Development of Online Problem-Based Learning Module for Impulsive Force Subtopic of Physics Form Four

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ABSTRACT

In this study, we developed an online problem-based learning (PBL) module for the Impulsive Force subtopic of Physics Form Four and studied its perceived usability among Physics trainee teachers. The research design of this study is developmental research and a quantitative study using a survey approach. The module was developed according to five phases of the ADDIE instructional design model; analysis, design, development, implementation and evaluation. The module had a high agreement percentage among three appointed experts for face validity (98%) and content validity (95%). The sample of this study were selected among Physics trainee teachers of Universiti Pendidikan Sultan Idris using a simple random sampling technique. The perceived usability level of the developed module among trainee teachers were determined using a usability questionnaire. The collected data were analyzed by calculating the frequency, mean (M) and standard deviation (SD) values. The findings indicated that trainee teachers has a high perceived usability level for each aspect; usefulness (M = 3.76; SD = 0.32), ease of use (M = 3.72; SD = 0.35) and satisfaction (M = 3.79; SD = 0.30) for the developed module. Overall, the module also has a high perceived usability level among trainee teachers (M = 3.76; SD = 0.32). Thus, the developed online PBL module is suitable as a learning aid for the Impulsive Force subtopic for Physics Form Four.

Keywords: *Online learning module, problem-based learning, impulsive force, development, perceived usability*

INTRODUCTION

Physics is often regarded as a challenging subject among secondary school students due to its abstract concepts, mathematical reasoning, and limited real-life context in traditional instruction. One of the particularly difficult subtopics is the Impulsive Force subtopic in the Form Four Physics syllabus. The concept of Impulsive Force is one of the fundamental concepts that students need to learn in the field of kinematics. However, students face challenges in understanding the concept of Impulse Force, even though it has been used to explain various phenomena occurring in daily life. Among the issues students face with the concept of Impulse Force is their belief that objects with greater mass generate larger impulse forces compared to objects with smaller mass (Ismail & Ayop, 2016), and that hard objects with short contact times produce larger impulses (Nurdiansyah, Tomo Djudin & Hamdani, 2021). Students also struggle to remember the relationship between impulse and momentum when they are given questions related to this subtopic (Saifullah, Sutopo & Wisodo, 2017). They also fail to understand the correct concept, despite having studied the subtopic of momentum and impulse in the Basic Physics course (Rosa, Cari, Aminah & Handhika, 2018).

The rapidly evolving educational landscape of the 21st century, integrating technology with pedagogical strategies has become essential for fostering meaningful learning experiences. However, the integration of digital technology in education have not been fully utilized in many Physics classrooms, where resources and instructional strategies remain traditional and teacher-centered. There is a clear need for innovative, technology-enhanced instructional materials that can actively engage students, promote self-directed learning, and align with the constructivist philosophy of knowledge construction through experience and interaction. In addition, conventional teaching methods that rely heavily on lectures, textbook explanations, and formula memorization have proven insufficient in promoting deep conceptual understanding and critical thinking skills, leading to low student engagement and poor academic performance in this area (Zacharia & Olympiou, 2011).

Problem-Based Learning (PBL) is a learner-centered instructional strategy that encourages students to construct knowledge through the investigation of real-world problems (Hmelo-Silver, 2004). It has been recognized as an effective approach to encourage active learning, inquiry, and critical thinking in science education. Previous studies have shown that PBL can improve student achievement and foster higher-order thinking skills, including critical thinking, problem-solving, decision-making, and reasoning skills (Mahamood & Hassan, 2018). PBL also creates an active learning environment among students (Kadir & Ling, 2021). However, the lack of structured, curriculum-aligned, and user-friendly digital PBL modules specifically designed for secondary Physics subtopics like Impulsive Force presents a significant gap in instructional resources. Additionally, there is limited empirical evidence on the usability and acceptance of such modules among Physics trainee teachers, who are future implementers of innovative pedagogies.

Therefore, an online PBL module for the Impulsive Force subtopic in Physics for Form Four students was developed in this study. It was developed as a digital learning aid according to the systematic development procedure of the ADDIE instructional design model by integrating the principles of constructivist learning theory, Cognitive Theory of Multimedia Learning (CTML) (Mayer, 2001; 2009) and Dual-Coding Theory (Paivio, 1971). The perceived usability level of the module among trainee Physics teachers at Universiti Pendidikan Sultan Idris (UPSI) that aligns with Technology Acceptance Model (TAM) principles—emphasizing perceived usefulness and ease of use were also determined in this study.

