THE DESIGN AND DEVELOPMENT OF A TEACHER TRAINING MODULE ON THE GAME-BASED LEARNING APPROACH IN TEACHING PHYSICS: A CONCEPTUAL FRAMEWORK BASED ON DESIGN AND DEVELOPMENT RESEARCH (DDR) APPROACH

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ABSTRACT

Physics, despite being a core STEM subject, often attracts less student interest than Chemistry and Biology as it demands strong mathematical skills, involves complex problem-solving, and requires memorisation of many formulas. Additionally, traditional teaching methods can make Physics seem uninteresting and hard to understand, hence reducing student engagement. Game-based learning (GBL) is a teaching method that incorporates games or game-like elements into lessons to create engaging learning experiences. Numerous studies have shown that integrating GBL into Physics instruction significantly enhances students' motivation, engagement, and learning outcomes. Despite these benefits, teachers often face challenges in effectively implementing GBL in their teaching practices, primarily due to a lack of knowledge, skills, or training in this area. Thus, professional growth through training or teaching and learning resources is essential to support teachers' GBL competence and enhance students' motivation and learning. Hence, this study proposes a conceptual framework outlining the structure of a teacher training module aimed to facilitate the integration of GBL and the creation of digital and non-digital educational games for Physics. The research design follows the Design and Development Research (DDR) approach, which is structured into three main phases: needs analysis, design and development, and evaluation. The module itself is developed using the ADDIE instructional design model, incorporating GBL models and relevant learning theories. During the needs analysis phase, the requirements and needs of the target users are identified. The evaluation phase assesses the usability and effectiveness of the module. The suggested conceptual framework could be a reference for module developers focusing on improving in-service or pre-service teachers' GBL competencies for the benefit of the educational stakeholders.

Keywords: Conceptual framework, educators, game-based learning (GBL), Physics, teacher training module

INTRODUCTION

In order to adapt to the rapid change of the Industrial Revolution (IR 4.0), the curriculum focused on Science, Technology, Engineering, and Mathematics (STEM) disciplines (Lase, 2019) to provide students with the skills and knowledge necessary to tackle challenges in the 21st century and prepares them for the workforce required in various industries, contributing to economic advancement. STEM education became a catalyst for advancing education quality.

However, recent studies have revealed a decline in Malaysian student enrollment in STEM-related fields at both secondary and higher education levels (Markus, Sungkim & Ishak, 2021; Ng & Chua, 2023). Furthermore, the decrease in enrollments could be attributed to students' lack of interest, and many primary and secondary students perceive STEM subjects as difficult and complex (Mohd Shahali et al., 2019; Mohtar et al., 2019; Ramli & Talib, 2017).

Physics is one of the STEM subjects that explores natural occurrences in our environment (Badruldin & Alias, 2022). However, multiple research outcomes indicate that students view Physics as the most demanding subject in the realm of sciences because they struggle to understand abstract concepts and solve complicated problems (Ibrahim, Zakiang & Damio, 2019). Furthermore, students encountered feelings of monotony within the conventional Physics classroom environment (Najib, Md-Ali & Yaacob, 2022). Students struggle to understand and visualise abstract concepts in traditional settings, so their focus wanes completely. Hence, the way of teaching has had a notable effect on students' perspectives on learning, especially in Physics.

To nurture students' interest and learning towards Physics, teachers need to discover novel and captivating teaching methodologies to engage students' curiosity. Game-based learning (GBL) is an innovative teaching approach that integrates game elements and interactive gameplay into the learning process (Becker, 2021). It employs educational games, whether in digital or non-digital form, as instruments to facilitate students in gaining knowledge, skills, and understanding. Thus, GBL is a method to teach Physics topics, drawing students towards the subject and facilitating meaningful and engaged learning within Physics classrooms compared to traditional teaching methods.

However, GBL adoption among teachers remains marginal due to insufficient expertise and training. In-service and pre-service teachers often lack the skills, knowledge, and experiences to design games and integrate GBL (Avdiu, 2019; Foster & Shah, 2020; Kamışlı, 2019; Siburian & Mahmud, 2022). Additionally, Becker (2017) mentioned that teachers who have incorporated GBL in their classrooms tend to fuse educational material with pre-existing games rather than crafting their own educational games. Moreover, educators often face constraints in preparing game-based lessons (Mozelius et al., 2017; Avdiu, 2019).

