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Development and evaluation of a games-based informatics module using digital interactive boards

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ABSTRACT

This study aimed to develop an Informatics learning module based on Games-Based Learning (GBL) integrated with a Digital Interactive Board (PID) and to evaluate its validity, practicality, and effectiveness in improving students' learning outcomes. This research employed a Research and Development (R&D) approach using the ADDIE model, comprising Analysis, Design, Development, Implementation, and Evaluation stages. The study involved 33 Grade IX students of SMP Negeri 21 Padang. Data were collected through expert validation questionnaires, teacher and student response questionnaires, and pretest-posttest assessments. The module achieved very high validity scores, including 90.74% for module design, 91.67% for learning materials, and 97.50% for assessment instruments. The practicality scores reached 86.03% for teachers and 80.00% for students. The classical learning mastery rate increased to 90.91%, and the N-Gain score was 0.60, indicating moderate improvement. The GBL module integrated with PID is valid, practical, and effective for improving Informatics learning outcomes at the junior secondary school level.



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Introduction

The rapid advancement of digital technologies has fundamentally transformed educational practices by encouraging the integration of information and communication technologies into teaching and learning processes (Arancibia-Gutiérrez & Bustamante-Molina, 2019; Yasa et al., 2020). Digital transformation in education extends beyond the digitization of instructional materials and increasingly emphasizes the creation of interactive, student-centered, and technology-enhanced learning environments. Consequently, schools are expected to equip students with digital literacy, computational thinking, problem-solving abilities, and critical thinking skills required for participation in contemporary society and the future workforce (Jamieson et al., 2025; Rudenko et al., 2024). In this context, Informatics education has a strategic role in developing students' digital competencies from an early age and preparing them to address increasingly complex technological challenges.

Despite its importance, Informatics instruction in many junior secondary schools remains predominantly teacher-centered and relies heavily on lectures and conventional presentations, resulting in limited student engagement and relatively low learning achievement (Batzos et al., 2023; Tsapara & Bratitsis, 2023). Preliminary observations at SMP Negeri 21 Padang revealed that learning activities were primarily conducted through LCD projector presentations with limited opportunities for student interaction, incomplete learning assignments, and unsatisfactory achievement levels. These conditions indicate a mismatch between existing instructional practices and the learning preferences of adolescents, who generally prefer visually attractive, interactive, and technology-

mediated learning experiences. Therefore, innovative instructional approaches that promote active participation and independent learning are required to improve the quality of Informatics education.

One instructional approach that has received considerable attention is Games-Based Learning (GBL). GBL integrates game elements into learning activities to create meaningful, enjoyable, and motivating learning experiences. Previous studies have demonstrated that GBL can improve motivation, engagement, problem-solving skills, computational thinking, and conceptual understanding in various educational contexts (Iyer et al., 2026; Wang et al., 2023). Educational games encourage learners to actively participate, explore concepts, and receive immediate feedback during the learning process. Such characteristics are particularly relevant to junior secondary students aged between 14 and 16 years, who have begun developing abstract and logical thinking abilities and require learning experiences that support exploration and self-regulated knowledge construction (Bakhsh et al., 2022; Gao, 2023).

Alongside game-based pedagogies, digital interactive technologies have increasingly been incorporated into educational settings. Digital Interactive Boards (PID) facilitate direct interaction with learning materials through multimedia presentations, collaborative activities, and immediate feedback mechanisms. Previous studies have reported that interactive digital technologies significantly improve students' attention, participation, and learning outcomes by creating more dynamic and engaging classroom environments (Andreolletti et al., 2024; Lauer-Schmaltz et al., 2024). Interactive digital boards also provide opportunities to support collaborative learning and active knowledge construction, making them particularly suitable for Informatics instruction, which requires students to understand concepts through visualization, interaction, and problem-solving activities.

