Smart Learning Module on Engineering Drawing: The Development and Acceptance of Simulation-Based Learning Approach for Pre-Service Teachers

Siti Faizzatul Aqmal Mohamad Mohsin[1,*], Nur Syamira Aliyah Mohamad Izam[2], Wan Nurlisa Wan Ahmad[1], Tang Jing Rui[1], and Mohd Syazwan Che Manshor[3]

[1]Department of Engineering Technology, Faculty of Technical and Vocational, Sultan Idris Education University, Tanjong Malim, Perak, Malaysia
[2]Faculty of Technical and Vocational, Sultan Idris Education University, Tanjong Malim, Perak, Malaysia
[3]Department of Mechanical and Manufacturing Technology, Seri Iskandar Vocational College, Seri Iskandar, Perak, Malaysia
Email: faizzatul@ftv.upsi.edu.my (S.F.A.M.M.); syamiraliea@gmail.com (N.S.A.M.I.); nurlisa@ftv.upsi.edu.my (W.N.W.A.); tangjingrui@ftv.upsi.edu.my (T.J.R.); syazwan.manshor@gmail.com (M.S.C.M.)
*Corresponding author

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***Abstract*—The lack of interactive, technology-enhanced teaching materials specifically designed for development drawing makes it difficult for teachers and students to master complex topics in engineering drawing. This research designed, developed, and evaluated a simulation-based learning module for engineering drawing, especially on development drawing topics. The module was developed through a structured process of analysis, design, development, implementation, and evaluation to address the challenges encountered by pre-service teachers in visualizing and representing three-dimensional objects in a two-dimensional form. As a result, an e-module known as the Smart Learning Module (SLM) has been developed, using 3D Blender and Articulate Storyline, to meet the standards of the content offered in the relevant university course. This research adopted a Research and Development (R&D) approach, guided by the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model to develop the SLM, and employed a quantitative approach to assess user acceptance of the SLM based on the Technology Acceptance Model (TAM), focusing on perceived ease of use, perceived usefulness, and intention to use among 30 pre-service teachers in TVET. The findings showed that the acceptance of SLM in terms of PEOU had a mean of 4.53 (SD = 0.57), PU with a mean of 4.55 (SD = 0.53), and BI with a mean of 4.60 (SD = 0.55). The SLM is therefore considered a valuable and useful instructional tool for engineering drawing, which supports teachers and students in leveraging modern technology to enhance their understanding.**

***Keywords*—interactive learning module, Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model, simulation-based learning, engineering drawing, Technology Acceptance Model (TAM)**

I. Introduction

Digitization of education creates a novel learning environment by using technological elements to facilitate a more dynamic, interactive, and accessible learning experience. In the context of the Fourth Industrial Revolution, marked by the convergence of technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and Virtual Reality (VR), these technologies are increasingly utilized in the educational process to enrich and enhance the learning experience and improve students' learning efficacy [1]. The rapid development of information technology, and the government's goal of making Malaysia a developed, forward-thinking country on a global level have led the Ministry of Education in Malaysia to reconsider the way the school curriculum is implemented [2]. The introduction of the Smart School concept, one of the seven flagship applications of the Multimedia Super Corridor, demonstrated the commitment of the government's efforts to this field. This reflects the model of 21st-century education, where multimedia technologies are at the core of management, teaching, learning, and communication systems, while retaining the National Education Philosophy to shape the proposed educational paradigm [3].

The National Technical and Vocational Education and Training (TVET) Council coordinates an industry-driven ecosystem to cultivate a highly skilled, high-income workforce in Malaysia through the National TVET Policy 2030. It meets the demand for skilled labor and enhances graduate employability compared to conventional programs with limited industry integration [4]. Realizing this objective necessitates the cultivation of proficient graduates, contingent upon educators' capacity to provide effective education. Consequently, it is essential to equip prospective educators with robust technological and pedagogical skills to fulfill the demands of Industry 4.0. In this regard, TVET institutions play a salient role in shaping and preparing pre-service teachers' readiness to meet industrial expectations. Nonetheless, numerous pre-service teachers continue to encounter difficulties in mastering intricate technical subjects due to inadequate pedagogical skills, insufficient exposure to technology integration, and a scarcity of new innovative instructional resources. These challenges highlight the necessity of developing technology-enhanced pedagogical approaches that not only boost future educators' instructional competencies but also align classroom instruction with advancing industry requirements. Teachers need to consider how to make better use of technology, particularly in the realms of teaching and learning. Therefore, it is imperative to provide a comprehensive array of innovative, creative, efficient, and accessible instructional resources to improve students' engagement and performance.