Since teachers have insufficient training and experience in GBL, they are not well-equipped with game design knowledge and skills. Thus, they could not proficiently execute GBL within their Physics classrooms. Therefore, teachers should receive appropriate professional growth opportunities to support and assist them in creating and linking games with their instructional methods.

In order to overcome the challenges faced while adopting GBL in teaching physics, providing an educational game design training module that could facilitate teachers' game design process and implementation of GBL in lessons is the key. This endeavor ultimately contributes to improved comprehension and engagement levels among students in the field of Physics.

This study aims to discuss the conceptual framework of designing and developing a teacher training module that enhances teachers' GBL competencies. It explains the fundamental idea and concept underlying the entire study that has been carried out. It outlines the main concepts, relationships, and theories that guide the research. In short, it offers a conceptual framework for understanding the study's focus and direction.

LITERATURE REVIEW

Game-Based Learning (GBL) in Physics Education

The integration of GBL into classrooms has shown significant effectiveness in enhancing student learning, particularly with games like "The World of Newton" by Alias and Ibrahim (2017), which successfully combines pedagogical elements, game mechanics, and real-life scenarios related to Newton's laws of motion. Similarly, Shute et al. (2019) highlighted that GBL supports student learning, as demonstrated by the game "Physics Playground," which allows teachers to assess students' understanding through game activities. Additionally, Jones, Caton, and Greenhill (2014) found that the prototype game "Junkyard Physics" effectively engaged students in learning the fundamental principles of forces. In another study, Stege, Van Lankveld, and Spronck (2012) confirmed that educational games can enhance students' understanding of electrical engineering theory. The use of educational games in Moroccan secondary schools has also been shown to improve students' motivation and engagement with Physics (Khouna et al., 2017). Similarly, Dewantara et al. (2020) demonstrated that GBL effectively enhanced students' understanding of logic gate material, leading to improved performance in post-tests after the intervention. Overall, previous studies have consistently demonstrated that GBL is an effective instructional strategy that makes learning Physics more enjoyable, promotes active engagement, and enhances student outcomes. These studies generally conclude that GBL can offer numerous educational benefits and, in some cases, maybe more effective than traditional non-game-based methods.

In short, whether using digital or non-digital games, GBL is effective in promoting student learning, motivation, and 21st-century skills, provided the games are carefully planned and designed to align with the learning content and theories. Incorporating appropriate game elements and facilitating classroom discussions after gameplay further enhances this effectiveness. Therefore, a teacher training module is essential to equip educators with the skills needed to design educational games that are well-suited to their student's needs and learning objectives.

Challenges Teachers Face in Implementing GBL

Past studies have shown that teacher involvement and guidance in a game-based classroom can create valuable learning opportunities for students (Foster & Shah, 2020). However, the GBL approach is challenging, requiring a level of expertise that may not be innate to all educators (Bell & Gresalfi, 2017; Eastwood & Sadler, 2013). Using GBL effectively demands specific skills to present academic content in an engaging manner that keeps students motivated and supports their learning (North et al., 2021). Jääskä and Aaltonen (2022) emphasised that successfully designing and implementing GBL practices requires teachers to integrate educational games seamlessly with the subject matter. In essence, teachers need GBL-specific skills, such as game literacy and technological proficiency, in addition to their subject knowledge and pedagogical expertise.

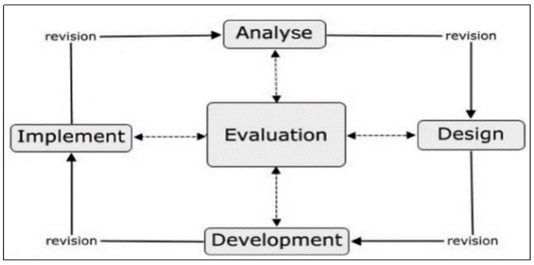
Shah (2019) highlighted the limited opportunities available for teachers to develop proficiency in GBL, noting a lack of comprehensive frameworks to support the integration of educational games into teaching. Moreover, teachers often struggle with time constraints and limited resources when attempting to incorporate educational games into their instruction. Finding suitable educational games can be difficult, as teachers frequently rely on chance discoveries or recommendations from colleagues who have used them (Jääskä & Aaltonen, 2022). Due to these challenges and the general lack of professional development, many teachers find it difficult to adopt GBL effectively.