RESEARCH METHOD

Research Design

This study is a development study design because an online PBL module for the Impulsive Force subtopic in Physics for Form Four students based on the ADDIE instructional design model was developed in this study. In addition, this study employs a quantitative research design using a survey approach to determine the perceived usability level of the module among Physics trainee teachers.

Development of the Online Problem-based Learning Module

The online PBL module is developed based on the ADDIE instructional design model which consists of five phases: Analysis, Design, Development, Implementation, and Evaluation. The Analysis phase involves identifying the problems faced by students regarding the concept of Impulsive Force from previous studies, such as their belief that objects with greater mass produce larger impulse forces compared to objects with smaller mass (Ismail & Ayop, 2016), and that hard objects with short contact times generate larger impulses (Nurdiansyah, Tomo Djudin & Hamdani, 2021). Students also struggle to recall the relationship between impulse and momentum when given questions related to this subtopic (Saifullah, Sutopo & Wisodo, 2017). Additionally, they did not understand the correct concept even though they have studied the subtopics of momentum and impulse in the Basic Physics course (Rosa, Cari, Aminah & Handhika, 2018).

The Design phase involves selecting suitable learning theories and instructional design models to design the online learning module, those are constructivist learning theory, CTML, dual-coding theory, TAM and ADDIE instructional design model. The Development phase involves developing the online PBL module for the Impulsive Force subtopic in Physics for Form Four students. This phase also includes developing

research instruments, validating the module and research instruments with experts, conducting a pilot study, and improving the module before it is used in the actual study. The Implementation phase involves conducting the study on the perceived usability of the online PBL module for the Impulsive Force subtopic in Physics for Form Four students, focusing on Physics trainee teachers. The Evaluation phase involves analyzing the data from the actual study to determine the perceived usability level of the developed online PBL module among Physics trainee teachers. Table 1 summarizes the implementation of five phases of the ADDIE model to develop the online PBL module.

Table 1. *Implementation of Five Phases of the ADDIE Model to Develop the Online PBL Module.*

Phase	Description
Analysis	• Identify the problems faced by students regarding the concept of Impulsive Force from previous studies.
Design	• Select suitable learning theories and instructional design models to design the online module.
Development	• Develop the online PBL module for the Impulsive Force subtopic in Physics for Form Four students and research instruments. • Validate the developed module and research instruments. • Conduct a pilot study. • Improve the developed module before it is used in the actual study.
Implementation	• Implement the study on the perceived usability of the online PBL module for the Impulsive Force subtopic in Physics for Form Four students among trainee Physics teachers.
Evaluation	• Analyze the data from the actual study.

Population and Sample

The popelation of this study were 103 Physics trainee teachers from Semester 7 of UPSI. The Semester 7 Physics trainee teachers were chosen because they have completed Teaching Practice 1, and thus are familiar with the characteristics of online modules suitable for use as they were taught to select the suitable teaching and learning aid for the teaching and learning sessions. According to the sample size determination table by Krecjie and Morgan (1970), the minimum number of samples were 80. Hence, a total of 80 Physics trainee teachers were selected as the sample of the study using simple random sampling technique to determine the perceived usability level of the online PBL module among Physics trainee teachers.

Research Instrument

The research instrument of this study was adapted from the USE Questionnaire (Lund, 2001). It was used to determine the perceived usability level of the online PBL module among Physics trainee teachers. It consists of two sections: the demographics of the respondents and their perceptions of the usability of the online PBL module for three aspects: usefulness, ease of use, and satisfaction. The respondents' agreement level was rated using a four-point Likert scale , as shown in Table 2.

Table 2. *Level of Agreement Based on a Four-Point Likert Scale*

Scale	Agreement Level
4	Strongly Agree (SA)
3	Agree (A)
2	Disagree (D)
1	Strongly Disagree (SD)

The four-point Likert scale was utilized in this study to eliminate the neutral option encouraged more differentiated responses from participants unfamiliar with rating scales (Teo, 2011; Ong et al., 2004) since midpoint responses can lead to socially desirable or disengaged answers (Chang, 1994; Garland, 1991). The validity of the questionnaire was determined by three experts, consisting of two Physics lecturers and one experienced Physics teacher. Table 3 shows the findings of the study for face validity and content validity of the usability questionnaire.

