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Enhancing 3D geometry learning: A differentiated educational game approach

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Abstract

This study aims to develop and evaluate a differentiated educational game to enhance junior high school students' understanding and engagement in learning three-dimensional geometry. Using a Research and Development (R&D) approach with the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation), a game titled "*Five Dragon Balls*" was designed with RPG Maker MV to accommodate diverse learning styles—visual, auditory, and kinesthetic. The participants were 25 eighth-grade students from a public junior high school in Cirebon Regency, Indonesia. Data were collected through observation, interviews, and documentation, then analyzed using inductive thematic analysis. Expert validation indicated high content and media validity (88.5% and 87.3%, respectively). Classroom implementation revealed improvements in students' conceptual understanding, motivation, and participation. Visual learners benefited from 3D representations, auditory learners from narration and cues, and kinesthetic learners from interactive exploration. The results demonstrate that a differentiated game-based learning approach can effectively support inclusive, engaging, and conceptually meaningful mathematics learning. This study contributes a practical framework for integrating differentiated instruction principles into digital learning environments that align with the *Merdeka Curriculum* and 21st-century educational goals.

Keywords:
Differentiation, Education, Game, Learning styles, Mathematics

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1. INTRODUCTION

Geometry learning, particularly on three-dimensional topics such as cubes, rectangular prisms, prisms, and pyramids, remains a major challenge at the secondary education level. Many students struggle to understand fundamental concepts such as surface area and volume because these topics require spatial visualization skills, the ability to imagine and mentally manipulate three-dimensional shapes (Phuong et al., 2022; Sors et al., 2025). Several studies have shown that junior high school students still experience considerable difficulties in learning three-dimensional geometry. Setambah et al. (2025) found that 62.5% of eighth-grade students struggled to determine the surface area and volume of solid figures due to limited understanding of spatial relationships among geometric elements. Similarly, Nursyamsiah et al. (2020) reported that 68.97% of students had difficulties representing three-dimensional objects through two-dimensional nets. In addition, Sudirman et al. (2023) revealed that most students were unable to connect three-dimensional forms with their two-dimensional representations, particularly when required to visualize or calculate spatial dimensions. Overall, these findings indicate that more than 60% of junior high school students continue to face challenges in spatial visualization and dimensional reasoning. This aligns with the conclusions of Lowrie and Logan (2023), who emphasized that spatial visualization skills play a crucial role in students' mathematical performance, especially in geometry-related topics.

Traditional teaching methods that rely mainly on lectures and paper-based exercises have proven less effective in developing these skills. As a result, students often struggle to solve problems involving spatial representation and geometric computation, leading to low academic achievement and reduced learning motivation. This situation highlights the urgent need for technology-based learning approaches, such as educational games or interactive visualization tools, which can help students grasp abstract geometric concepts more concretely and accommodate diverse learning styles (visual, auditory, and kinesthetic) (Hisda et al., 2025; Pramuditya et al., 2022; Vankúš, 2021).

One promising approach to address these challenges is the integration of educational games that combine interactivity with curriculum-based content to enhance students' engagement and conceptual mastery (López-Hernández et al., 2023; Mandala et al., 2025; Park & Kim, 2022; Pramuditya et al., 2019; Wijayanto et al., 2022). Previous research has also demonstrated the effectiveness of differentiated learning approaches in improving students' achievement and motivation compared to conventional methods (Rimayasi et al., 2025). Moreover, the use of educational games and visualization tools, such as GeoGebra, has been shown to significantly improve students' spatial reasoning skills (Anggoro et al., 2025). However, most prior studies have primarily focused on enhancing spatial visualization without fully addressing the heterogeneity of students' learning styles. In other words, there remains a lack of systematic research on how educational games can be designed based on differentiated instruction principles to simultaneously meet the needs of visual, auditory, and kinesthetic learners.

To address this research gap, the present study investigates the impact of a differentiated instruction based educational game on junior high school students' engagement and academic achievement in three-dimensional geometry. The developed game integrates interactive 3D diagrams for visual learners, formula narration for auditory learners, and drag-and-drop activities for kinesthetic learners. This approach aims to accommodate the heterogeneous needs of students while aligning with the demands of modern curricula for personalized and technology-enhanced learning (Lestari et al., 2024; Supartiningsih & Wibowo, 2023; Susilowati et al., 2025).

This study introduces a pedagogical innovation by incorporating formative feedback mechanisms with progress-based rewards and utilizing an accessible platform, RPG Maker MV, enabling teachers to independently design similar instructional media. Beyond demonstrating the effectiveness of differentiated educational games in mathematics learning, this research also proposes a practical framework for developing inclusive and easily implementable interactive media (Debrenti, 2024; López-Hernández et al., 2023; Park & Kim, 2022).

Ultimately, this research is grounded in the identified gap the lack of systematic evaluation of differentiated educational games tailored to students' learning characteristics at the secondary level. By integrating multimedia learning theory and differentiated instruction principles, the developed educational game is expected not only to enhance students' conceptual understanding but also to foster higher levels of engagement and academic achievement in learning 3D geometry.

2. METHOD

2.1. Research Design

This study employed a Research and Development (R&D) approach, which is widely used in educational research to design, develop, and evaluate innovative instructional products that enhance learning effectiveness (Sugiyono, 2019). The development process followed the ADDIE instructional design model (Analysis, Design, Development, Implementation, and Evaluation) as a systematic framework for creating and refining an educational game. The game was developed using RPG Maker MV to accommodate diverse student learning styles (visual, auditory, and kinesthetic) within the topic of three-dimensional geometry.