To cope with the prevailing trend, it is essential to align the education system with technological advancements by enhancing pedagogical tools and learning methodologies [5]. The impact of the education revolution is also evident in the field of technical drawing, which requires students to have a significant level of imagination. Technical drawing is a standard drawing that encompasses various information for the use and guidance of a design, concept, machine components, software, and more. Engineering drawing is an essential element in the field of engineering that demands accuracy, clarity, and a profound understanding of geometric principles and object transformation. Engineering drawing is an important competency in engineering and manufacturing education, serving as a basis for interpreting and understanding technical designs and ensuring precision in production processes [6]. Among its components, development drawing is particularly demanding because it requires advanced spatial visualization. Engineering drawing not only conveys design information but also strengthens students' visual and analytical skills [7]. However, according to Papakostas *et al.* [8], students still experience difficulties due to low levels of visualization skills, limitations in student-centered teaching approaches, and the lack of effective teaching aids to explain three-dimensional concepts practically and interactively. Students also face difficulties in learning topics such as orthographic projection due to its abstract nature, which requires a thorough understanding of the transformation from three-dimensional to two-dimensional objects. Traditional approaches in engineering drawing, such as lectures and textbook use, often fail to meet students' needs in grasping these concepts [9]. These challenges indicate that teachers must use more interactive teaching approaches to enhance student learning.

In order to overcome these obstacles, interactive learning modules, especially those that incorporate simulations and visualization tools, have proven to be effective strategies to address these challenges. According to Dai *et al.* [10], simulation-based modules enables learners to improve engagement, comprehension, and practical skills by allowing them to visualize ideas more dynamically and practice in a virtual setting. In the context of TVET, these modules help educators bridge the gap between classroom instruction and real-world applications by strengthening their capacity to deliver instruction that is in line with industry practices [11]. Studies highlight that an ideal interactive module should integrate 3D visualization to ensure flexibility [12, 13]. These features encourage and support self-directed learning, increase motivation, and accommodate a range of learner needs. Nevertheless, comprehensive and specific interactive on engineering drawing modules are still lacking. According to Mujiarto *et al.* [14], multimedia technology, including animation, simulation, and interactive elements, will help students to understand engineering drawings.

This study aims to assess the acceptance of the simulation-based e-module in engineering drawing administered to 30 pre-service teachers in the Technical and Vocational Education and Training (TVET) field. The research questions guiding this study are as follows:

1) What are the needs for developing an interactive module for the topic of development in the Engineering Drawing course for pre-service teachers?
2) How can the interactive module be developed based on the Engineering Drawing course for the development topic?
3) What is the acceptance of the developed module for the Engineering Drawing course specifically on the topic of development drawing from the perspective of pre-services teachers?

The interactive e-module proposed is designed to support self-directed learning by providing visual elements such as animations, simplified learning notes, and interactive exercises to reinforce students' understanding of the topic of development drawing. This e-module is intended to benefit pre-service teachers by offering flexible self-learning and new interactive teaching tools, but also to support them with more effective and new interactive teaching tools relevant to modern technical education. To evaluate the acceptability of the SLM, this research adopts the Technology Acceptance Model (TAM), which emphasizes perceived ease of use (PEOU), Perceived Usefulness (PU), and behavioral intention (BI) to use the technology [15]. TAM has been widely recognized for predictive power in educational technology research and ensures that the developed solution aligns with pedagogical objectives [16].

