the suitability of the M-MIAP learning model via Metaverse for developing engineering competencies for pre-engineering students.

B. *Research Hypothesis*

The results of the expert's evaluation of the suitability of the M-MIAP model were at a very good level.

C. *Conceptual Framework*

The conceptual framework of the research was presented in the form of system flow, namely the input, process, and output. As part of the input, the researcher synthesized theories related to the Metaverse and MIAP learning from relevant literature and research. Then, the results of synthesis were used to develop the M-MIAP model to develop pre-engineering students to have engineering competency to prepare them to step into the future world as shown in Fig. 2.

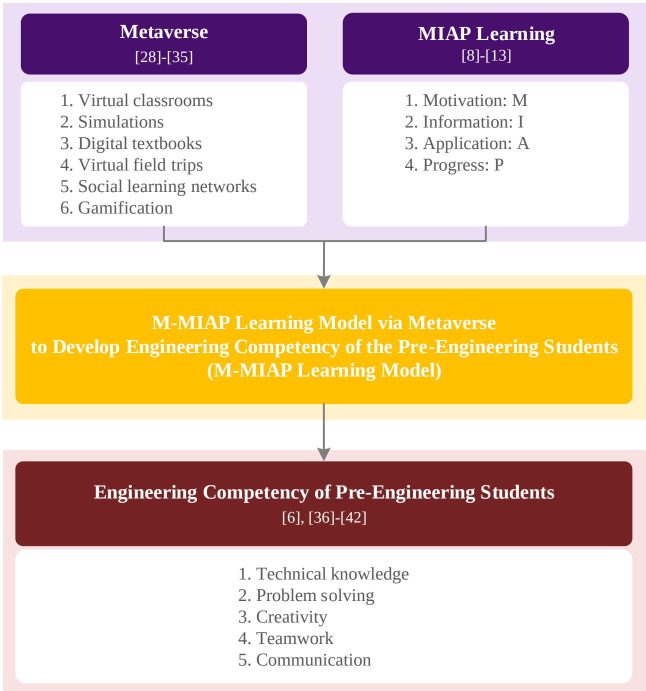

Fig. 2. Conceptual framework.

The development of the M-MIAP model includes the following steps: to study the learning process of MIAP, which is a teaching technique that focuses on learners' competency and is suitable for teaching a pre-engineering curriculum that focuses on practical skills training for learners. The MIAP learning process consists of four steps: motivation, information, application, and progress. Next, to synthesize elements of the Metaverse, a technology that creates an immersive learning experience for learners and increases the opportunity for them to practice their skills better. Then, to use the M-MIAP model. From the synthesis of engineering competencies from relevant documents and research, learners must acquire technical knowledge, problem-solving skills, creativity, teamwork skills, and communication skills.

II. Research Methodology

The research method was divided into two phases according to the research objectives as follows:

Phase 1: Develop the M-MIAP model. First, MIAP learning, Metaverse, and engineering competency were reviewed. There were 47 issues published in the international research-based system between 2018 and 2023. After that, elements of Metaverse were synthesized, and engineering competency was presented in an illustration plan and essay, as shown in Fig. 3 and Fig. 4. The research tool's validity was analyzed by content analysis.

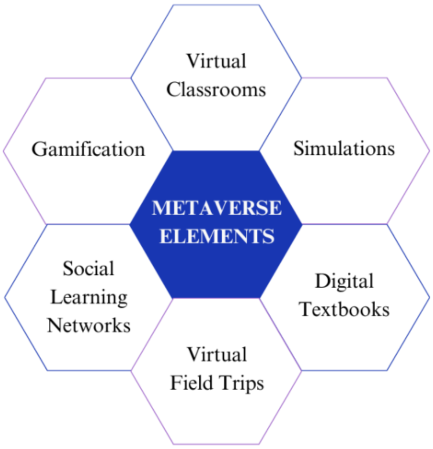

Fig. 3. Element of Metaverse.

Fig. 4. Engineering competency.

Phase 2: The suitability of the M-MIAP model was evaluated using questionnaires as a data collection tool to gather the judgements of nine experts, who each have more than five years of experience in the relevant field. Therefore, the experts were selected, each with a specialism in communication and information technology for education, the Metaverse, and pre-engineering. The research instrument was the M-MIAP model. All survey questions utilized a 5-point Likert scale. Arithmetic mean and standard deviation were utilized in the data analysis.