Despite these obstacles, surveys suggest that both in-service and pre-service teachers are increasingly receptive to the integration of GBL in classrooms (Takeuchi & Vaala, 2014). Therefore, it is crucial to provide substantial professional development opportunities and resources to equip teachers with the skills needed to effectively use educational games and implement GBL in teaching, especially for Physics.

The ADDIE Model

ADDIE stands for Analyse, Design, Develop, Implement, and Evaluate. It is an instructional design framework used to create educational materials and training programs (Bamrara & Chauhan, 2018). As shown in Figure 1, the ADDIE model follows a structured process: it starts with analysing users' needs and then moves to design objectives, strategies, and content. Next, materials are developed, followed by implementation and evaluation of the final products. Due to its adaptable nature, it allows designers to enter, re-enter, or modify its stages as needed.

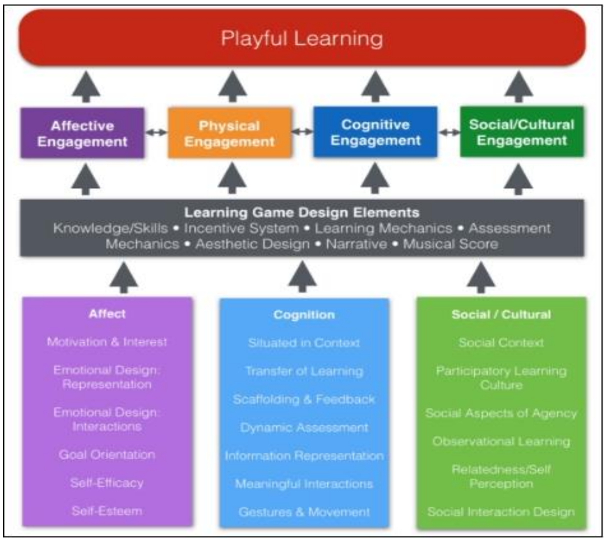
Figure 1. The ADDIE Model (Bamrara & Chauhan, 2018)



The Integrated Design Framework of Playful Learning

The Integrated Design Framework of Playful Learning shown in Figure 2 was proposed by Plass, Homer and Kinzer in 2015. This framework aims to provide educators with a set of guidelines highlighting the educational potential of games. The three key components, affect, cognition and social or culture, are integrated into designing games that ensure learners remain actively engaged with the intended learning objectives throughout the gaming experience.

Figure 2. Integrated Design Framework of Playful Learning (Plass, Homer, & Kinzer, 2015)



Gagne's Nine Events of Instruction

Table 1 shows Gagne's Nine Events of Instruction, proposed by Robert Gagne in 1985, which guides the design and delivery of instruction and stimulates the learning process. According to Iqbal, Siddiqie and Mazid (2021), many educators worldwide have integrated Gagne's Nine Events of Instruction into their lesson planning because these steps take into account the unique qualities and characteristics of each learner, aligning the instructional approach with their cognitive abilities, readiness to learn, and motivation, resulting in a more tailored and effective learning experience.

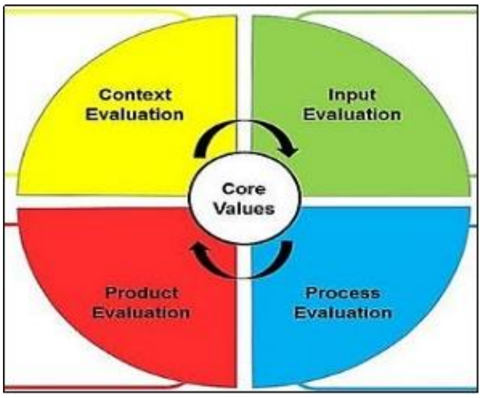
Table 1. Gagne's Nine Events of Instruction (Northern Illinois University Center for Innovative Teaching and Learning, 2020)

No.	Instructional Event
1.	Gain attention
2.	Explain objectives
3.	Stimulate recall of prior knowledge
4.	Present content
5.	Provide guidance
6.	Elicit performance
7.	Provide feedback
8.	Assess performance
9.	Enhance retention

The CIPP Evaluation Model

Figure 3 shows the CIPP evaluation model developed by Stufflebeam between the 1960s and 1970s. The essential elements of this model encompass the evaluation of context, input, process and product, which is the acronym of the CIPP evaluation model (Stufflebeam, 2000). It has been widely used to evaluate programs, products, and institutions from different fields (Sopha & Nanni, 2019).