II. Methods

A. The Development of Interactive Smart Learning Module (SLM)

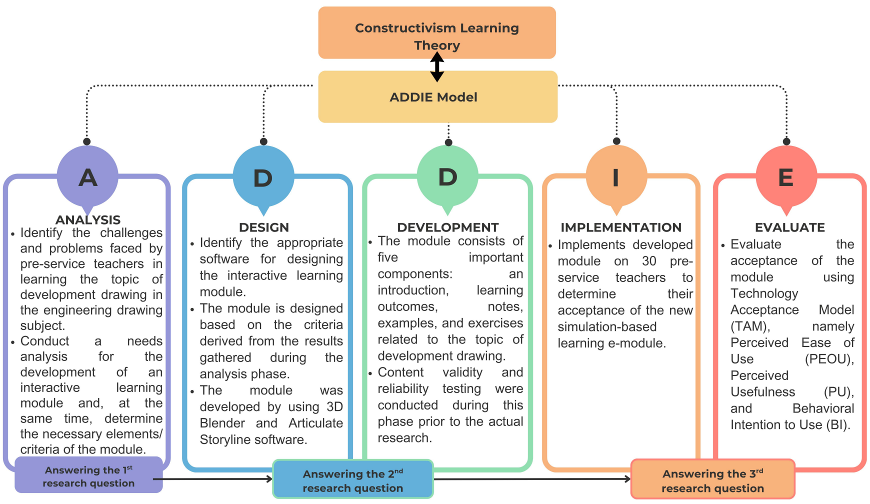

Fig. 1. The depiction of the development processes of SLM.

The module was developed in accordance with the constructivism learning theory and guided by the ADDIE instructional design model. The ADDIE model is used as the principal framework in creating and developing interactive simulated-based instructional materials, which consists of 5 phases: analysis, design, development, implementation, and evaluation. The model is often used to define a systematic methodology for instructional development [17]. The research aims to develop an interactive SLM that integrates multiple multimedia technologies, namely 3D Blender and Articulate Storyline. Fig. 1 describes the development processes of SLM.

All research questions were addressed using the five phases in the ADDIE model. Fig. 1 illustrates the activities carried out in each phase. The first research question was addressed in the analysis phase, the second research question was addressed in the design and development phases, and the third research question was addressed in the implementation and evaluation phase.

B. Analysis Phase

The analysis phase is the initial stage of the ADDIE model. A needs analysis was conducted during this phase. The SLM is based on the identification of challenges and problems encountered in teaching and learning the topic of development drawing in the engineering drawing subject, especially from the perspective of the experts. The SLM is intended for pre-service teachers enrolled in the Engineering Drawing course, which is designed for university students at the Bachelor of Education level. The SLM is developed on the basis of the proforma for the course. Data from a needs checklist administered to five experts who are university lecturers with more than five years of teaching experience indicated that pre-service teachers face challenges in understanding this topic. The experts agreed that existing learning materials are less engaging and ineffective in stimulating students' three-dimensional visualization skills. This indicates that students require a more interactive learning module, particularly one that integrates visual and technological elements. Table 1 shows the results from the needs analysis.

Table 1. The needs analysis results

Aspects	Results
Existing teaching process	80% of experts agreed that the existing materials do not effectively support the visualization of development drawings.
Existing module content	100% of experts suggested the use of animations and 3D elements to clarify abstract concepts.
Existing module design	100% of experts stated that the less engaging module design reduces students' interest.
Requirements for the module to be developed	100% of experts emphasized that interactive modules could enhance learning enhancement through self-directed elements.

To improve conceptual understanding, experts advise integrating multimedia elements, including animations and simulations. To increase engagement, they emphasized the use of succinct notes, interactive visuals, and user-friendly design. Self-assessment tools such as quizzes and exercises were also recommended to strengthen learning. Thus, the developed e-module takes into account the elements recommended by experts to meet the demands of the course and is also in line with 21st-century teaching and learning.

C. Design and Development Phase

The design and development phase of the e-module begins with several steps. This process involves selecting the most appropriate font size and color, buttons, background music, image, and shape for the design of the user interface based on the recommendations of the experts and the results of the needs analysis. This choice is crucial for creating and designing a user-friendly yet creative module that can have a positive impact on users [18]. The researcher also needs to finalize the appropriate software for building the interactive learning module. The development of SLM consists of five important elements, as suggested based on results gathered from the analysis phase, namely, introduction, learning outcome, notes, examples, and exercises for the topic of development drawing. Details of the design and development phase are as follows.

1) The primary interface

After the user logs into the interactive SLM application, a new interface will appear in Fig. 2. Additionally, the SLM homepage interface provides users with a wide range of learning opportunities geared specifically to the development of drawing topics.

Fig. 2. The primary interface of SLM.

2) Learning objectives interface

The learning objectives that students are expected to achieve after using the developed interactive module are illustrated in Fig. 3. The SLM aims to achieve three specific learning objectives:

1) Understand basic concepts of development drawing in engineering drawing.
2) Recognize the role of development drawing in various engineering situations.
3) Apply development drawing techniques in various engineering situations.