A. Population and Sample

The population used in this research were experts with expertise in information and communication technology, Metaverse, and pre-engineering. They were selected using a purposive sampling method as follows:

1) Information technology and communication academics who specialize in information technology and communication, graduated with a doctorate degree, and have a position as assistant professor or higher.
2) Metaverse experts with at least five years of knowledge and experience in the Metaverse and are knowledgeable about the Metaverse implementation in education.
3) Pre-engineering specialists who are academic personnel in pre-engineering schools and have at least ten years of teaching experience in pre-engineering programs.

B. Variables

The independent variable was the M-MIAP learning model via Metaverse for developing engineering competency in the pre-engineering students.

The dependent variable was the evaluation results of the appropriateness of the M-MIAP learning model via Metaverse to develop engineering competency in the pre-engineering students.

III. Results of Research

A. The Result of Developing the M-MIAP Model

1) The synthesis of Metaverse elements

The Metaverse has the potential to transform education by providing immersive and interactive learning experiences for students.

The researcher has synthesized documents and related research about elements of the Metaverse (see Table I) and found that the key components of the Metaverse for education include:

- Virtual Classrooms: digital environments where students and teachers can interact in real-time. Virtual classrooms can be customized to fit the needs of specific classes, with features such as whiteboards, interactive 3D models, and real-time collaboration tools.
- Simulations: created in the Metaverse to provide students with hands-on learning experiences. For example, science classes could use simulations to study the human body, while history classes could use simulations to recreate historical events.
- Digital textbooks: these can be digitized and embedded with multimedia content, such as videos, animations, and interactive quizzes. Digital textbooks can be accessed from anywhere, making education more accessible to students.
- Virtual field trips: the Metaverse can be used to take students on virtual field trips to places that may be too distant or too expensive to visit in person. For example, students can explore ancient ruins, visit art museums, or take a virtual tour of a foreign country.
- Social learning networks within the Metaverse: these can provide a platform for students to connect and collaborate

with each other. These networks can be used to facilitate group projects, peer-to-peer learning, and online discussions.

- Gamification: this can be used to make learning more engaging and interactive. For example, students could earn points, badges, or rewards for completing assignments, which can increase motivation and help to reinforce learning.

Together, these components can create a more engaging and interactive learning experience for students, allowing them to explore and learn in a digital environment that is both fun and educational.

TABLE I: THE SYNTHESIS ELEMENT OF METAVERSE

Metaverse Elements	[28]	[29]	[30]	[31]	[32]	[33]	[34]	[35]	Metaverse Elements
Virtual Classrooms	✓	✓	✓	✓	✓	✓	✓	✓	✓
Simulations	✓	✓		✓	✓	✓			✓
Digital Textbooks	✓	✓	✓	✓	✓		✓	✓	✓
Virtual Field Trips	✓	✓	✓	✓		✓		✓	✓
Social Learning Networks	✓	✓	✓	✓	✓	✓	✓	✓	✓
Gamification	✓		✓		✓	✓		✓	✓

TABLE II: THE SYNTHESIS OF ENGINEERING COMPETENCY

Engineering Competencies	[6]	[36]	[37]	[38]	[39]	[40]	[41]	[42]	Engineering Competencies
Technical knowledge	✓	✓	✓	✓	✓	✓	✓	✓	✓
Problem solving	✓	✓	✓	✓	✓	✓		✓	✓
Creativity			✓	✓	✓	✓	✓	✓	✓
Teamwork	✓	✓	✓		✓	✓	✓	✓	✓
Communication	✓	✓	✓	✓	✓		✓		✓

2) The synthesis of engineering competence

Engineering competence refers to the ability to apply scientific and technical knowledge to solve complex problems and design solutions for real-world challenges. It involves a combination of technical skills, critical thinking, and practical experience that allows an engineer to successfully execute their responsibilities [43–45].

Accordingly, the researcher has synthesized documents and related research about engineering competency (see Table II) and found that the knowledge, skills, and characteristics that engineers need in order to work efficiently are as follows (see also Fig. 4):

- Technical knowledge skills: engineers must have a deep understanding of the scientific principles that underpin their field of work. This includes knowledge of mathematics, physics, and other sciences that inform the design and development of engineering solutions.
- Problem-solving skills: engineers must be able to analyze complex problems, identify potential solutions, and select the best course of action based on available data and resources. This requires a strong analytical mind and the ability to think creatively.
- Creativity skills: the ability to think creatively, invent ideas, and find innovative solutions to resolve difficult situations.
- Teamwork skills: the ability to effectively collaborate with others, working with cross-functional teams, including colleagues, clients, and contractors, to achieve mutual goals.
- Communication skills: engineers must be able to effectively communicate their ideas and solutions to a variety of audiences, including other engineers, stakeholders, and non-technical colleagues. This requires strong verbal and written communication skills.