Table 3. *Face Validity and Content Validity of the Usability Questionnaire*

Expert	Face Validity (%)	Content Validity (%)
1	90	95
2	100	95
3	100	100
Average	97	97

According to Table 3, the usability questionnaire has a high percentage of expert agreement for both face validity and content validity, with 97% for both aspects. According to Nordin (1995), a percentage of expert agreement exceeding 70% is considered to have good validity. Therefore, the questionnaire has good face validity and content validity.

A pilot study was conducted among 15 Physics trainee teachers from UPSI to determine the reliability of the questionnaire. According to Johanson and Brooke (2010), the acceptable number of samples for pilot study is 15 to 30. The pilot study results showed that the questionnaire has a high reliability coefficient of 0.92. According to Tavakol and Dennick (2011), the minimum acceptable reliability coefficient for a research instrument is 0.70. Therefore, the questionnaire is suitable to be used to determine the perceived usability level of the online PBL module among Physics trainee teachers in the actual study.

Data Analysis

The collected data in the actual study were analyzed using descriptive statistical analysis to calculate the values of frequency, mean (M), and standard deviation (SD) using the Statistical Package for Social Sciences (SPSS). The perceived usability level of the online PBL module among Physics trainee teachers were determined based on the mean values shown in Table 4.

Table 4. *Perceived usability level of the module based on the mean values.*

Mean Value	Perceived Usability Level
1.00 – 2.00	Low
2.01 – 3.00	Moderate
3.01 – 4.00	High

Source: Talib (1996)

RESEARCH FINDINGS AND DISCUSSION

Online Problem-Based Learning Module

The online PBL module for the Impulsive Force subtopic has been developed based on the ADDIE instructional design model and TAM. Figure 1 shows the main display of the online PBL module developed in this study.

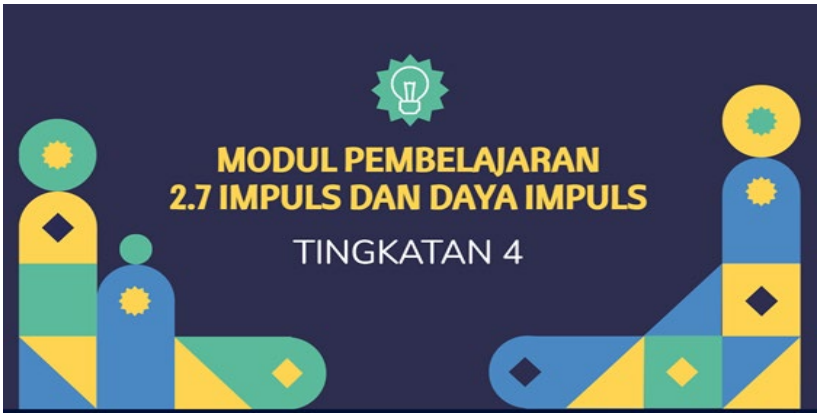


Figure 1. *Main Display of the Developed Online PBL Module.*

The module consists of four main sections: introduction, activities, assessment, and additional information. The introduction section contains the purpose of the module's development, user manual, and learning objectives for the Impulse Force subtopic. Figure 2 shows the display of the introduction section.