Figure 3. The key components of the CIPP evaluation model (Stufflebeam, 2000)

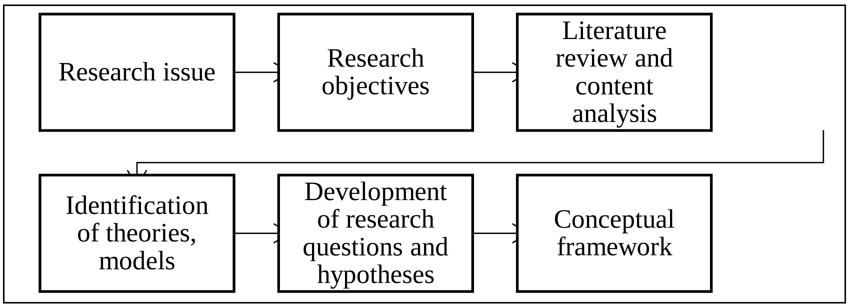


METHODOLOGY

A deductive research approach was employed to shape the conceptual framework of this study. According to Varpio et al. (2020), a conceptual framework consists of a literature review, an overview of the relevant theories, how the theory can offer insights within the specific context, a justification for the chosen research methodology, and a set of outcomes or variables. Hence, the relevant theories, models, and elements were collected from the literature review to develop a framework that could provide an overview of the study and a layout of the methodological foundations for designing and developing a teacher training module for GBL.

Figure 4 shows the block flow diagram, which outlines the steps taken in shaping the conceptual framework of this study. Firstly, the research issue is being identified: the lack of students' interest towards Physics and the lack of GBL professional development among Physics teachers, followed by the research objectives: the design and development of a teacher training module to enhance teachers' GBL competency and foster students' learning and motivation. Then, a thorough literature review and content analysis are conducted to identify the relevant theories and models to be included in the study. After that, the selected theories and models are used to develop the research questions and hypotheses and identify the variables involved in the study. Finally, the conceptual framework is derived, and the methodology to be adopted in the study is also presented in the conceptual framework.

Figure 4. The development of the conceptual framework



RESULTS AND DISCUSSION

Figure 5 shows the conceptual framework for designing and developing a teacher training module to enhance teachers' GBL competency. The framework was formed following the Design and Development Research (DDR) approach proposed by Richey and Klein in 2007, which consists of three main stages: Needs Analysis, Design and Development, and Evaluation.

The procedures that could be taken to produce a training module are outlined in Figure 5, starting with identifying needs through analysis, followed by defining the structure, format and objectives of the educational materials, creating materials aimed at fulfilling these goals during the design and development phase, and finally, implement and assess the effectiveness in the last phase (Richey & Klein, 2007).