Overall, engineering competence is a critical component of successful engineering practice, allowing engineers to design and implement solutions that address complex problems and drive innovation in a wide range of industries.

3) Development of M-MIAP learning model

The researcher used the results from the synthesized literature and relevant research on issues related to MIAP learning, Metaverse, and competency engineering to design and develop the M-MIAP model as shown in Fig. 5.

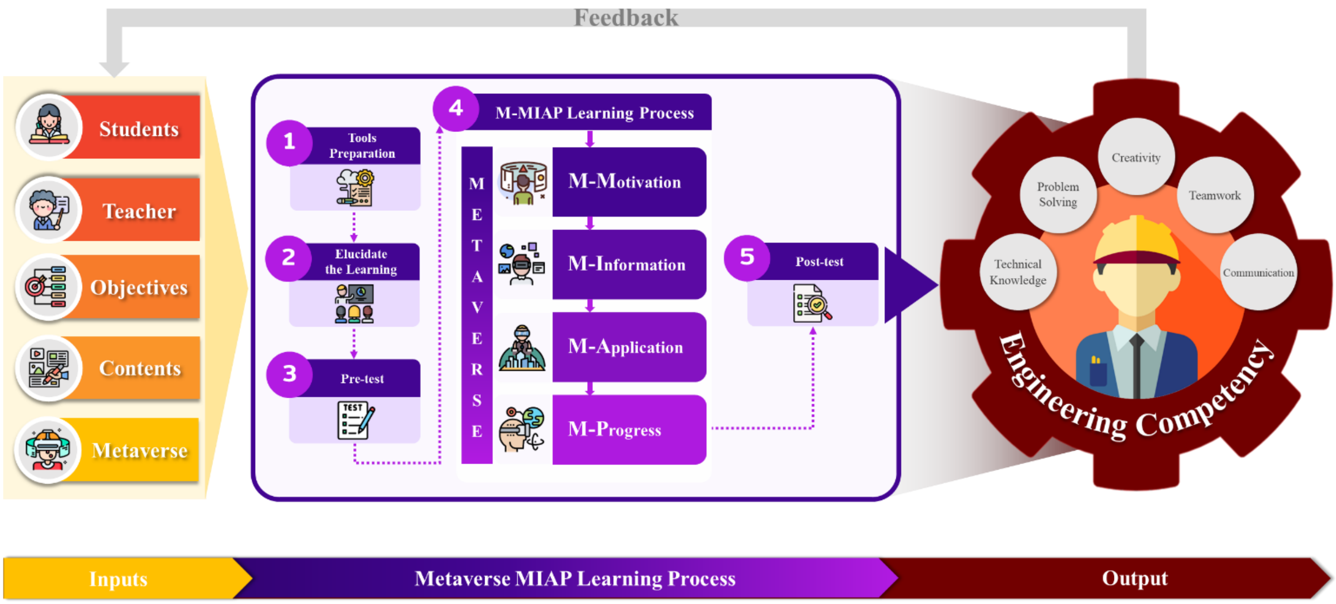

Fig. 5. M-MIAP learning model via Metaverse to develop engineering competency of pre-engineering students (M-MIAP learning model).

From Fig. 5, the M-MIAP model consists of four components:

a) Inputs

The separate inputs are as follows:

1) Students

Pre-engineering students who are proficient with computer technology and can communicate via the internet.

2) Teachers

Persons who are capable of imparting knowledge to students while being able to use Metaverse across other platforms.

3) Objectives

The learning objectives and skills that the teacher decides for the students. This must be consistent with the topic of knowledge in each class and what the students wish to accomplish.

4) Contents

Subject matter of the vocational courses of The Thai-German Pre-engineering School, KMUTNB, Thailand.

5) Metaverse

The virtual 3D space shared by students and teachers represented through digital avatars to interact without boundaries as if in the real world. This can be used as a learning management area to develop students' engineering competencies.

b) Metaverse-MIAP Learning Process

This section deals with the process of learning with Metaverse technology, which is divided into five steps.

1) Tools preparation

Teachers prepare materials, software, and hardware useful for M-MIAP Learning via Metaverse. This can help the pre-engineering students to develop their engineering competencies at all levels, including checking their own devices, which they use to learn. This will allow the students to familiarize themselves with the tools which they use for their experiment.

2) Descriptive learning

This explains in detail how the M-MIAP learning process is used to improve learners' engineering competencies, so that they understand the learning objectives, how to learn, evaluate their learning, and use technology in the Metaverse environment.