Fig. 3 The learning objectives interface of SLM.

3) *The notes interface*

According to Bellinger and DeCaro [19], a proper preparation of notes, particularly from lower-order to higher-order levels, improves students' metacognitive abilities. The SLM provides users with concise short notes and emphasizes simulation examples in development drawings to help users understand the layout of drawings. Concise and precise notes show significant importance, as it is believed that an individual may struggle to grasp and retain essential knowledge due to a limited ability to manage excessive information [20]. Figs. 4 and 5 illustrate the notes interface after the user logs into the interactive SLM application.

Fig. 4. The notes interface in SLM.

Fig. 5. The notes about development drawing in SLM.

4) *Examples*

Fig. 6 illustrates the examples embedded in SLM.

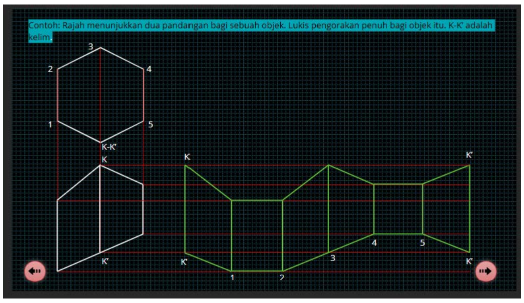

Fig. 6. Examples of development drawing in SLM.

5) *The simulation*

The simulation created in this e-module results from integrating the 3D Blender application and Articulate Storyline, providing a comprehensive visualization of an object demonstrated through a drawing layout utilizes simulation. The use of simulation in the SLM aims to enhance users' understanding and support their spatial abilities in visualizing the transformation from three-dimensional to two-dimensional shapes. Simulations can proficiently enhance spatial abilities, allowing students to understand the transition between three-dimensional and two-dimensional representations [21, 22]. Figs. 7 and 8 depict the SLM simulations associated with the development drawing topic.

Fig. 7. The simulations of development drawing of a box in SLM.

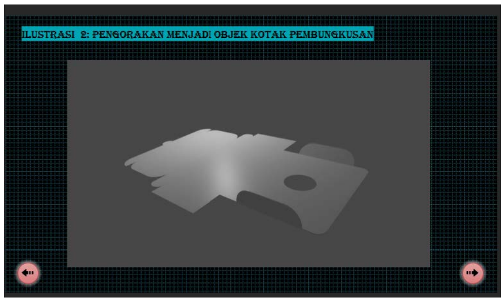

Fig. 8. The simulations of development drawing of a gift box in SLM.

6) *The exercises*

Figs. 9 and 10 illustrate the exercise in SLM for the users.

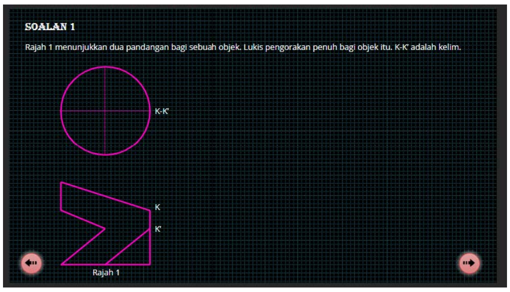

Fig. 9. Exercise in SLM.

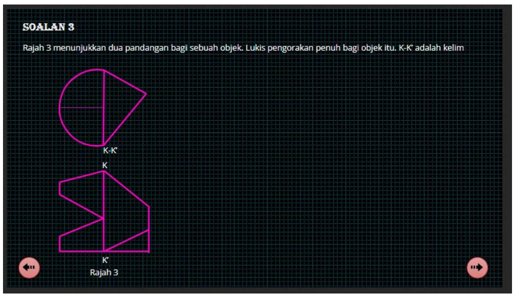

Fig. 10. Exercise in SLM.

SLM offered users information and knowledge that was covered in the Engineering Drawing course while also offering an opportunity to learn drawing in a new setting, using simulation technology. Users can answer questions to assess their understanding of the development drawing topic. During this phase, appropriate text, video graphics, and various multimedia applications were integrated into the SLM. The implementation of interactive simulation features in the SLM as a conventional approach has been considered inadequate in teaching the development drawing topic. This is because interactive learning environments that utilize various multimedia positively influence students' creative thinking [23].