2.2. Participants and Setting

The research was conducted with 25 eighth-grade students (aged 13–14) from a public junior high school in Cirebon Regency, Indonesia, during the second semester of the 2024/2025 academic year. The participants comprised 8 male and 17 female students from mixed academic backgrounds. Grade 8 was chosen based on curriculum relevance, as the topic of rectangular prisms (cuboids) is formally taught at this level. The school represented a typical Indonesian public school context where exposure to technology-based learning media (particularly educational games) remains limited. All activities were carried out in the school's computer laboratory using laptops and tablets provided by the school to ensure equitable access. Participants were selected using purposive sampling, considering their learning styles, topic alignment, and teacher collaboration. This method was deemed appropriate, as the qualitative nature of R&D prioritizes contextual depth over sample size (Creswell & Poth, 2018; Sugiyono, 2019).

2.3. Research Procedure

The research procedure followed the ADDIE model, illustrated in Figure 1. The process was iterative and developmental, ensuring continuous refinement based on feedback and validation.

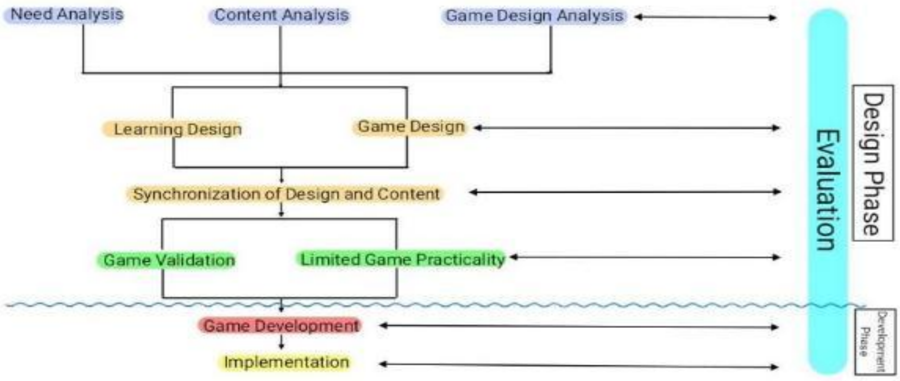


Figure 1. Procedural framework of the study based on the ADDIE model

Analysis Phase

During the Analysis phase, preliminary data were collected from three junior high schools in Cirebon Regency to identify common learning challenges and instructional needs related to 3D geometry. This preliminary needs analysis involved interviews with teachers and students from different schools, while the subsequent design, development, and implementation stages were conducted with 25 eighth-grade students from one selected school. The analysis focused on understanding student needs and aligning instructional content. It included needs analysis (via surveys and interviews to identify learning preferences and difficulties), content analysis (to align materials with curriculum standards), and game design analysis (to determine interaction, mechanics, and visual elements that support engagement).

Design Phase

In this stage, both learning design and game design were structured to integrate differentiated learning principles. The game narrative, challenges, and reward systems were tailored to accommodate visual, auditory, and kinesthetic learning preferences. Previous findings by Hamari et al. (2014) and Pramuditya et al. (2022) guided the integration of interactive and motivational elements.

Development Phase

The prototype was developed using RPG Maker MV, enabling interactive game creation without complex programming. Validation was conducted by a mathematics education expert to ensure content accuracy and pedagogical soundness. Limited trials were performed with a small student group to test usability and functionality before classroom implementation.

Implementation Phase

The validated game was implemented in classroom settings involving all 25 participants. Students interacted with the game according to their identified learning styles. Data were gathered through observations, interviews, and focus group discussions to evaluate engagement, motivation, and conceptual understanding.

Evaluation Phase

Both formative and summative evaluations were carried out. Formative evaluation occurred throughout the ADDIE stages to improve the product iteratively, while summative evaluation assessed the overall effectiveness of the game in enhancing students' learning and motivation.

2.4. Instruments and Data Collection

The instruments used consisted of observation, interviews, and documentation. Observations were conducted to observe student engagement during learning, including: (1) student focus on activities, (2) active participation in completing tasks, (3) interactions with friends, and (4) responses to the use of games. Observations were recorded using observation sheets and supported by photo/video documentation. Interviews with teachers and students provided deeper insights into their experiences, while documentation in the form of field notes, photos, and videos of student activities during learning were used to support the results of observations and interviews. Data collection was conducted in three stages (pre-implementation (baseline), during implementation (direct observation and feedback), and post-implementation (impact evaluation)).

2.5. Data Analysis

The collected data were analyzed using inductive thematic analysis. All qualitative responses were transcribed, coded, and categorized to identify recurring themes related to engagement, learning styles, and conceptual understanding. This analytical approach allowed for an in-depth interpretation of how the RPG Maker based educational game supported differentiated learning and influenced students' cognitive and affective outcomes.

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Analysis Phase

The needs analysis was conducted prior to the selection of the implementation site and involved three junior high schools in Cirebon Regency. Data were collected through interviews with mathematics teachers and students to identify common learning challenges, instructional conditions, and perceptions regarding the use of game-based media for three-dimensional geometry learning, particularly rectangular prisms. The findings revealed that most students struggled to visualize and interpret 3D shapes, especially when applying formulas for surface area and volume. Teachers also reported that classroom instruction relied heavily on lectures and textbook-based exercises, with limited use of interactive learning media, which contributed to low motivation and engagement. A summary of the main findings from the teacher and student interviews across the three schools is presented in Table 1, highlighting key learning difficulties and their implications for the design of the educational game.