3) Pre-test

This is a test to determine the engineering skill level of students before learning through Microsoft Teams, and to inform teachers about the students' condition before beginning their studies.

4) M-MIAP learning process

The M-MIAP learning process consists of four steps: M-Motivation, M-Information, M-Application, and M-Progress. Each step has different learning activities, and such learning activities were organized in the Metaverse classroom space on the Metaverse platform as shown in Table III. The Metaverse classroom space is as follows:

- The live-learning space: a space used for live learning where students and teachers interact in real time through an online learning platform using technology and tools to communicate and share information.
- The self-learning space: a learning space that the school provides for students who want to use it to review lessons backwards or expand their learning beyond the lesson content. Students can use the service without limitation on time or place of learning.
- The co-learning space: a space for students to use for shared activities or learning to enhance their learning experience and exchange of knowledge among themselves.

However, if a student's learning achievements do not meet the established objectives, the teachers can review the previous learning process to re-explain sections that the students did not grasp, or repeat the exercise again to gain deeper comprehension. The above are the four crucial steps of the learning process which, when not followed, may cause the learning process to fail.

TABLE III: M-MIAP LEARNING PROCESS

M-MIAP Process	Metaverse Classroom Space	Learning Activity
Metaverse-Motivation	- Live-learning space	- The teacher takes the students into the Metaverse, introduces the topic, and explains the learning objectives in the live-learning space on the Metaverse platform, so that the student is informed of the topic and lesson objectives. - The teacher motivates the students to take an interest in the lesson by presenting examples of real-life situations in the live-learning space for students to visualize and to encourage students to analyze the situation and solve problems that arise. - The teacher summarizes and identifies the issues of interest in resolving the problems in the live-learning space to ready the students for the information process.
Metaverse-Information	- Live-learning space - Self-learning space	- Teachers provide knowledge content to students, in accordance with the learning objectives, through presentation slides or videos in the live-learning space on the Metaverse platform. In addition, if students want to review lessons or learn more later, they can enter the self-learning space on the Metaverse platform at any time to study independently.
Metaverse-Application	- Live-learning space - Co-learning space	- Teachers assign tasks to students so they can apply their knowledge to solve problems or create collaborative work in the live-learning space on the Metaverse platform. After that, each group of representatives present their knowledge or creations based on the problems assigned by the teachers in the live-learning space on the Metaverse platform.
Metaverse-Progress	- Live-learning space - Co-learning space	- The teacher assesses the engineering competencies of the pre-engineering students through quizzes or assignments that they have assigned to the students in the live-learning space and co-learning space on the Metaverse platform. The engineering competencies for pre-engineering students have a total of five competencies, as follows: 1) Technical knowledge 2) Problem solving 3) Creativity 4) Teamwork 5) Communication

5) Post-test

This is a test that measures students' content knowledge on engineering competencies through Microsoft Teams to evaluate their learning achievements after completing the M-MIAP learning process.

c) Output

This section deals with the evaluation of students' engineering competency after using M-MIAP model to improve the quality of their teaching and learning. At this phase, the student's engineering competency is assessed in the cognitive domain, affective domain, and psychomotor domain. The engineering competency is divided into five sub-competencies: technical knowledge, problem solving, creativity, teamwork, and communication.

d) Feedback

To develop the engineering competencies in pre-engineering students and to optimize the advantages of M-MIAP model, it is necessary to analyze the gathered data and student outcomes, along with the recommendations, expert opinions, and the results of the learning process. This can be helpful in improving the quality of the M-MIAP learning process.

B. Evaluation of the Suitability of M-MIAP Model

The M-MIAP model was evaluated by nine experts in information technology and communication, Metaverse, and pre-engineering. It was evaluated through a suitability assessment form developed by the researcher. The results are shown in Table IV.

TABLE IV: THE APPROPRIATENESS OF THE M-MIAP LEARNING MODEL

Description	Result		Rate of
	Mean	S.D.	Appropriateness
1. Input			
1.1 Students	4.78	0.44	Very good
1.2 Teacher	4.78	0.44	Very good
1.3 Objectives	4.78	0.44	Very good
1.4 Contents	4.67	0.71	Very good
1.5 Metaverse	4.56	0.73	Very good
Average	4.71	0.15	Very good
2. M-MIAP Learning Process			
2.1 Tools Preparation	4.78	0.44	Very good
2.2 Elucidate the Learning	4.78	0.67	Very good
2.3 Pre-test	4.89	0.33	Very good
2.4 Learning Process (Motivation, Information, Application, Progress)	4.67	0.50	Very good
2.5 Post-test	4.89	0.33	Very good
Average	4.80	0.14	Very good
3. Engineering Competency			
3.1 Technical knowledge	4.89	0.33	Very good
3.2 Problem solving	4.67	0.50	Very good