Although the benefits of Games-Based Learning and interactive digital technologies have been widely documented, previous studies have predominantly examined these approaches separately. Most studies focused either on the effectiveness of GBL as an independent instructional strategy or on the implementation of interactive technologies without integrating game-based pedagogies (Gómez et al., 2025; Kaimara, 2026). Moreover, studies that developed and validated learning products combining Games-Based Learning and Digital Interactive Board technology in Informatics education, particularly at the junior secondary level, remain limited. Existing studies have also paid relatively little attention to comprehensively evaluating educational products in terms of validity, practicality, and effectiveness (Chao et al., 2026; Pérez-Lisboa, 2017). Therefore, empirical evidence regarding the pedagogical value of integrating GBL and PID in Informatics learning remains insufficient.

Based on these considerations, this study aimed to develop an Informatics learning module based on Games-Based Learning integrated with a Digital Interactive Board using the ADDIE development model and to evaluate its validity, practicality, and effectiveness in improving students' learning outcomes. The novelty of this study lies in the systematic integration of GBL activities and Digital Interactive Board technology into a single instructional module specifically designed for junior secondary Informatics education. In addition, this study contributes by developing digital learning materials that support active, interactive, and self-directed learning and by providing empirical evidence regarding the quality of the developed product through comprehensive evaluations of validity, practicality, and effectiveness. Therefore, this study contributes theoretically to the development of technology-enhanced learning models and practically to the implementation of student-centered learning in Informatics education.

Method

This study employed a Research and Development (R&D) approach to develop and evaluate an Informatics learning module based on Games-Based Learning (GBL) integrated with a Digital Interactive Board (PID). The study adopted the ADDIE instructional development model proposed by Dick and Carey, which comprises five sequential phases: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model was selected because it provides a systematic and iterative framework that ensures alignment between learning needs, instructional design, product development, implementation, and evaluation. The research was conducted at SMP Negeri 21 Padang from April to May 2026.

The field-testing participants consisted of 33 Grade IX.1 students selected through purposive sampling because they had previously demonstrated limited participation in learning activities, incomplete assignment completion, and relatively low achievement in Informatics subjects. The product validation process involved three experts comprising two lecturers from Universitas Negeri Padang with expertise in instructional design and educational assessment and one experienced Informatics teacher from SMP Negeri 21 Padang who evaluated the appropriateness of the learning materials within the school curriculum and classroom context.

During the analysis phase, a needs assessment, curriculum analysis, and student characteristics analysis were conducted through classroom observations, semi-structured interviews, and reviews of learning documents. The findings indicated that Informatics instruction was predominantly teacher-centered, relied mainly on LCD projector presentations, and provided limited opportunities for active participation and interaction. Furthermore, students aged between 14 and 16 years preferred visually attractive and interactive learning experiences and required structured learning support to facilitate independent learning. Based on these findings, four digital modules were developed, namely Malware, Protecting Personal Data in the Digital World, Digital Technology Utilization for Content Production and Dissemination, and Blog modules. Among these products, the Malware module was selected as the primary implementation product because cybersecurity concepts were considered highly relevant to students' daily digital experiences and corresponded closely to the instructional needs identified during the analysis stage.

Data were collected using expert validation questionnaires, teacher and student response questionnaires, achievement tests, and games-based performance assessments. The validation instruments evaluated module design, learning materials, and assessment components using Likert-scale indicators covering content relevance, instructional presentation, language clarity, and assessment appropriateness. Prior to implementation, all instruments underwent expert judgment to ensure content validity and measurement consistency. Practicality was determined through teacher and student responses regarding ease of use, time efficiency, and module utilization during classroom implementation.