Table 1. Summary of needs analysis findings from teachers and students

Category	Findings	Sources	Implications
Learning difficulties	Students struggle to visualize 3D objects and apply formulas for surface area and volume of rectangular prisms.	Teacher & student interviews (all schools)	Game must include 3D visual aids and manipulable objects to strengthen spatial reasoning.
Instructional approach	Learning is dominated by lectures and textbook-based exercises; limited use of interactive media.	Teachers (3 schools)	Integrate exploratory gameplay to promote active engagement and self-paced learning.
Student motivation	Students feel that learning mathematics is monotonous; they prefer interactive, game-like activities.	Students (all schools)	Incorporate challenges, rewards, and progress tracking to enhance motivation.
Technology exposure	Schools have access to basic ICT facilities, but teachers and students rarely use game-based learning tools.	Teachers (3 schools)	Game should be simple, accessible offline, and compatible with school computers.
Learning preferences	Students exhibit varied learning styles: visual (graphs, diagrams), auditory (narration), and kinesthetic (hands-on tasks).	Surveys & interviews	Game should support multimodal learning—visual cues, sound effects, and drag-and-drop features.

Classroom instruction was found to rely predominantly on traditional methods such as lectures and textbook-based exercises. Although teachers occasionally used PowerPoint slides or YouTube videos, these materials remained largely passive and failed to sustain students' engagement. Consequently, participation and motivation were low, especially among learners who preferred more interactive and visually oriented activities.

Interviews with students confirmed these findings. Many described conventional instruction as monotonous and expressed that interactive approaches like educational games made learning "more exciting, fun, and challenging." Students reported that game-based learning allowed them to "learn while playing" and "understand better through practice." These insights highlight the need for innovative, technology enhanced learning tools capable of visualizing geometric concepts concretely while accommodating diverse learning styles visual, auditory, and kinesthetic.

Based on this need, the content analysis examined the Grade 8 mathematics curriculum, focusing on the topic of rectangular prisms (*balok*). The objective was to align the game's learning materials with national competency standards, including identifying geometric properties, calculating surface area, and determining volume. These competencies were translated into structured, game-based learning activities using RPG Maker MV, where each map represented a specific learning outcome and each interactive event served as a narrative-driven mathematical task. Table 2 summarizes the main content components and their pedagogical integration into the game design.

Table 2. Summary of content elements and learning integration

Learning Objective	In-Game Representation	Pedagogical Purpose
Identify and describe the properties of rectangular prisms	NPC (non-player characters) provide explanations and guided questions during dialogues	Supports conceptual understanding through narrative-based instruction
Calculate surface area of rectangular prisms	Puzzle-based missions where players solve geometry problems to unlock new areas	Encourages problem-solving and reinforces formula application
Calculate the volume of rectangular prisms	Quest missions requiring players to collect items by solving volume-related challenges	Promotes active learning and exploration through reward mechanisms
Connect geometric concepts to real-life contexts	Environmental objects (books, maps, buildings) provide contextual clues	Strengthens transfer of knowledge through contextual visualization
Develop persistence and motivation in learning	Progression system (five dragon balls, levels, and rewards)	Enhances motivation and engagement through gamified learning progression

The storyline, titled "*Prince Naveen's Geometry Quest*," follows a young prince who must master geometry to prove his worthiness as a future king. Players navigate virtual environments such as the *Forest*, *Floating City*, and *Big House*, each representing distinct learning missions. Within these settings, dialogue, quests, and puzzles serve as the main learning interactions, with NPCs acting as virtual tutors who provide guidance and feedback. This narrative–content integration ensures that gameplay remains both engaging and educationally meaningful. The content analysis confirmed that the game's instructional elements align with the mathematics curriculum, ensuring conceptual accuracy and pedagogical relevance. This stage established a foundation for integrating curriculum objectives into interactive gameplay.

Further game analysis highlighted the role of *maps* and *events* as core design components in RPG Maker. Maps function as virtual learning spaces that encourage exploration and contextual understanding, while events provide interactive learning experiences connecting gameplay with mathematical concepts. Different types of events—dialogue, quests, puzzles, item interactions, and story transitions—were designed to promote engagement and conceptual understanding. A summary of these components and their educational functions is presented in Table 3.

Table 3. Summary of game analysis (maps and events)

Aspect	Definition / Description	Educational Function	Examples
Maps (Learning Environment)	Virtual spaces designed in RPG Maker to support learning through exploration and interaction.	Enable students to learn while playing and connect lesson topics to meaningful contexts.	Players explore maps containing lesson-related areas and complete learning challenges.
Dialog Event	NPCs provide information, questions, or instructions through dialogue.	Deliver concepts and explanations in an interactive form.	NPC guides students to understand a concept through conversation.
Quest / Mission Event	Tasks assigned to players to progress in the game.	Encourage problem-solving and learning through goal-oriented tasks.	Players solve questions or tasks to move to the next stage.