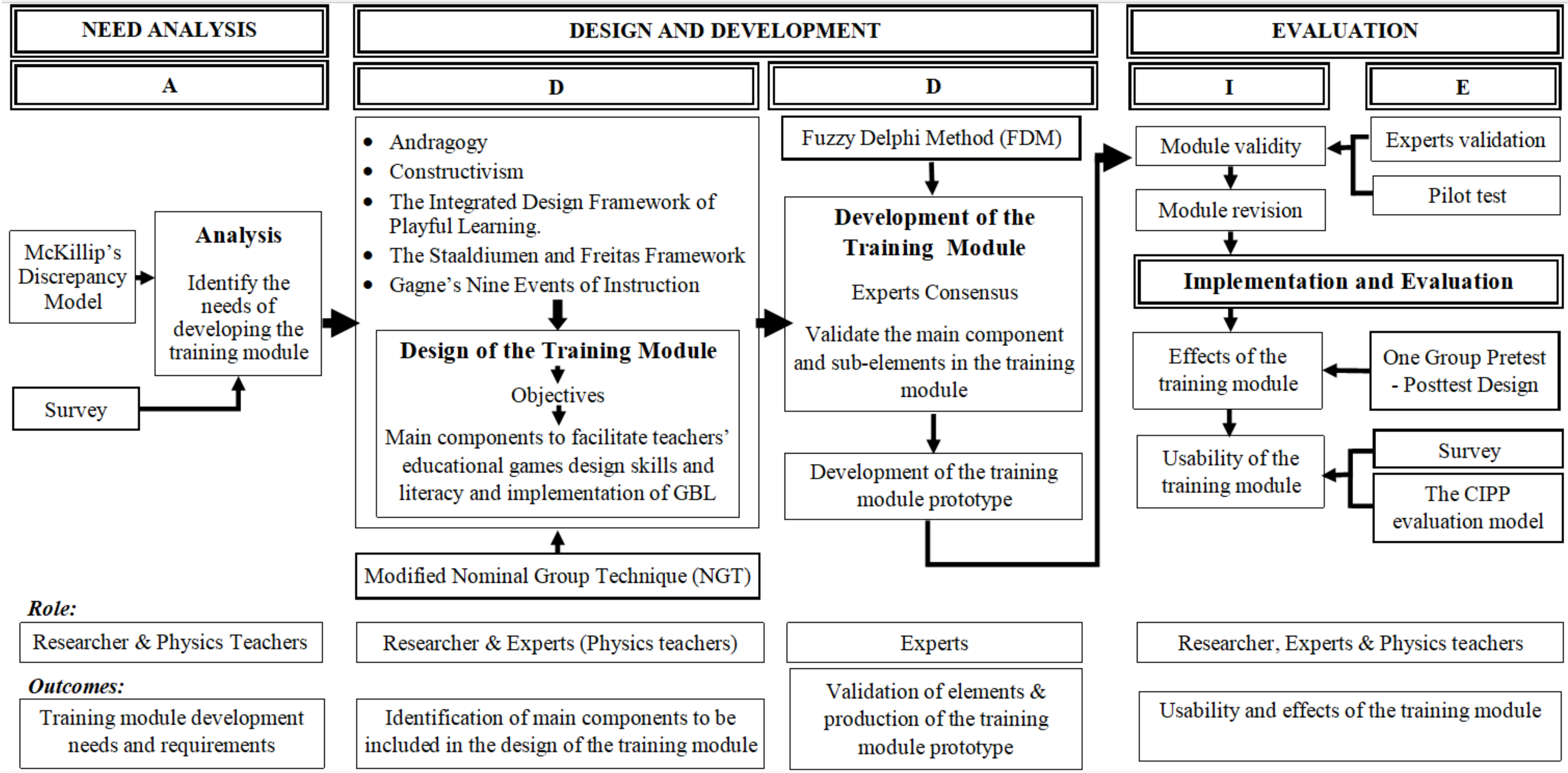
Phase 1- Need Analysis

The first phase of the DDR approach is need analysis, which is a data-gathering process that provides the necessary information to be used as the foundation for creating a product that suits users' needs (Akyel & Ozek, 2010). McKillip (1987) proposed three models that could serve as the basis for the needs analysis phase: Discrepancy Model, Marketing Model and Decision-Making Models. The Discrepancy Model was selected in this study because it highlights the significance of recognising discrepancies between the current state of affairs and the desired state.

Before developing a teacher training module, it is essential to conduct a need analysis to identify the need to create the module and the challenges faced during the teaching and learning process. The research questions for this study are: (i) What challenges do teachers and students face while teaching and learning Physics? (ii) What are teachers' attitudes towards using GBL in teaching and learning Physics? (iii) What is teachers' readiness for implementing the GBL approach to teach Physics? (iv) Is professional development needed for the GBL approach in teaching and learning Physics? Collectively, these research questions serve to provide a holistic understanding of the current state of Physics education with respect to GBL. The insights gained will directly inform the design and development of a teacher training module, ensuring it is both relevant and responsive to the needs of educators and students alike.

A quantitative research approach could be employed by using a survey to gather input from Physics teachers regarding the challenges encountered when teaching and learning Physics and the necessity for creating a teacher training module. The data gathered will undergo descriptive analysis, with an emphasis on calculating mean scores and standard deviations. This analysis will provide insights into the extent of teachers' need for a training module designed explicitly to integrate GBL into teaching Physics.