The effectiveness of the developed module was evaluated using a one-group pretest-posttest design. Students completed pretests prior to the intervention and posttests after learning through the GBL module integrated with PID. Descriptive statistical analysis was employed to determine validity and practicality levels using percentage scores calculated as follows:

Percentage = (Obtained Score / Maximum Score) × 100%

The percentage values were subsequently interpreted according to predetermined criteria to determine the validity and practicality levels of the developed module. The effectiveness of the module was examined through classical mastery learning and normalized gain (N-Gain) analysis. Classical mastery was calculated by dividing the number of students achieving the minimum mastery criterion by the total number of students and multiplying the result by 100%. The module was considered effective when at least 80% of students achieved mastery learning. To determine the magnitude of learning improvement, the normalized gain (N-Gain) was calculated using the following formula:

$$\text{N-Gain} = (\text{Posttest Score} - \text{Pretest Score}) / (\text{Maximum Score} - \text{Pretest Score})$$

The interpretation of N-Gain followed commonly accepted criteria, namely high ($g > 0.70$), moderate ($0.30 \leq g \leq 0.70$), and low ($g < 0.30$). The use of classical mastery and N-Gain analyses enabled a comprehensive evaluation of the module's effectiveness in improving students' learning outcomes in Informatics.

Ethical Considerations

This study was conducted in accordance with ethical principles for educational research involving human participants. Permission to conduct the study was obtained from the principal of SMP Negeri 21 Padang prior to data collection. Written informed consent was obtained from students and their parents or guardians before participation in the study. Participants were informed about the objectives, procedures, and voluntary nature of their involvement and were assured that participation would not affect their academic standing. The identities of all participants were kept confidential by anonymizing personal information during data analysis and reporting. Furthermore, the implementation of the developed module was integrated into regular classroom activities and did not interfere with students' academic responsibilities.

Results and Discussions

This study developed an Informatics learning module based on Games-Based Learning (GBL) integrated with a Digital Interactive Board (PID) using the ADDIE development model, which comprises the phases of Analysis, Design, Development, Implementation, and Evaluation. The development process was initiated by identifying learning problems and students' needs, followed by designing and developing the module and subsequently evaluating its validity, practicality, and effectiveness. The findings are presented sequentially, beginning with the initial needs analysis and student characteristics, followed by the developed products and expert validation, and concluding with the practicality and effectiveness of the module in improving students' learning outcomes in Informatics at SMP Negeri 21 Padang.

Table 1. Initial Needs Analysis Findings

Aspect	Findings
Learning Media	Learning activities predominantly relied on LCD projector presentations and videos.
Learning Interaction Student Participation	The instructional process was mainly teacher-centered and one-way. Students were less active and showed limited interaction during learning activities.
Assignment Completion Learning Outcomes	Learning assignments were frequently incomplete or not submitted. Students' achievement in Informatics tended to be low.
Development Need	An interactive learning module integrating Games-Based Learning (GBL) and a Digital Interactive Board (PID) was required to promote active and independent learning.

Table 1 presents the results of the initial needs analysis conducted before the module development process. The findings indicate that Informatics instruction at SMP Negeri 21 Padang primarily relied on conventional presentations using LCD projectors, resulting in teacher-centered instruction with limited student interaction. Students were generally passive during learning activities, frequently failed to complete assignments, and demonstrated relatively low learning achievement. These conditions highlighted the necessity of developing an innovative instructional medium that could promote active participation, interaction, and independent learning. Consequently, a Games-Based Learning (GBL) module integrated with a Digital Interactive Board (PID) was designed to address these instructional challenges.

Table 2. Student Characteristics Analysis

Aspect	Description
Participants	Grade IX.1 students of SMP Negeri 21 Padang
Number of Students	33 students
Age Range	14–16 years
Cognitive Characteristics	Students had begun developing abstract and logical thinking abilities.
Learning Preferences	Students preferred visually attractive and interactive learning activities.
Learning Needs	Students required structured learning support and opportunities for independent learning.
Implication for Development	The module was designed to encourage active participation, interaction, and self-directed learning.