Aspect	Definition / Description	Educational Function	Examples
Puzzle Event	Problem-solving challenges related to learning content.	Develop reasoning and analytical skills through interactive play.	Students complete geometry puzzles to unlock new areas.
Item Interaction Event	Interaction with in-game objects such as books or maps.	Provide additional information and promote exploration.	Clicking an object gives hints or further explanation.
Story / Transition Event	Narrative changes influenced by player choices.	Increase engagement and ownership of learning.	Player actions affect storyline and learning progression.

The results indicated that the integration of maps and events creates a meaningful and engaging learning environment. Maps serve as the structural setting where learning takes place, while events transform abstract concepts into interactive learning experiences. This analysis provided a strong conceptual basis for designing the educational game in the subsequent development phase.

3.1.2. Design Phase

The design phase translated the analytical findings into a structured learning framework and a prototype educational game titled "*Five Dragon Balls*." This stage focused on aligning gameplay with curriculum objectives through the principles of Game-Based Learning and Differentiated Instruction. The design integrated narrative, learning materials, and assessments to create an engaging, pedagogically meaningful experience for eighth-grade students studying rectangular prisms (*balok*).

In the storyline, Prince Naveen must prove his worth as a future king by mastering the concept of cuboids. Each stage of his journey corresponds to a learning objective: the *Forest* introduces cuboid properties, the *Floating City* emphasizes surface area, the *Big House* focuses on volume, and the final missions serve as review and mastery. This structure provides a clear learning progression from conceptual understanding to procedural fluency.

Figure 2 presents the opening interface of the "*Five Dragon Balls*" game, featuring a fantasy-themed environment designed to attract students' attention and support intuitive navigation. The layout combines engagement and simplicity through options such as *New Game*, *Continue*, and *Options*, while the background illustration reinforces exploration and adventure consistent with the game's learning objectives.

Figure 2. The main interface of the "Five Dragon Ball"

The subsequent design stages focused on refining pedagogical features and learning mechanics to ensure that gameplay meaningfully supported student learning outcomes. The interface and structure were intentionally designed to encourage exploration, discovery, and reflection hallmarks of effective game-based learning.

To emphasize the pedagogical intent, Figure 3 presents the core mission of the game, which centers on improving students' understanding of rectangular prisms through interactive and contextualized experiences. The mission highlights four primary objectives: (1) promoting active learning, (2) encouraging collaboration, (3) providing immediate feedback, and (4) aligning content with curriculum standards. These objectives illustrate the game's role as both a learning environment and a motivational tool.

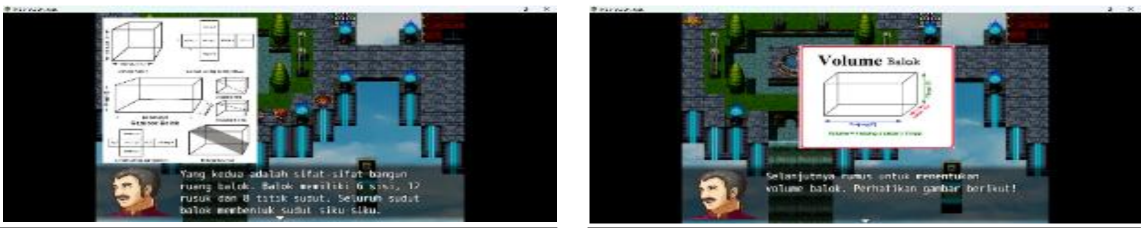
Translate:
"Prince Naveen was ordered by the king to find the five dragon balls. The first clue was to meet an old man."

Figure 3. The educational mission of the "*Five Dragon Balls*" game

Figure 3 presents the opening scene in which Prince Naveen receives a royal command to collect five dragon balls as a test of wisdom and perseverance. Guided by an old sage, he begins his quest, setting the narrative and educational context of the game. This introduction links the storyline with the learning mission, inviting students into an environment where motivation, exploration, and conceptual understanding are integrated.

After the introduction, the game implements differentiated mechanics to accommodate various learning styles and abilities. Students can adjust difficulty levels based on their readiness, while adaptive quizzes and puzzles provide real-time feedback to maintain both challenge and support.

Figure 4 illustrates how the game addresses three primary learning styles—visual, auditory, and kinesthetic. Visual learners benefit from colorful 3D representations and spatial animations that clarify geometric relationships. Auditory learners engage through narrative dialogue, sound cues, and verbal explanations that reinforce understanding. Kinesthetic learners interact with the virtual environment by exploring spaces, solving puzzles, and manipulating objects, allowing them to learn through active participation. These multimodal design features ensure that all students can engage meaningfully with the content and develop a deeper understanding of geometric concepts.



Translate:
"The second is the properties of a cuboid. A cuboid has 6 sides, 12 edges, and 8 vertices. All the corners of a cuboid are right angles."

Translate:
"Next, the formula for determining the volume of a cuboid. Look at the image."

Figure 4. Differentiation of learning styles

The differentiated design ensures that students' individual learning preferences are accommodated throughout gameplay. Through multimodal features, the game provides equitable access to learning opportunities, enabling each student to approach geometric problems according to their strengths. This personalization enhances engagement and establishes the foundation for effective feedback and reinforcement mechanisms described in the next section.

Building on this framework, the game incorporates an integrated feedback and reinforcement system to maintain motivation and support conceptual mastery. Students receive immediate feedback through visual cues, hints, and explanations for both correct and incorrect responses. Reinforcement elements—such as points, badges, and level progression—promote persistence, confidence, and self-regulated learning.