At this phase, a checklist emphasizing face validity and content validity was used to assess SLM's validity. Five experts who are university lecturers participate in the validity process. All of the lecturers have more than five years of teaching experience and are from the Engineering Technology department. They are also knowledgeable about the field of design and technology in education. One of the most important steps in ensuring that the resources offered are suitable for educational objectives is the validity analysis of the SLM's development conducted by the content experts. Table 2 delineates the background information of the experts involved in this study.

Table 2. Expert's profile

Experts	Position	Expertise	Experience
E1	Lecturer	Pedagogy & Technology in education	8 years
E2	Lecturer	TVET	7 years
E3	Lecturer	Pedagogy	More than 10 years
E4	Lecturer	Design and Innovation in education	More than 10 years
E5	Lecturer	TVET	6 years

The scoring system is based on the Likert scale ranging from 1 (Strongly disagree) to 5 (Strongly agree). The total score given by the experts on the Likert scale is divided by the maximum score of 12. The quotient is subsequently multiplied by 100 percent to determine the content validity value as presented in Eq. (1).

$$Content\ Validity = \frac{Number\ of\ marks\ from\ experts}{Maximum\ score\ (12)} \times 100\% \quad (1)$$

According to Anuar *et al.* [24], to determine good content validity, a score of 70% and above is required to be considered high content validity. Table 3 displays the overall percentage and content validity as agreed by the experts.

Table 3. Overall finding of content validity for the SLM from five experts

No.	Item	Percentage	Content Validity	Expert Opinion
1	The e-module content is aligned with the target population, which is prospective teachers in the field of engineering drawing.	100	1.00	Accepted
2	The developed e-module's content pertains to the topic of development drawing.	100	1.00	Accepted
3	The e-module content includes comprehensive notes regarding development drawing.	92	0.92	Accepted
4	The e-module content includes videos that are appropriate for the topic of development drawing.	100	1.00	Accepted
5	This e-module contains exercises relevant to the topic of development drawing that are simple and help enhance students' understanding.	88	0.88	Accepted
6	The developed e-module is easy to use.	100	1.00	Accepted
7	The developed e-module has a suitable font size.	100	1.00	Accepted
8	The developed e-module uses appropriate font type.	100	1.00	Accepted
9	The developed e-module uses suitable colors.	88	0.88	Accepted
10	The developed e-module incorporates appropriate graphics.	100	1.00	Accepted
11	The developed e-module includes engaging interactive elements.	100	1.00	Accepted
12	The developed e-module can attract users' interest in learning.	100	1.00	Accepted
	Overall	97	0.97	Accepted

Based on Table 3, the SLM module achieved an overall content validity score of 97% with a content validity coefficient of 0.97, indicating that its content is well-structured, relevant, and appropriate for the target population. The uniform expert agreement further supports its reliability and effectiveness.

The experts evaluated the validity of the developed e-module, and the questionnaire used in this study to identify the e-module's acceptance also underwent a pilot test. Internal consistency reliability was assessed using Cronbach's alpha coefficient, with a value exceeding 0.7 considered acceptable. A pilot study involving 30 participants was conducted to confirm the clarity and reliability of the questionnaire prior to the main data collection phase. The final instrument for data collection was a close-ended questionnaire based on the 5-point Likert scale, consisting of 8 items. This instrument was validated through expert review and pilot testing to ensure its effectiveness in assessing the acceptance and quality of the developed SLM.

D. Implementation Phase

In this implementation phase, the researcher implements SLM on 30 pre-service teachers to determine their acceptance of the new simulation-based learning e-module. This phase is crucial to ensure the future use of the developed SLM as a teaching aid. The SLM was also evaluated to ensure that all important elements can be met. During this phase, it is crucial to identify errors so that the users can fully utilize the system.

E. Evaluation Phase

This phase is intended to assess the acceptance of SLM.

The acceptance of SLM was determined by using the Technology Acceptance Model (TAM), specifically focusing on Perceived Ease of Use (PEOU), Perceived Usefulness (PU), and Behavioral Intention to Use (BI). According to Yuviler-Gavish *et al.* [25], TAM is recognized as the most influential model of technology and is appropriate for examining the acceptance of new technology. Hence, this model was utilized to assess the acceptance of the new simulation-based learning in the Engineering Drawing course among 30 pre-service teachers at a university of education, particularly within the TVET field. Table 4 presents the indicators, and measurement points pertinent for this research. The degree of estimation was specified using the values of the resultant means, which were encoded to a 5-points Likert scale [26] as presented in Table 5. Table 6 presents a descriptive analysis of respondents' acceptance of the simulation-based learning e-module. Meanwhile, Fig. 11 presents the summary of the acceptance levels of the SLM among pre-service teachers involved in this study.