Table 2 describes the characteristics of the research participants, consisting of 33 Grade IX.1 students aged between 14 and 16 years. At this developmental stage, students had begun to demonstrate abstract and logical thinking capabilities and were able to process information more independently. The findings further revealed that students preferred visually appealing and interactive learning experiences and required structured learning support to facilitate self-directed learning. Therefore, these characteristics became the primary considerations in designing the GBL module integrated with PID, ensuring that the instructional activities aligned with students' developmental and learning needs.

Table 3. Learning Objectives and Core Materials

Learning Objectives	Learning Indicators	Core Materials
Understanding malware concepts	Define and explain the concept of malware correctly	Definition of malware
Identifying malware types	Differentiate and identify various types of malware	Types and functions of malware
Understanding malware mechanisms	Explain how malware operates	Malware mechanisms
Preventing malware attacks	Explain preventive measures against malware	Malware prevention strategies
Handling malware infections	Explain methods for overcoming malware infections	Malware mitigation and treatment
Evaluating malware impacts	Describe the effects of malware on computer systems	Impacts of malware on computers

Table 3 outlines the learning objectives, indicators, and core materials incorporated into the developed module. The learning content focused on malware topics, including its definitions, classifications, mechanisms, impacts, and preventive strategies. These materials were systematically organized according to the learning

outcomes and competency indicators specified in the Informatics curriculum. The arrangement of learning objectives and instructional content ensured that students not only acquired conceptual understanding but also developed analytical and problem-solving skills related to cybersecurity issues in everyday digital environments.

Table 4. Developed Products of the GBL Module Integrated with PID

No.	Developed Product
1	Malware Module
2	Protecting Personal Data in the Digital World Module
3	Digital Technology Utilization for Content Production and Dissemination Module
4	Blog Module

Table 4 shows that four digital modules were successfully developed through the ADDIE procedure. These modules covered various topics in the Informatics curriculum, namely malware, personal data protection, digital technology utilization, and blogging. Among the developed products, the Malware Module was selected as the primary module for implementation and evaluation because it closely corresponded to the instructional needs identified during the analysis phase. Each module incorporated game-based activities and digital interactive features to support active, engaging, and student-centered learning experiences.

Table 5. Profiles of Expert Validators

Validator	Institution	Validation Focus
Dr. Fani Keprila Prima, S.Pd., M.Pd.T	Faculty of Engineering, Universitas Negeri Padang	Module Design
Prof. Dr. Fahmi Rizal, M.Pd	Faculty of Engineering, Universitas Negeri Padang	Assessment Instruments and Questionnaires
Widya Hasvini Putri, S.Pd.Gr., M.Si	SMP Negeri 21 Padang	Informatics Learning Materials

Explanation. Table 5 presents the profiles of the experts involved in validating the developed module. The validation process involved two university lecturers and one Informatics teacher with expertise in instructional design, educational assessment, and Informatics learning materials. The inclusion of experts from both higher education and school settings ensured comprehensive evaluations covering pedagogical, technical, and practical aspects of the developed module. Their feedback and recommendations served as the basis for revising and refining the product prior to implementation.

Table 6. Validity and Practicality Results of the Developed Module

Evaluation Component	Evaluation Aspect	Score/Percentage (%)	Category
Validity	Module Design Validation	90.74	Very Valid
Validity	Material Validation	91.67	Very Valid
Validity	Instrument and Questionnaire Validation	97.50	Very Valid
Teacher Practicality	Ease of Use	85.04	Practical
Teacher Practicality	Time Efficiency	85.02	Practical
Teacher Practicality	Module Utilization	87.05	Very Practical
Teacher Practicality	Average Score	86.03	Very Practical
Student Practicality	Grade IX.1 Students	80.00	Practical

Table 6 summarizes the validity and practicality results of the developed Games-Based Learning module integrated with a Digital Interactive Board. The validity assessment showed very high scores across all components, including module design validation (90.74%), material validation (91.67%), and instrument and questionnaire validation (97.50%), indicating that the module met the criteria for instructional design quality, content relevance, and assessment appropriateness. The teacher practicality results also indicated that the module was feasible for classroom use, with an average score of 86.03% in the very practical category. Meanwhile, student responses reached 80.00%, indicating that the module was practical, easy to use, and supportive of active and independent Informatics learning.