Figure 5 illustrates how these mechanisms operate in practice, showing how students receive real-time responses after completing mathematical challenges, enabling them to monitor progress and stay motivated to improve.

Translate:
"Good job, your answer is correct. I will give you the third Dragon Ball. I admire your determination, young prince."

Translate:
"Which of the following is not one of the characteristics of a cuboid?
It has six faces, All faces are squares, It has twelve edges, It has eight vertices."

Figure 5. Differentiation of learning styles

Figure 5 shows how feedback and reinforcement are embedded within the gameplay, enabling students to monitor their understanding while staying motivated to improve. The immediate visual and textual feedback encourages students to reflect on their learning progress, while rewards such as points or level achievements sustain engagement and persistence. This integration of motivation and reflection ensures that learning remains interactive and goal-oriented rather than purely task-based.

Together, the differentiation features and feedback mechanisms form the pedagogical foundation of the "*Five Dragon Balls*" educational game. To summarize how these elements interact within the learning design, Table 4 presents an overview of the educational, narrative, and technical components integrated into the game.

Table 4. Summary of design components in the "*Five Dragon Balls*"

Component	Description / Implementation	Educational Function
Game Concept	"*Five Dragon Balls*" an RPG-based educational game where students solve geometry challenges to collect five dragon balls.	Combine storytelling with mathematical learning to enhance motivation and engagement.

Component	Description / Implementation	Educational Function
Main Character & Narrative	Prince Naveen learns about cuboids to prove his worthiness as king. Each mission represents a subtopic: properties, surface area, volume, and mastery.	Link narrative progression with curriculum objectives and contextual learning.
Differentiated Learning Design	Supports visual, auditory, and kinesthetic learning through 3D visuals, dialogues, and interactive puzzles.	Accommodate diverse learning styles for inclusive participation.
Learning Content	Definition, characteristics, surface area, and volume of cuboids aligned with Grade VIII mathematics standards.	Strengthen conceptual and procedural understanding of 3D geometry.
Feedback and Reinforcement	Immediate feedback, hints, and reward system (points or badges) for each task.	Reinforce mastery, maintain engagement, and promote self-regulation.
Assessment Tools	In-game quizzes, worksheets, and reflection activities.	Provide formative assessment and allow self-evaluation of learning progress.
Classroom Integration	Teacher-guided play sessions with reflection discussions and learning review.	Connect digital gameplay with structured classroom instruction for deeper learning.

Overall, the design phase demonstrates that the "*Five Dragon Balls*" educational game was systematically developed to integrate curriculum-based content, differentiated learning, and interactive feedback. Through its storyline, adaptive features, and immediate response mechanisms, the game transforms traditional geometry learning into an engaging, student-centered experience. This design foundation guided the next stage, Development Phase, which involved prototype creation, expert validation, and preliminary classroom trials.

3.1.3. Development Phase

The development phase aimed to transform the design blueprint into a functional prototype of the "*Five Dragon Balls*" educational game using RPG Maker MV. This stage focused on translating the game's storyline, learning objectives, and differentiated learning features into interactive gameplay elements. Based on the design outputs from the previous phase, the researcher created three core learning maps (*Forest*, *Floating City*, and *Big House*) representing sequential learning goals: identifying properties, calculating surface area, and determining the volume of cuboids.

The development process began with the creation of visual assets and in-game dialogues that aligned with the Grade 8 mathematics curriculum. The learning tasks were integrated into quest-based gameplay, where students progressed by solving geometry problems embedded within the narrative. Each mission incorporated differentiated mechanics to accommodate diverse learning preferences: visual learners benefited from colorful 3D representations, auditory learners received verbal instructions and sound cues, while kinesthetic learners engaged with interactive puzzles requiring manipulation of virtual objects.

After the prototype was completed, preliminary usability testing was conducted internally to ensure that the navigation, dialogue triggers, and mathematical content functioned properly. The finalized prototype, labeled Version 1.0, was then subjected to expert validation to assess its content accuracy, media feasibility, and alignment with differentiated learning principles.

The prototype of the "*Five Dragon Balls*" educational game underwent an expert validation process to ensure that the product met pedagogical and technical quality standards before being implemented in the classroom. The validation involved two experts in mathematics education and one expert in educational media technology, who independently assessed two key dimensions: the material aspect, focusing on mathematical accuracy, curriculum alignment, and learning clarity; and the media aspect, emphasizing usability, interface design, interactivity, and engagement. Each indicator was evaluated using a 5-point Likert scale, ranging from 1 (very poor) to 5 (very good), and the percentage of validity was calculated using the formula proposed by Sugiyono (2019):

$$\text{Validity Percentage} = \frac{\text{Total Score Obtained}}{\text{Maximum Possible Score}} \times 100\%$$

The results of expert evaluation, presented in Table 5, show that the material validity score reached 88.5%, while the media validity score was 87.3%. According to the classification criteria by Sugiyono (2019), a validity score between 81%–100% is categorized as very valid, indicating that the product is appropriate for use without major revisions. These findings confirm that the "*Five Dragon Balls*" educational game demonstrates strong content validity and media feasibility as a differentiated learning tool within the *Merdeka Curriculum* framework.