Table 4. Indicators and measurement items

Variable	Indicators	Items
Perceived Ease of Use (PEOU)	PEOU1	The e-module is easy to use.
	PEOU2	The e-module provides simple steps for learning the topic.
Perceived Usefulness (PU)	PU1	The e-module helps me learn the topic effectively.
	PU2	The e-module helps me understand the topic better.
	PU3	The e-module helps me understand the topic quicker.
	PU4	It is easier to learn the topic by using the developed e-module.
Behavioral Intention to Use (BI)	BI1	I would recommend this e-module to other peers.
	BI2	Overall, I find the e-module enjoyable to use.

Table 5. Distribution of the means scores on 5-point Likert scale

Mean Score	Interpretation of Mean Score
1.00–1.80	Very Low
1.81–2.60	Low
2.61–3.40	Moderate
3.41–4.20	High
4.21–5.00	Very High

Table 6. Descriptive analysis

Variable	Mean	Standard Deviation (SD)	Interpretation
Perceived Ease of Use (PEOU)	4.53	0.57	Very High
Perceived Usefulness (PU)	4.55	0.53	Very High
Intention to Use (BI)	4.60	0.55	Very High

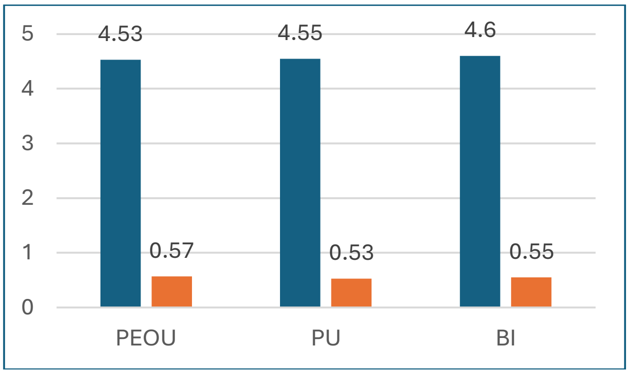

Fig. 11. Results of the SLM acceptance.

Descriptive analysis was carried out to examine pre-service teachers' perceptions of the acceptance of the interactive e-module on the Engineering Drawing course. Table 6 demonstrates that users responded positively to the simulation-based learning e-module for Engineering Drawing. The high mean scores for Perceived Ease of Use (PEOU) were 4.53 (SD = 0.57), signifying a very high agreement. Similarly, the Perceived Usefulness (PU) was averaged at 4.55 (SD = 0.53), which was also interpreted as very high agreement. While the Behavioral Intention to Use (BI) obtained the highest mean value of 4.60 (SD = 0.55), which is likewise categorized as very high agreement. This score reflects very positive perceptions and indicates positive user experience. These findings affirm that SLM is highly accepted by the user and extremely usable, engaging, and supportive of effective learning. These results demonstrate that the SLM is perceived as useful, easy to use, and strongly supported for future use by pre-service teachers.

III. Discussion

The Smart Learning Module (SLM) was developed successfully to address the requirements of each phase in the ADDIE process. This procedure is essential to ensure that SLM demonstrates high validity and reliability, facilitating its use as a teaching aid in future development drawing topics.

Prior studies have conducted content validity assessments on modules, as indicated in [27–29]. This study's findings demonstrate that the SLM underwent a thorough validation process, including assessments of content validity and reliability, to confirm the e-module's appropriateness for the target group. The SLM exhibited a significant level of acceptance among pre-service teachers in this study.

The developed simulation-based e-module has effectively attracted the interest of users. The elements, such as the design, layout, and multimedia in the e-module, could capture the attention of the users and thus increase their involvement in the learning process. The integration of diverse multimedia in the developed simulation-based learning e-module aims to attract Generation Z and enhance their engagement in the learning process. This strategy is consistent with the development of interactive modules reported in previous studies [10–14]. Generation Z is characterized as digital natives that favor an independent learning approach that is more active and more visual and kinesthetic [30]. Therefore, pre-service teachers need to be prepared for the revolution in the education sector to keep pace with the technological advancements.