Figure 5. A framework for designing and developing a teacher training module for facilitating the implementation of GBL in Physics classrooms (Adaptation of the ADDIE model & Padzil, Abd Karim & Husnin, 2021)



Phase 2- Design and Development

The design and development phase helps the researchers to produce relevant final products and guarantee their advantageous impact on the intended users. The ADDIE model is employed to design and develop the teacher training module because it helps researchers visualise the whole instruction design process in creating the module.

Learning theories must be included in designing training modules, as theories provide a solid foundation to produce modules that could cater to the users' needs, enable knowledge transfer, and offer impactful learning experiences. Since this teacher training module is intended to provide teachers with a platform to improve their educational game design skills and facilitate the implementation of GBL, the adult learning model – Andragogy, was included as one of the theories used to design the module. Andragogy refers to educating and training adults, which promotes lifelong learning.

Constructivism learning theory is included in designing the module because this teacher training module is meant to guide teachers with educational game design. When teachers design educational games using the teacher training module, they create experiences that resonate with their students' needs and interests. This process encourages applying knowledge in meaningful contexts, aligning with the constructivist idea.

Apart from that, the Integrated Design Framework of Playful Learning is selected as the core of the module as the GBL framework could be a guideline in helping teachers decide on the types of games that should be used in the lessons and factors to be considered to create educational games that suit the curriculum and students' needs.

Gagne's Nine Events of Instruction is the best choice to provide guidelines for educators to successfully implement the GBL approach in Physics classrooms because it is a systematic framework that is action-oriented, which enables educators to improve their teaching efficacy. According to McKivigan (2019), following the nine steps to instruct lessons helps educators organise the classes and students' learning process. Finally, it enables students to gain knowledge, retain and apply it in a real-world context.

These selected models and theories must be aligned with the main objectives of module development. In the context of this study, the primary goal is to improve teachers' GBL competency so that teachers can adopt GBL successfully in a Physics classroom and foster students' learning and motivation.

When the theoretical foundation of the teacher training module is built, the next stage is to identify the main components to be included in the module's design. A Nominal Group Technique (NGT) could be employed because it allows the experts to share their expertise and perspectives in identifying the training module's main components and sub-elements. NGT is a method for facilitating group consensus and action planning through structured face-to-face sessions on a specific topic (Ghazali et al., 2021). The data collected via NGT will be analysed based on ranking and percentage of agreement. If the percentage of agreement is more than 70%, then the main components are accepted.

After the design of the teacher training module has been determined, the Fuzzy Delphi Method (FDM) could be applied in the development phase to achieve consensus among experts regarding the pre-determined elements and sub-elements collected via the NGT workshop and literature review. Vasodavan, DeWitt and Alias (2022) highlighted the utility of FDM as a valuable decision-making instrument. It facilitates collective decision-making for intricate problems by employing fuzzy set logic and theory. This method combines expert viewpoints through cumulative frequency and fuzzy scores instead of relying solely on individual perspectives. Hence, FDM is suitable for gathering the insights and consensus of experts, aiming to assess and validate the appropriate components and elements to be integrated into developing a teacher training module.

The elements to be included in developing a training module are determined through the following conditions of Triangular Fuzzy Numbers: (i) Threshold value, $d \leq 0.2$, (ii) Percentage of experts consensus > 75%, (iii) Defuzzification process (Fuzzy Score, $A \geq$ α-cut value = 0.5. Based on the consensus achieved by the experts, a prototype of a teacher training module could be developed. The content and design of the produced prototype must be validated by a group of experts, and a pilot test must be conducted to determine its reliability. Then, the prototype could be revised based on the comments from the experts and the users, as shown in Figure 5.

Phase 3- Evaluation

According to Basaran et al. (2021), getting users' feedback could identify whether the products' goals have been achieved. Through this process, users' behaviour and preferences could be gathered, and improvements could be made before the product is released to a broader audience. The quality of the product and users' satisfaction could be ensured.

The CIPP evaluation model is used to assess the usability of the developed teacher training module. This model evaluates the module's effectiveness, efficiency, and user satisfaction within a specific context are determined. This process helps identify the strengths and weaknesses of the teacher training module. A quantitative approach, such as a survey, may be employed to evaluate the module's usability.