Table 5. Expert validation results

Aspect	Indicator	Score	Validity (%)	Category
Material	Alignment with curriculum standards	4.5	90.0	Very Valid
	Accuracy of mathematical concepts	4.4	88.0	Very Valid
	Clarity of instructions and language	4.3	86.0	Very Valid
	Relevance of learning objectives	4.5	90.0	Very Valid
	Support for differentiated learning	4.4	88.0	Very Valid
	Average (Material Validity)		**88.5%**	**Very Valid**
Media	Interface design and layout	4.3	86.0	Very Valid
	Ease of navigation and accessibility	4.4	88.0	Very Valid
	Interactivity and feedback responsiveness	4.4	88.0	Very Valid
	Visual and audio integration	4.3	86.0	Very Valid
	Consistency between game mechanics and learning goals	4.4	88.0	Very Valid
	Average (Media Validity)		**87.3%**	**Very Valid**

In addition to quantitative scores, experts also provided qualitative feedback to further refine both the pedagogical content and media design. The feedback emphasized improving the clarity of mathematical expressions, enhancing text readability, and reinforcing the link between learning objectives and in-game activities. These comments were carefully analyzed and implemented into design revisions, as summarized in Table 6.

Table 6. Summary of expert feedback and revisions

Aspect	Validator's Suggestion	Action / Revision
Content Accuracy	Clarify the difference between cubes and cuboids within the dialogue to avoid misconceptions.	Adjusted NPC dialogue to explicitly contrast cube and cuboid characteristics.
Mathematical Task Design	Simplify the phrasing of geometry problems to increase student comprehension.	Revised wording in in-game tasks using concise and accessible language.
Curriculum Alignment	Include clear learning objectives in the Teacher Guide for each stage of the game.	Added explicit learning goals for each mission: *Forest, Floating City,* and *Big House.*
User Interface	Improve font size and enhance contrast between text and background.	Updated interface design with larger fonts and semi-transparent dialogue boxes.
Game Navigation	Reduce the number of transition events to minimize loading delays.	Streamlined map transitions and optimized event triggers for smoother gameplay.
Audio-Visual Feedback	Provide sound or visual cues for correct answers to increase motivation.	Added positive sound effects and animation for successful task completion.

Overall, the expert validation results confirmed that the "*Five Dragon Balls*" educational game achieved a very valid rating in both content and media dimensions. The high validity scores, supported by expert recommendations, indicate that the game is pedagogically appropriate, technically reliable, and suitable for classroom use. The improvements derived from expert feedback have strengthened the educational integrity and user experience of the game, ensuring its readiness for the implementation phase in real learning settings.

3.1.4. Implementation Phase

The implementation phase aimed to examine the practicality and learning impact of the "*Five Dragon Balls*" educational game in a real classroom setting. The activity was conducted in the school's computer laboratory, where 25 eighth-grade students worked in small groups under the teacher's supervision. Each student interacted with the game using laptops or tablets, while the teacher facilitated the session by guiding discussions and providing support when needed. To illustrate the classroom implementation, Figure 6 presents students engaging with the "*Five Dragon Balls*" game during a mathematics lesson in the school's computer laboratory. The image highlights the integration of digital media within a collaborative learning environment.

Figure 6. Students engaging with the "*Five Dragon Balls*"

Students were actively involved in exploring the missions within the game, discussing strategies, and helping one another complete challenges related to the properties, surface area, and volume of cuboids. Before the activity, students were introduced to the game's objectives, storyline, and control navigation to ensure accessibility. The learning session was conducted over two meetings (2 × 80 minutes), where students individually explored the game's missions but were encouraged to collaborate and discuss problem-solving strategies. Teachers acted as facilitators, guiding reflection sessions after each mission to reinforce learning objectives aligned with *Merdeka Curriculum*.

Analysis of student activity sheets showed strong indicators of conceptual understanding and engagement (see Table 7). Students successfully articulated definitions and properties of cuboids in their own words, such as "*a three-dimensional object that has length, width, and height*." They differentiated between cuboids and cubes by explaining that "*a cuboid has rectangular faces, while a cube has square faces*," and correctly applied formulas for surface area and volume.

Students also demonstrated the ability to connect concepts with real-life examples, identifying cuboid-shaped objects (e.g., cabinets or boxes) and explaining that these shapes "*have six faces and eight vertices*." This suggests that learners not only remembered formulas but also developed spatial reasoning through contextualized experiences. The storyline (featuring the *Old Man*, *Pak Tua*, and *Prince Naveen*) kept students emotionally engaged throughout gameplay. They often referred to these characters in their written reflections, showing how the narrative helped sustain focus and motivation. Rewards and progress mechanisms, such as collecting "Dragon Balls," further encouraged persistence and enjoyment in learning mathematics.

Table 7. Observation summary based on student activity sheets

Observed Competence	Example of Student Response	Interpretation
Concept Identification	"A cuboid is a three-dimensional shape that has length, width, and height."	Students correctly defined cuboids using their own language, showing conceptual comprehension.
Concept Differentiation	"A cuboid has rectangular faces, while a cube has square faces."	Students distinguished between cuboids and cubes, indicating analytical understanding.
Application of Formulas	"L = 2 × (pl + pt + lt)" and explanation of volume unit "cm^3."	Students applied formulas accurately, demonstrating procedural fluency.
Contextual Reasoning	Selected cabinet image as cuboid because it has "6 faces and 8 vertices."	Students related geometry to real-life contexts.
Engagement and Reflection	Mentioned characters (Pak Tua, Goblin, Prince) in reflections.	Indicates narrative-based immersion and emotional engagement.