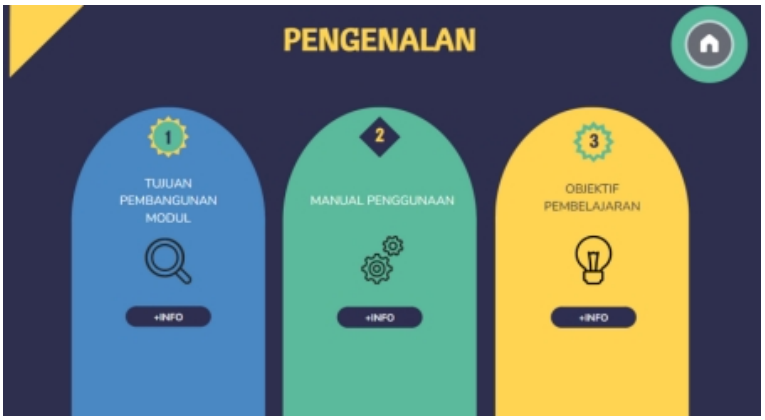
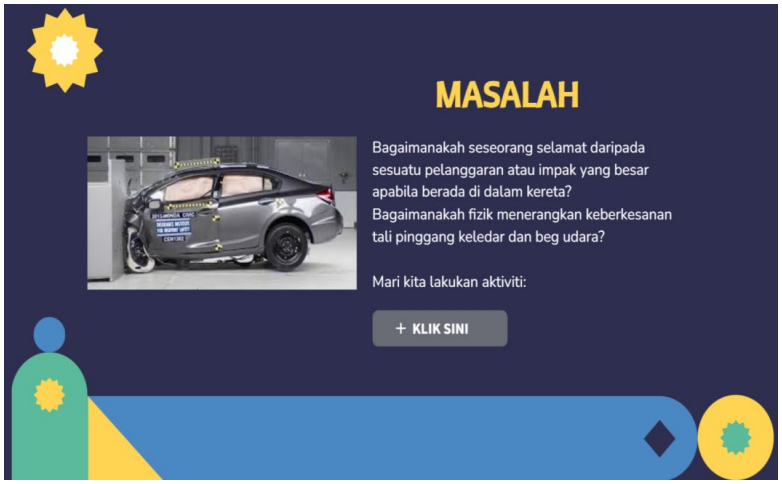
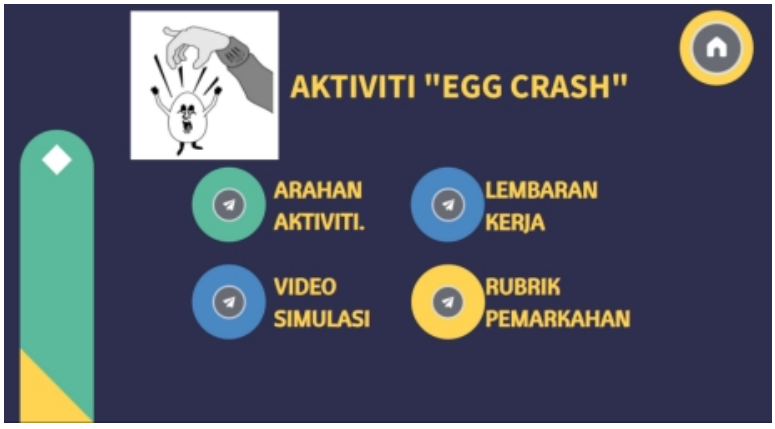


Figure 2. *Display of the Introduction Section*

The activity section includes activities organized based on PBL strategy by implementing constructivist learning theory, CTML and dual-learning theory. At the beginning of the activity section, a real-life problem situation involving the Impulsive Force subtopic is presented, and several questions related to the situation are posed. Following this, users are guided to answer the questions based on the provided activity instructions. The activity section also includes worksheets, simulation videos, and rubrics as guides for users to carry out the activities. Figure 3 shows the display of the activity section.



(a)



(b)

Figure 3. *The Activity Section Consists of (a) Real-Life Problem Situation and (b) Activity.*

The assessment section contains reinforcement questions, quizzes, and topic-based tests. This section is provided to test users' understanding after using the developed module for the Impulsive Force subtopic. Figure 4 shows the display of the assessment section.