Pre-service teachers are defined as individuals who are formally enrolled in the teacher training programs at higher education institutions, particularly in the field of Technical and Vocational Education and Training (TVET) but have not yet obtained full professional qualifications as teachers. They are usually in the practicum phase or attending courses such as Engineering Drawing. However, pre-service teachers face weaknesses in digital skills and technological competencies, which are essential to support technology-based teaching and 21st-century learning [31]. Exposure to the integration of two or more technologies is necessary to address this shortcoming and produce more effective teaching aids. Therefore, the development of the SLM is the result of combining two applications that are increasingly gaining attention, particularly in the development of simulation-based modules, especially in Engineering Drawing. The advantages of this integration may remain unknown if studies on the development of e-modules such as the SLM are not widely disseminated.

The findings of this study revealed that the combination of the applications used in the SLM received positive acceptance among pre-service teachers. The high PEOU score suggests that SLM's functionality is intuitive, reducing the learning curve and enabling students to focus more on mastering the development drawing subtopics rather than grappling with technical difficulties. The interactive e-module developed was user-friendly and allowed students to access the training material without encountering technical difficulties and thus remain focused on the course material. Using interactive technology, mobile technology, and AI-powered interactive technology, users can learn more easily, more personally, and more engagingly through technology and can use technology to support learning [32, 33].

Meanwhile, the high PU score shows that users perceive tangible benefits from using SLM, such as improved understanding and engagement, which are the key factors for the adoption of a new educational approach in learning engineering drawing by using simulation. The amalgamation of technology and education has the significant potential to meet students' specific needs, improve engagement, and maximize learning outcomes [33]. Hence, the use of graphics, colors, and fonts in the module was also assessed as appropriate and not detrimental to the learning process. The visual elements of the module have been carefully chosen to draw the users' attention to the subject rather than divert it. The growing convergence of technology and education has transformed how knowledge is delivered and acquired. In TVET, the shift from Industry 4.0 to 5.0 requires educators to integrate technology into teaching as machine learning becomes central to educational practice [34].

The use of simulation in engineering drawing has been gaining increasing attention among researchers in the field of TVET. However, these engineering drawing simulations have so far focused mainly on mechanical drawings and orthographic drawings but not on development drawings [35–37]. The high score for BI shows that users enjoy using SLM and would recommend it to other peers. This is because the e-module includes resources to help students understand the material, such as videos, notes, and simple exercises. The user could assess and reinforce their knowledge through practical activities using interactive materials, such as exercises and videos. The elements and design used in the module were found to be attractive, interesting, and appropriate to the needs of users. These elements boost users' engagement, transforming learning into a dynamic and enjoyable process. Hence, analysis indicates that the developed e-module can be used as a teaching and learning tool to improve students' understanding.

IV. Conclusion

This study indicates that the development of an interactive module in the Engineering Drawing course based on simulation technology proposes a new teaching and learning approach. Overall, positive perceptions across all TAM dimensions indicate that simulation-based learning e-modules can play a crucial role in modernizing engineering drawing. These tools can help users learn and use them more effectively and for a longer time. By providing interactive, effective, and engaging learning experiences, these tools can help users to learn and use them effectively. To enable users to learn actively and effectively, the integration of multimedia technologies in teaching and learning is a key element for students to learn actively and effectively. These findings may assist future application developers in amalgamating two or more applications to develop a more sophisticated but meaningful application.

Furthermore, this research contributes to the growing literature on the use of simulation technology in Technical and Vocational Education and Training (TVET). The use of the Research and Development (R&D) approach, guided by the ADDIE model in the development of the SLM, has proven capable of producing a reliable project, as it has undergone all processes of validity and reliability through systematic evaluation. It also provides guidance for educators in designing interactive teaching materials. Recommendations for future research include expanding this research to other Engineering Drawing topics and evaluating the effects of simulation-based e-module usage on students' academic achievement. The education system can continue to evolve and offer more meaningful learning experiences to students.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Siti Faizzatul Aqmal Mohamad Mohsin: wrote the paper; supervision; analyzed data; review and editing; developed the e-module. Nur Syamira Aliyah Mohamad Izam: conducted research; collected data; developed the e-module. Wan Nurlisa Wan Ahmad, Tang Jing Rui and Mohd Syazwan Che Manshor: analyzed data, final review and final editing. The final version was approved by all authors.

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