Student Responses Based on Learning Style Characteristics

Observations also revealed distinct patterns of engagement based on students' learning styles (visual, auditory, and kinesthetic), confirming that the differentiated features embedded in the game effectively accommodated diverse learner preferences.

Visual learners were notably focused on graphical representations, spatial animations, and colorful game environments. They often pointed out that the visuals made geometric relationships easier to understand. For example, one student commented, "*The picture helps me see which sides and edges belong to the cuboid*." Auditory learners responded strongly to the narration and sound cues within the game. They were attentive to verbal explanations and in-game dialogue, which helped them recall problem-solving steps. One student reflected, "*I knew what to do because the sound gave me hints*." Kinesthetic learners showed high persistence and enjoyment during exploration. They were observed actively moving characters, retrying puzzles, and engaging with manipulable elements of the environment. A kinesthetic learner stated, "*I kept trying until I succeeded—it was fun because I could move and test it directly*."

These patterns demonstrate that the multimodal design successfully supported differentiated learning. Each learning style contributed to engagement and understanding in distinct yet complementary ways (see Table 8).

Table 8. Observation of student engagement based on learning styles

Learning Style	Observed Behavior	Student Expression	Interpretation
Visual	Focused on 3D visuals, colors, and object details.	"The pictures make it easier to understand."	Visual elements enhanced spatial reasoning.
Auditory	Followed narration and responded to sound cues.	"I know what to do because there are voice instructions guiding me."	Verbal feedback improved comprehension and memory.
Kinesthetic	Actively moved characters and repeated tasks until solved.	"I kept repeating it until I got it right, it's fun because I can try it right away"	Hands-on interaction fostered persistence and problem-solving skills.

The combination of visual, auditory, and kinesthetic engagement confirmed that the game design met the principles of differentiated instruction, providing equitable access to mathematical learning across various learning preferences.

3.1.5. Evaluation Phase

The Evaluation Phase focused on assessing the game's effectiveness, practicality, and user satisfaction after classroom implementation. Both formative and summative evaluations were conducted, following the criteria of product evaluation in Research and Development by Sugiyono (2019). The formative evaluation occurred during the iterative design, validation, and implementation stages, ensuring continuous product refinement. The summative evaluation, conducted after implementation, was based on teacher reflections, classroom observations, and student activity sheets.

Teachers reported that the "*Five Dragon Balls*" game enhanced student motivation and comprehension, especially for those who were typically less active in traditional learning. They highlighted that the game made it easier for students to visualize and connect abstract geometric ideas with concrete representations. Meanwhile, students described the learning process as "*fun*," "*challenging*," and "*different from usual math lessons*."

Table 9. Summary of evaluation results

Evaluation Aspect	Indicator	Evidence from Implementation	Conclusion
Practicality	Ease of use and classroom integration	Students navigated the game independently; teacher facilitation ran smoothly.	The game is practical and user-friendly for classroom use.
Effectiveness	Engagement and conceptual understanding	Students defined, differentiated, and applied formulas accurately.	The game effectively improved comprehension and engagement.
Satisfaction	Motivation and enjoyment	Students expressed enthusiasm and engagement during gameplay.	The game fosters motivation and positive learning attitudes.

Overall, the evaluation confirmed that the "*Five Dragon Balls*" educational game is a valid, practical, and effective instructional tool for differentiated mathematics learning (see Table 9). The integration of multimodal interaction (visual, auditory, and kinesthetic) ensured that students of various learning styles could actively and meaningfully participate. As suggested by Sugiyono (2019), a product that meets these three criteria is considered ready for broader implementation and classroom dissemination.

3.2. Discussion

The findings of this study demonstrate that the "*Five Dragon Balls*" educational game successfully addressed the research goal of enhancing students' conceptual understanding and engagement in 3D geometry through a differentiated learning approach. By integrating visual, auditory, and kinesthetic modalities within a narrative-driven digital environment, the game provided an inclusive learning experience that met the diverse cognitive and affective needs of junior high school students. This outcome aligns with the broader objective of systematically evaluating differentiated educational games tailored to students' learning characteristics a gap previously identified in mathematics education research.

The visual design of the game significantly enhanced students' spatial reasoning and conceptual understanding of cuboids. Through the use of animated 3D representations, color-coded edges, and manipulable geometric models, students could visualize relationships among faces, vertices, and edges more effectively. This finding supports research by Lavicza et al. (2023), who found that interactive visualizations improve spatial visualization and geometry comprehension by fostering mental model construction and visual-spatial connections. Similarly, Radu and Schneider (2019) noted that digital visualization allows students to experience geometric transformations dynamically, making abstract mathematical structures more concrete. These results affirm that visual learning tools (when integrated within a game narrative) act as powerful scaffolds for developing spatial reasoning in 3D geometry contexts.

Auditory features such as narrative cues, verbal instructions, and sound effects supported procedural fluency and helped maintain learner focus during gameplay. Students said auditory guidance clarified the steps and reinforced correct procedures when solving geometry puzzles. This aligns with Setiawati et al. (2024), whose meta-analysis showed that interactive audio-visual media improve students' conceptual understanding in mathematics. Similarly, Albus and Seufert (2023) reported that combining audio and visual inputs in virtual reality environments can affect cognitive load, enhancing learning when designed properly. In an SD context, Mutiasari and Rusnilawati (2022) found that animation audio-visual media improved problem-solving ability and student autonomy. Thus, the auditory elements in the game likely enhance understanding and engagement by offering continuous, clarifying feedback.