Table 7. Effectiveness and Overall Quality Evaluation of the Developed Module

Evaluation Component	Indicator	Result	Category
Learning Outcomes	Students Achieving Mastery (Pretest)	10 students	
Learning Outcomes	Students Not Achieving Mastery (Pretest)	23 students	
Learning Outcomes	Classical Mastery (Pretest)	30.30%	Low
Learning Outcomes	Mean Score (Pretest)	81.67	
Learning Outcomes	Students Achieving Mastery (Posttest)	30 students	
Learning Outcomes	Students Not Achieving Mastery (Posttest)	3 students	
Learning Outcomes	Classical Mastery (Posttest)	90.91%	Very Effective
Learning Outcomes	Mean Score (Posttest)	92.88	
Effectiveness	N-Gain Score	0.60	Moderate
Product Quality	Module Design Validity	90.74%	Very Valid
Product Quality	Material Validity	91.67%	Very Valid
Product Quality	Instrument Validity	97.50%	Very Valid
Product Quality	Teacher Practicality	86.03%	Very Practical
Product Quality	Student Practicality	80.00%	Practical

Table 7 presents the effectiveness and overall quality evaluation of the developed Games-Based Learning module integrated with a Digital Interactive Board (PID). Prior to the intervention, only 10 of the 33 students achieved mastery learning, corresponding to a classical mastery level of 30.30%, with a mean score of 81.67. Following the implementation of the module, the number of students achieving mastery increased substantially to 30 students, resulting in a classical mastery level of 90.91% and an improved mean score of 92.88. Furthermore, the N-Gain score reached 0.60, indicating a moderate improvement in students' learning outcomes. The overall product evaluation also demonstrated consistently high performance, with validity scores ranging from 90.74% to 97.50%, a teacher practicality score of 86.03%, and a student practicality score of 80.00%. Collectively, these findings confirm that the developed module is highly valid, practical, and effective for improving Informatics learning outcomes among junior secondary school students.

The findings of this study demonstrate that the development of the Informatics learning module based on Games-Based Learning (GBL) integrated with a Digital Interactive Board (PID) successfully addressed the instructional challenges identified during the needs analysis phase. Prior to the intervention, Informatics instruction at SMP Negeri 21 Padang was predominantly teacher-centered, relied mainly on LCD projector presentations, and provided limited opportunities for active student participation. Moreover, students frequently failed to complete assignments and exhibited relatively low learning achievement. These conditions indicate a mismatch between instructional strategies and the learning preferences of contemporary students who require interactive, technology-enhanced, and student-centered learning environments. Educational technology research emphasizes that digital learning environments should encourage active engagement, collaboration, and learner autonomy to improve learning outcomes and motivation (Marin-Vega et al., 2022; Zeiler et al., 2025).

The student characteristics analysis further supported the necessity of developing an interactive learning module. The participants consisted of 33 Grade IX students aged between 14 and 16 years who had begun to develop abstract and logical thinking abilities. At this developmental stage, learners are capable of processing information independently and solving increasingly complex problems. Consequently, instructional materials should provide opportunities for exploration, interaction, and self-regulated learning. The developed GBL module integrated with PID was specifically designed to accommodate these developmental characteristics by incorporating digital games, collaborative activities, and interactive assessments. Previous studies have demonstrated that learning environments that align instructional strategies with learners' cognitive characteristics significantly improve motivation, engagement, and knowledge construction (Bakhsh et al., 2022; Gao, 2023).