Meanwhile, a single-group pre-test and post-test (SGPP) design is integrated to investigate the effects of the training module on teachers' attitudes toward the GBL approach in teaching Physics and involvement in the game design process. SGPP is frequently utilised to assess training programs (Carlson & Schmidt, 1999). As the teacher training module is provided to teachers through a professional development initiative, it is deemed a training program.

This phase is designed to address three research questions: (i) Does the teacher training module help teachers design and develop educational games to enhance students' learning and motivation in Physics? (ii) Does the teacher training module help teachers adopt GBL to teach Physics? (iii) What is the influence of the usage of the teacher training module on teachers' attitudes toward implementing GBL and involvement in educational game design?

In summary, the research questions are crafted to evaluate both the immediate and long-term impacts of the teacher training module on Physics educators. Specifically, they aim to ascertain whether the module successfully achieves its primary objectives: enhancing teachers' skills in educational game design, fostering the adoption of the GBL approach, and positively shaping teachers' attitudes toward innovative instructional practices. Then, the data analysis focuses on descriptive measures such as percentage, mean, and standard deviation to investigate the effects of the teacher training module on teachers' perceptions of GBL and game design and the usability of the training module.

Implications of the Study

The proposed framework serves as a general guideline for designers and developers interested in creating teacher training modules related to GBL. When designing and developing a teacher training module, designers should consider relevant theoretical backgrounds, learning theories, and GBL models. They should follow the proposed steps to produce a prototype and evaluate its usability. This flexible framework can be customised for various projects focused on module design and development to enhance the GBL approach. The outlined steps streamline the process of crafting successful GBL modules, promoting the incorporation of GBL in diverse subject areas. Consequently, it provides valuable guidance for designing and developing teacher training modules and serves as a resource for future research.

Developing this teacher training module contributes to teachers' professional development as they learn how to create educational games aligned with the Physics curriculum and suit their students' needs. By training teachers in this area, education becomes more relevant and effective in catering to the needs and preferences of current students. Teachers with positive attitudes toward integrating GBL in teaching Physics could reshape their instructional strategies and teaching methods. This could lead to a transformation in the teaching and learning process.

Once teachers' GBL competencies have improved, it could increase the adoption of GBL in teaching Physics, and indirectly, it could benefit the students as their teachers could apply the knowledge gained through the teacher training module to offer innovative and creative educational games and learning environment that boosts their engagement in Physics. Thus, students are more motivated to learn Physics. It indirectly helps improve students' academic performance, and Physics will no longer be labelled dull and challenging. Moreover, it will be able to nurture future generations who are more creative, innovative, and equipped with critical thinking and problem-solving skills, producing heightened societal competitiveness.

CONCLUSION, LIMITATIONS AND RECOMMENDATIONS

This study concerns creating and producing a teacher training module that could facilitate teachers' implementation of GBL in teaching Physics and improve teachers' GBL competencies. Creating this teacher training module involved three primary stages within the Design and Development Research (DDR) framework: needs analysis, design and development, and evaluation. Through the production of this teacher training module, stakeholders and teachers' academic institutions could offer pre-service and in-service teachers opportunities for professional growth and learning concerning the GBL methodology. Consequently, stakeholders and the Ministry of Education could consider funding to develop educational games to promote the implementation of GBL in enhancing students' learning in Physics.

This study has several limitations. Firstly, the study primarily assesses the immediate effects of the training module, potentially overlooking the long-term impact on teachers' practices and student outcomes. Additionally, the reliance on self-reported data through surveys introduces potential biases, such as social desirability bias, which may affect the accuracy of the responses. These limitations suggest that further research is necessary to validate the findings and explore the module's broader impact.

Several recommendations and directions for future research are proposed. First, conducting longitudinal studies would provide valuable insights into the long-term impact of the training module on teachers' practices and student outcomes, thereby assessing the sustainability of its effects over time. Future research should consider employing mixed methods approaches, such as classroom observations and interviews, to gain a more comprehensive understanding of the module's effectiveness. This would minimise the potential biases associated with self-reported data. Besides, it is also recommended that future studies explore the application of the training module across diverse educational settings, including different subject areas, grade levels, and cultural contexts, to determine its adaptability and effectiveness in various environments.

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