Kinesthetic components (such as interactive missions, object manipulation, and puzzle-based challenges) were crucial in promoting active engagement and motivation. Students repeatedly interacted with objects and replayed tasks until mastery, demonstrating persistence and self-regulated learning behaviors. This finding corroborates Reeve et al. (2022) and Chestnutt (2025), who observed that kinesthetic activities stimulate embodied cognition and strengthen conceptual retention through movement-based learning. Furthermore, Perrem (2025) showed that kinesthetic interaction in digital environments fosters deeper engagement and enhances students' sense of autonomy, aligning with the self-determination theory (Deci & Ryan, 2000; Noto et al., 2018). Within the *Merdeka Curriculum* framework, this reflects the principle of learner agency students actively constructing meaning through exploratory and hands-on learning experiences.

Linking back to the research question, the differentiated design allowed students with diverse learning preferences to engage meaningfully and achieve conceptual mastery at their own pace. Visual learners benefited from spatial visualization, auditory learners from guided narration, and kinesthetic learners from active manipulation demonstrating that differentiation through media design can effectively address individual learning differences. Recent studies, such as Tang et al. (2023) and Jager et al. (2022), further confirm that adaptive digital environments can boost motivation and learning performance by accommodating varied cognitive and perceptual styles. The results of this study thus substantiate that integrating differentiated mechanics within a gamified environment leads to improved engagement and academic performance in mathematics.

Teacher reflections during implementation revealed a shift toward more facilitative teaching roles, where the educator acted as a guide rather than a transmitter of information. This transformation supports the goals of *Merdeka Curriculum*, emphasizing autonomy, collaboration, and contextualized learning. The synergy between differentiated instruction and game-based learning echoes findings by Hamari et al. (2014) and Hamidah et al. (2025), who argued that gamified learning environments foster motivation by satisfying learners' intrinsic needs for competence and relatedness. In this study, the narrative structure, feedback mechanisms, and reward systems (e.g., collecting Dragon Balls) fulfilled these psychological needs, promoting sustained engagement and self-regulated learning behaviors.

In summary, each differentiated component of the "*Five Dragon Balls*" game contributed uniquely to achieving the research objectives. Visual elements enhanced spatial reasoning, auditory feedback reinforced procedural fluency, and kinesthetic interaction encouraged active engagement. Collectively, these findings provide empirical evidence that differentiated game-based learning can bridge the gap between conceptual understanding and motivational engagement in secondary mathematics. This study extends current scholarship by demonstrating how a systematically developed and validated educational game can operationalize differentiated instruction principles within a digital learning context, offering both theoretical and practical contributions to 21st-century mathematics education.

While the findings of this study demonstrate the effectiveness of the "*Five Dragon Balls*" differentiated educational game, several limitations must be acknowledged. First, the implementation involved a relatively small and context-specific sample from one junior high school in Cirebon Regency, limiting the generalizability of the results. Future research should include larger and more diverse samples across schools with varying technological and socio-cultural contexts to enhance external validity.

Second, the evaluation relied mainly on qualitative and descriptive data from observations, interviews, and student reflections. Although these methods provided rich insights, they limited statistical inference. Future studies could employ mixed-method or experimental designs to quantitatively measure the game's impact on learning achievement, spatial reasoning, and motivation across different learning styles.

Third, the current version of the game was developed for geometry learning at the junior high school level. Further research could adapt the differentiated game model to other mathematical topics such as algebra, measurement, or data representation and integrate adaptive analytics for personalized learning paths. Longitudinal studies could also examine the long-term effects of game-based differentiation on students' self-regulated learning and digital literacy within the *Merdeka Curriculum* framework.

Despite these limitations, this study provides a valuable foundation for the development and evaluation of differentiated digital learning environments in mathematics education. It contributes to efforts to integrate pedagogically grounded game-based approaches aligned with national curricular reforms and global 21st-century learning trends.

4. CONCLUSION

The "*Five Dragon Balls*" educational game successfully demonstrated the potential of differentiated game-based learning to enhance students' engagement, motivation, and conceptual mastery in three-dimensional geometry. By combining multimodal features visual, auditory, and kinesthetic the game provided equitable learning opportunities for students with diverse preferences and strengths. Visual learners improved spatial reasoning through dynamic 3D representations, auditory learners benefited from verbal cues that reinforced procedural understanding, and kinesthetic learners developed persistence and problem-solving skills through interactive exploration.

Teachers observed a shift from teacher-centered instruction toward facilitative, student-centered learning, consistent with the principles of the *Merdeka Curriculum*. The narrative structure, reward system, and immediate feedback mechanisms maintained students' motivation while supporting deeper conceptual understanding.

Overall, the findings confirm that integrating differentiated instruction principles into digital game design can bridge cognitive and affective dimensions of learning in mathematics. The study provides both theoretical and practical contributions to 21st-century education by offering a validated model for inclusive and engaging technology-enhanced learning. Future research is recommended to involve larger and more diverse populations, employ quantitative measures of achievement and motivation, and explore the application of differentiated digital games across broader mathematical domains.

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Declarations

Author Contribution	: SAP: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Supervision, and Writing - original draft; RW: Methodology, Resources, Validation, Visualization, and Writing - review & editing; PF: Data curation, Software, Validation, Visualization, and Writing - review & editing.
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