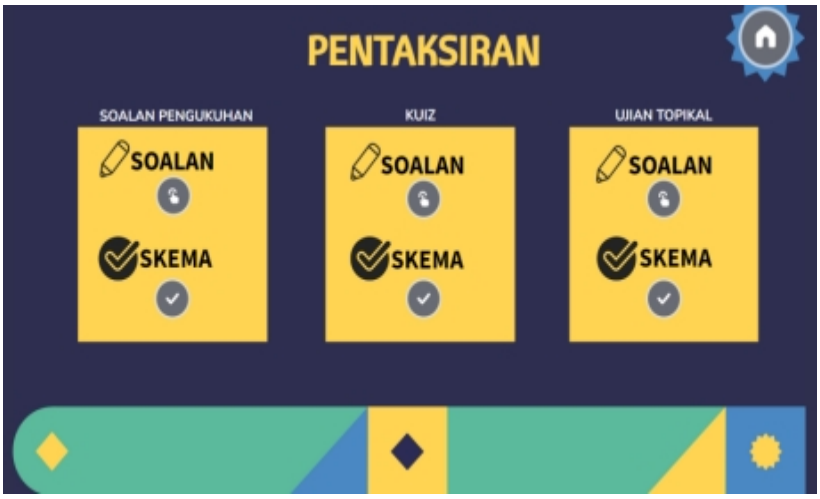


Figure 4. *Display of the Assessment Section*

The final section, additional information, contains brief notes, concept maps, slide notes, and misconceptions. This section provides supplementary information to users for the Impulsive Force subtopic. Figure 5 shows the display of the additional information section.

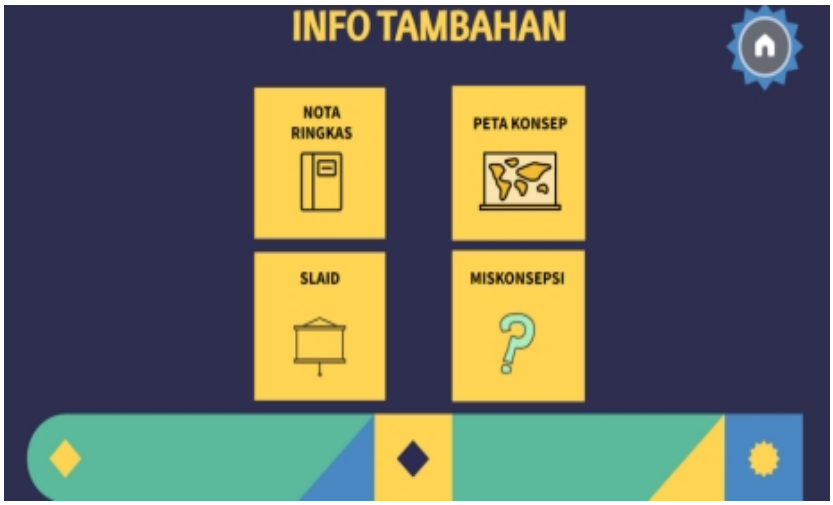


Figure 5. *Display of the Additional Information Section.*

The developed online PBL module has several advantages, such as promoting active student engagement in teaching and learning sessions by integrating the PBL method in its design. The module also incorporates interactive elements with buttons that allow users to access content. Therefore, the module is designed to attract students' attention to learn its content. Additionally, the module is easily accessible to both teachers and students as it was developed using the Genially web platform. It also applies the concept of e-learning to ensure that students can use the module regardless time and location.

Validity of the Online Problem-Based Learning Module

Table 5 shows the study results for the face validity and content validity of the online PBL module, which was determined by three selected experts.

Table 5. *Face validity and content validity of the online problem-based learning module.*

Expert	Face Validity (%)	Content Validity (%)
1	95	90
2	100	95
3	100	100
Average	98	95

Based on Table 5, the developed online PBL module has high agreement percentages for face validity (98%) and content validity (95%). Therefore, the module is considered to have good validity since the experts' agreement percentage exceeds 70% (Nordin, 1995).

Perceived Usability of the Online Problem-Based Learning Module

The perceived usability of the developed online PBL module was assessed from the aspects of usefulness, ease of use and satisfaction by 80 Physics trainee teachers. Table 6 shows the demographic distribution of the respondents involved in the actual study.

Table 6. *Demographic distribution of respondents.*

No.	Aspect	Frequency (*N*)	Percentage (%)
1	Gender		
	Male	31	38.7
	Female	49	61.3
2	Ethnicity		
	Malay	66	82.5
	Chinese	1	1.2
	Indian	0	0.0
	Bumiputera (Sabah & Sarawak)	11	13.8
	Other	2	2.5

Usefulness Aspect

Table 7 shows the findings for the perceived usefulness of the developed online PBL module among Physics trainee teachers. In this study, perceived usefulness refers to Physics trainee teachers' intention to use the developed online PBL module as a teaching aid to attract students' interest in learning, encourage their participation, save their time and improve their understanding towards the Impulsive Force subtopic.