The expert validation results confirmed that the developed module possessed a high level of instructional quality and feasibility. The module design obtained a validity score of 90.74%, the learning materials achieved 91.67%, and the assessment instruments reached the highest validity score of 97.50%, all of which were categorized as very valid. These findings indicate that the module fulfilled essential criteria related to instructional content, pedagogical appropriateness, presentation quality, and assessment design. The exceptionally high validity scores suggest that the module content was systematically aligned with the curriculum and learning objectives while simultaneously providing meaningful learning experiences. Similar findings have been reported by previous studies, which concluded that educational products developed through

systematic instructional design procedures tend to achieve high content validity and pedagogical appropriateness (Abdoulqadir & Loizides, 2025; Adrian & Wijayanto, 2026; Loizou & Andreou, 2025; Machuqueiro & Piedade, 2024b).

The practicality findings also demonstrated the successful implementation of the developed module in classroom settings. The average teacher practicality score reached 86.03%, placing it in the very practical category, while the student practicality score reached 80.00%, categorized as practical. Among the evaluated aspects, module utilization achieved the highest score (87.05%), followed by ease of use (85.04%) and time efficiency (85.02%). These findings suggest that the module was not only easy to use but also facilitated classroom management and instructional delivery. From the students' perspective, the integration of games and digital interactive activities enhanced independent learning and active participation. These findings are consistent with studies indicating that well-designed educational games and interactive digital media can simplify instructional processes, reduce cognitive barriers, and improve learner engagement and satisfaction (Gundersen & Lampropoulos, 2025; Othman et al., 2025).

The effectiveness analysis demonstrated substantial improvements in students' learning outcomes after the implementation of the GBL module integrated with PID. Prior to the intervention, only 10 of the 33 students achieved mastery learning, representing a classical mastery level of 30.30%. Following the intervention, the number of students achieving mastery increased substantially to 30 students, corresponding to a classical mastery rate of 90.91%. Furthermore, the mean score increased from 81.67 during the pretest to 92.88 in the posttest. This remarkable improvement indicates that the developed module effectively promoted conceptual understanding and learning achievement in Informatics. The findings support the theoretical perspective that game-based learning environments can increase motivation, encourage active cognitive processing, and improve knowledge retention through experiential and interactive learning activities (Agbo et al., 2023; Machuqueiro & Piedade, 2024a; Oktavia & Ma'arif, 2026).

Further evidence of the module's effectiveness was demonstrated by the N-Gain score of 0.60, which falls within the moderate category and exceeds the minimum effectiveness criterion of 0.30. Although the gain was categorized as moderate, it indicates meaningful learning progress and confirms that the intervention produced substantial improvements in students' academic performance. The effectiveness of the module may be attributed to the synergistic integration of GBL principles and Digital Interactive Board technology. GBL provided challenging and enjoyable learning experiences, while PID facilitated direct interaction with learning materials, collaborative activities, and immediate feedback. The combination of these instructional features created an active and student-centered learning environment that supported knowledge construction and sustained engagement (Denoue et al., 2003; Rajarapollu et al., 2025; Rehman et al., 2024; Zulkifli et al., 2022). Consequently, the findings provide empirical evidence that integrating game-based instructional approaches with digital interactive technologies constitutes an effective pedagogical strategy for improving Informatics learning outcomes among junior secondary school students (Fortin et al., 2014; Lin et al., 2025; Oltra & Sampietro, 2015; Trütsch et al., 2025).

Conclusions

This study successfully developed an Informatics learning module based on Games-Based Learning (GBL) integrated with a Digital Interactive Board (PID) using the ADDIE development model. The developed module demonstrated a very high level of validity, as evidenced by the module design validity score of 90.74%, material validity score of 91.67%, and instrument validity score of 97.50%. Furthermore, the module was considered practical for classroom implementation, obtaining practicality scores of 86.03% from teachers and 80.00% from students. In terms of effectiveness, the module substantially improved students' learning outcomes, as indicated by a classical mastery level of 90.91% and an N-Gain score of 0.60 in the moderate category. Therefore, the GBL module integrated with PID can be concluded to be a valid, practical, and effective learning medium for enhancing Informatics learning outcomes among junior secondary school students.

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