Description	Result		Rate of Appropriateness
	Mean	S.D.	
3.3 Creativity	4.56	0.53	Very good
3.4 Teamwork	4.67	0.50	Very good
3.5 Communication	4.89	0.33	Very good
Average	4.73	0.10	Very good
4. Feedback (Assessment results of engineering competency of pre-engineering students)	4.78	0.44	Very good
5. The M-MIAP learning model via Metaverse to develop engineering competency of pre-engineering students is suitable for practical use.	4.67	0.50	Very good
Overall average	**4.75**	**0.48**	**Very good**

Table IV shows the evaluation by nine experts of the appropriateness of the M-MIAP model. With respect to the evaluation results of the M-MIAP model, overall, it was found to be at a very good level (Mean = 4.75, S.D. = 0.48). When examining each component, input was at a very good level (Mean = 4.71, S.D. = 0.15), while the M-MIAP learning process and engineering competency were found to be at the very good level of Mean = 4.80, S.D. = 0.14, and Mean = 4.73, S.D. = 0.1, respectively. Furthermore, feedback was found to be at a very good level (Mean = 4.78, S.D. = 0.44). Overall, the results are at a very good level (Mean = 4.78, S.D. = 0.44), suggesting that the M-MIAP model can be of practical use to develop the engineering competencies of pre-engineering students.

IV. Discussion and Conclusions

The M-MIAP learning model to develop engineering competencies in pre-engineering students via the Metaverse consists of four components: input, M-MIAP learning process, engineering competency, and feedback. The input comprises five parts: students, teachers, objectives, contents, and Metaverse. The M-MIAP learning process consists of five parts: tools preparation, elucidation of the learning, pre-test, learning process, and post-test. Engineering competency is an evaluation of student engineering competency, there are a total of five sub-competencies: technical knowledge, problem-solving, creativity, teamwork, and communication. The last element is feedback. This is a performance assessment of engineering competency. Once specialists had evaluated the M-MIAP model's suitability, it was determined that the overall picture satisfied the "very good" criteria. The four components of the M-MIAP model—input, M-MIAP learning process, engineering competency, and feedback—were all rated "very good". The results show that the M-MIAP model can be used to develop engineering competencies for pre-engineering students, consistent with research by Benjamaha and Uantrai that found active learning management based on the MIAP model is effective in improving student learning achievement. MIAP learning is also an effective learning method and suitable for vocational education [46].

The M-MIAP model is a promising approach to developing engineering competency in pre-engineering students. This model integrates the MIAP learning approach with Metaverse, a virtual reality platform, to provide students with immersive and interactive learning experiences that can enhance their engineering competencies. The use of Metaverse in the M-MIAP model can provide students with opportunities to engage in realistic simulations and experiments that are difficult or impossible to conduct in a traditional classroom setting. By providing a risk-free environment for practicing engineering competencies, students can develop their skills and knowledge in a safe and controlled manner. Additionally, the M-MIAP model can enhance students' collaboration and communication skills. By connecting students from different locations and backgrounds, Metaverse can provide opportunities for interdisciplinary knowledge exchange and collaboration, which can be invaluable for developing competencies that require interdisciplinary knowledge and teamwork [44, 45].

In addition, there are many other learning styles that can be used in virtual worlds. One of them, is the MVLM-Gt model, a metaverse virtual learning management model based on gamification techniques. It was developed to enhance the total experience of students. The model has four core components: inputs, metaverse learning management process based on gamification techniques, evaluation, and feedback [47]. The core components of the MVLM-Gt model are aligned with the core components of the M-MIAP model, with both learning models being used to develop learners' competencies in the virtual world.

One potential limitation of this model is the cost and availability of the technology required to access Metaverse. However, as virtual reality technology becomes more widely available and affordable, this limitation may become less salient.

In conclusion, the M-MIAP model is a promising approach to developing engineering competencies in pre-engineering students. By providing immersive, interactive, and interdisciplinary learning experiences, this model can prepare students for the challenges of a rapidly changing engineering industry. Further research on and implementation of this model can help to determine its effectiveness and the potential for its broader adoption in engineering education.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Junjiraporn Thongprasit conducted the research by studied the literature, collected the information, analyzed the data, designed the model, created the evaluation form, and wrote the paper. Pallop Piriyasurawong contributed to the conduction of the research methodology and supervision of the research throughout the study. All authors had approved the final version.

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