According to Table 7, most Physics trainee teachers agreed that the developed online PBL module can enhance students' understanding of the Impulsive Force subtopic (M = 3.75; SD = 0.49) and encourage active students' participation during learning (M = 3.76; SD = 0.46). It indicates that the design of this module aligned with the constructivist learning theory that encourages exploration and problem-solving (Renninger, 2023), enabling learners to analyze their experiences and construct their own understanding (Saunders, 1992) and create an active learning environment (Thomas & Surat, 2021).

They also agreed that the online PBL module could attract students' interest in learning the Impulsive Force subtopic (M = 3.76; SD = 0.43) and save students' time when studying the Impulsive Force subtopic (M = 3.68; SD = 0.52). It suggests that the features of this module including images, text and simulation video aligned with the CTML to help students to process information better by reducing extraneous load (Mayer, 2001; 2009). These features also apply the dual-learning theory as the use of verbal and visual representations help to engage the learner cognitively and emotionally (Paivio, 1971).

They also agreed that the online PBL module could be used as a teaching aid for the Impulsive Force subtopic (M = 3.86; SD = 0.35) because the module's content is aligned with the curriculum for the Impulsive Force subtopic. Overall, the online PBL module has a high level of perceived usefulness among Physics trainee teachers, as the mean value is within the highest range of 3.51 to 4.00. It indicates that the module can be utilized as a teaching aid to attract students' interest in learning, encourage their participation, save their time and improve their understanding towards the Impulsive Force subtopic.

Table 7. *Perceived Usefulness of the Online Problem-Based Learning Module Among Physics Trainee Teachers*

No.	Statement	Frequency (Percentage, %)				M	SD
		SD	D	A	SA		
1	This module can be used as a teaching aid for the Impulsive Force subtopic.	0 (0.0)	0 (0.0)	11 (13.7)	69 (86.3)	3.86	0.35
2	This module can attract students' interest in learning the Impulsive Force subtopic.	0 (0.0)	0 (0.0)	19 (23.8)	61 (76.2)	3.76	0.43
3	This module can encourage active student participation in learning the Impulsive Force subtopic.	0 (0.0)	1 (1.2)	17 (21.3)	62 (77.5)	3.76	0.46
4	This module can save students' time when studying the Impulsive Force subtopic.	0 (0.0)	2 (2.5)	22 (27.5)	56 (70.0)	3.68	0.52
5	This module can improve students' understanding of the Impulsive Force subtopic.	0 (0.0)	2 (2.5)	16 (20.0)	62 (77.5)	3.75	0.49
	Overall					3.76	0.32

Ease Of Use Aspect

Table 8 shows the findings for the perceived ease of use of the developed online PBL module among Physics trainee teachers. In this study, perceived ease of use refers to Physics trainee teachers' perception whether the developed module is easy to use and user-friendly, and they can use it without referring to the user manual, regardless specific time and location.

According to Table 8, most Physics trainee teachers agreed that the developed online PBL module is easy to use (M = 3.78; SD = 0.48) and user-friendly (M = 3.75; SD = 0.44), indicated that the module adheres to CTML principles such as only essential information is included (Coherence Principle), content is divided into several parts (Segmenting Principle) and text and visuals are placed closely (Contiguity Principle). These elements support efficient processing and learning while avoiding cognitive overload (Mayer, 2001; 2009).

They also agreed that they could use the developed online PBL module without referring to the user manual (M = 3.69; SD = 0.52) and it can be used anytime (M = 3.69; SD = 0.54) and anywhere (M = 3.68; SD = 0.55). It indicates that the developed module utilized the e-learning concept that support self-directed learning (Najib, Abu Bakar & Othman, 2016; Sanova, et al., 2022). Overall, the module has a high level of perceived ease of use among Physics trainee teachers, as the mean value is within the highest range, between 3.51 and 4.00. It indicates that the module was easy to use and user-friendly, and they can use it without referring to the user manual, regardless specific time and location.

Table 8. *Perceived Ease of Use of the Online Problem-Based Learning Module Among Physics Trainee Teachers*

No.	Statement	Frequency (Percentage, %)				M	SD
		SD	D	A	SA		
1	This module is easy to use.	0 (0.0)	2 (2.5)	14 (17.5)	64 (80.0)	3.78	0.48
2	This module is user-friendly.	0 (0.0)	0 (0.0)	20 (25.0)	60 (75.0)	3.75	0.44
3	I can use this module without referring to the user manual.	0 (0.0)	2 (2.5)	21 (26.2)	57 (71.3)	3.69	0.52
4	This module can be used at any time.	0 (0.0)	3 (3.7)	19 (23.8)	58 (72.5)	3.69	0.54
5	This module can be used anywhere.	0 (0.0)	3 (3.7)	20 (25.0)	57 (71.3)	3.68	0.55
	Overall					3.72	0.35

Satisfaction Aspect

Table 9 shows the results of the study for the satisfaction of the developed online PBL module among

Physics trainee teachers. In this study, satisfaction refers to Physics trainee teachers' attitude towards the developed module, whether they were satisfied with the module, it was functioned as they expected, they woulid like to own it, it was fun to use and they would like to recommend it to other trainee teachers.

According to Table 9, most Physics trainee teachers agreed that they were satisfied with the developed online PBL module (M = 3.74; SD = 0.50) and that the module functions as they expected (M = 3.73; SD = 0.45). It indicates that the content of the module was organized according to the PBL method. Respondents also agreed that the module fun to use (M = 3.80; SD = 0.43), indicated that the CTML principles such as Modality (use of narration with visuals to prevent overload), Segmenting (breaking down content for easier absorption) and Personalization (using a conversational tone to increase motivation) were applied in the module. These principles help reduce extraneous cognitive load and enhance learner engagement and comprehension (Mayer, 2001; 2009).

They also expressed a desire to own the developed online PBM module (M = 3.83; SD = 0.36) and stated that they would recommend the developed online PBL module to other trainee teachers (M = 3.85; SD = 0.39). It indicates that the module can be used as a learning aid for the Impulsive Force subtopic, as it incorporates interactive concepts that align with the needs of 21st-century teaching and learning (Ibrahim, Rusli, Shaari, & Nallaluthan, 2021).

Overall, the module has a high level of satisfaction among Physics trainee teachers, as the mean value is within the highest range, between 3.51 and 4.00. It indicates that they were satisfied with the module, it was functioned as they expected, they woulid like to own the module, it was fun to use and they would like to recommend the module to other trainee teachers.

Table 9. S*atisfaction of the online problem-based learning module among Physics trainee teachers.*

No.	Statement	Frequency (Percentage, %)				M	SD
		SD	D	A	SA		
1	I am satisfied with this module.	0 (0.0)	2 (2.5)	17 (21.3)	61 (76.2)	3.74	0.50
2	This module functions as I expected.	0 (0.0)	0 (0.0)	22 (27.5)	58 (72.5)	3.73	0.45
3	I would like to own this module.	0 (0.0)	0 (0.0)	12 (15.0)	68 (85.0)	3.85	0.36
4	This module is fun to use.	0 (0.0)	1 (1.2)	14 (17.5)	65 (81.3)	3.80	0.43
5	I would recommend this module to other trainee teachers.	0 (0.0)	1 (1.2)	10 (12.5)	69 (86.3)	3.85	0.39
	Overall					3.79	0.30

The perceived usability of the developed online PBL module among Physics trainee teachers was also determined from an overall aspect as shown in Table 10. According to Table 10, Physics trainee teachers has high usability level towards the developed online PBL module has a high usability level for all aspects; usefulness (M = 3.76; SD = 0.32), ease of use (M = 3.72; SD = 0.35), and satisfaction (M = 3.79; SD = 0.30). and overall (M = 3.76; SD = 0.32). Therefore, the module has a high perceived usability level as a learning aid for the Impulsive Force subtopic.

Table 10. *Perceived usability of the online problem-based learning module among Physics trainee teachers from an overall aspect.*

No.	Aspect	M	SD	Perceived Usability Level
1	Usefulness	3.76	0.32	High
2	Ease of use	3.72	0.35	High
3	Satisfaction	3.79	0.30	High
	Overall	3.76	0.32	High

CONCLUSION

The online PBL module for the Impulsive Force subtopic for Form Four Physics has been successfully developed in this study. The findings show that the module received high agreement percentages from three experts of 98% and 95% for face validity and content validity, respectively. The module also has a high perceived usability level among Physics trainee teachers in terms of usefulness, ease of use, and satisfaction. However, the finding of this study only reveals the perceived usability level among Physics trainee teachers. Hence, further research should be conducted to assess the effectiveness of the developed module as a learning aid for the Impulsive Force subtopic.

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