

DESIGNING THE COOPERATIVE BOARD GAME “NUMERACY EXPEDITION” AS A MATHEMATICS LEARNING MEDIUM FOR GRADE 10 SENIOR HIGH SCHOOL STUDENTS

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Received: 22 May 2026
Revised: 27 May 2026
Accepted: 31 May 2026
Published: 1 September 2026

Abstract. Indonesian students' mathematics performance remains below the OECD average, with a mean PISA 2022 mathematics score of 366 compared with 472 for the OECD average. Previous studies also report the presence of mathematics anxiety among Indonesian students. This educational challenge is also associated with students' reported experiences of mathematics anxiety, while some existing mathematics learning games employ competitive or chance-based mechanics. This study presents the design and development of “Ekspedisi Numerasi,” a purely cooperative board game developed as a mathematics learning medium for Grade X senior high school students. Using the ADDIE instructional design model (Analysis, Design, Development, Implementation, Evaluation), the game was designed to integrate numeracy intrinsically into its core mechanics, eliminating dice-based chance in favour of strategic decision-making and team collaboration. Six asymmetric character roles inspired by historical mathematicians were developed alongside a modular hexagonal board comprising 22 interchangeable tiles, produced through FDM and SLA 3D-printing techniques. A limited implementation trial was conducted with 25 Grade X students at SMAN 6 Semarang. Summative evaluation using a post-trial Likert-scale questionnaire (1–5) yielded an overall mean score of 4.55 out of 5.00, with all ten assessed dimensions spanning visual design, learning content, and gameplay engagement rated as “Very Good.” The highest-rated aspect was mathematics symbol readability (4.68), while the lowest was the overall colour palette (4.44). The findings indicate positive student perceptions of the visual design, learning content, and cooperative gameplay of the developed medium.

Keywords: ADDIE model, cooperative board game, game-based learning, intrinsic integration, numeracy learning media

1. Introduction

Numeracy skills are one of the basic competencies that determine students' readiness to face academic challenges and daily life. However, various international reports show that the numeracy achievement of Indonesian students is still at a worrying level. The latest data that has been released from the Organisation for Economic Co-operation and Development through the PISA 2022 Results (Volume I) report shows that the average mathematics score of Indonesian students is at 366, far below the OECD average of 472 and far behind the neighboring country, Singapore, which reached the highest score in mathematics at 575 (*PISA 2022 Results (Volume I)*, 2023). It can be seen from the data chart presented below.

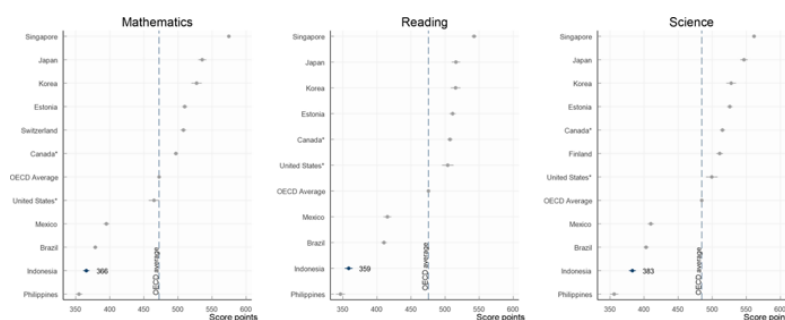


Figure 1. PISA 2022 Results Factsheets Indonesia PUBE, 2023

Source: OECD, Database PISA 2022, Table I.B1.2.1, I.B1.2.2 and I.B1.2.3.

These findings indicate a fundamental problem in the understanding of numeracy concepts, especially in contextual problem-solving skills. These problems are not only related to the cognitive aspect, but also the affective dimension. Math anxiety is one of the factors that contribute to low student performance. Fear of being wrong, lack of confidence, and the perception that math is a rigid and difficult subject, often make students avoid numeracy challenges. In a study conducted by Tiara Citra at SMAN 1 Jiwan, it was found that from 26 students, 4 students (15.4%) were categorized as having high levels of math anxiety, 20 students (76.9%) were identified as having moderate levels of math anxiety, and 2 students (7.7%) were classified as having low-level math anxiety (Firdaus et al., 2025).

Along with the development of the educational paradigm, various alternative approaches have begun to be developed to increase student involvement, one of which is the use and development of learning media that can be a tool for students to understand the material and be more motivated in improving their learning abilities (Pratiwinindya & Zairin, 2025). In helping the learning process, learning media that is quite often implemented is also game-based learning. The urgency of designing game-based learning media is rooted in the low ability to solve mathematical problems among high school students in class X, data found in a study conducted by Sholikah on the results of daily mathematics tests of grade X students of SMAN 1 Karangbinangun is still low, only reaching an average score of 60.93 from the specified KKM score of 75 (Sholikah et al., 2023). Teachers may face difficulties explaining abstract concepts when adequate learning aids are unavailable, as found in a study at SMA Muhammadiyah 18 Sunggal (Fadzuani, 2025), that teachers have difficulty explaining abstract concepts without the help of adequate teaching aids, the limited number of projectors is the main reason that audio-visual-based learning media cannot be conveyed to students, with these limitations teachers are forced to return to teaching using only the lecture method.

Some mathematics learning media use game-based formats with competitive mechanisms. Popular games such as the numeracy snake and ladder adaptation tend to put students in situations of beating each other to achieve victory. This structure has the potential to widen the gap between students with high abilities and students with less confidence (Fish et al., 2023). In competitive situations, students who feel left behind often experience additional pressure that actually amplifies math anxiety (Buschang et al., 2011).

Based on this phenomenon, media that has cooperative characteristics is needed, so that it is in accordance with the problems that occur. Learning media with cooperative play types that have the advantage of fostering prosocial behavior, increasing confidence and motivation, are more likely to continue playing compared to competitive games that require a lot of energy and trigger aggressive behavior during play. This condition occurs because players tend to focus on individual victories, so there is an urge to outperform opponents intensely (Marker & Staiano, 2015). Departing from these problems, the design of the cooperative game board "Ekspedisi Numerasi" was developed as an effort to present a learning media that integrates numeracy intrinsically into the game mechanism. Different from the competitive model, this game puts all players on a team with a common goal. Success is not determined by who is fastest or most superior individually, but rather by the group's ability to collaborate, communicate, and strategize problem-solving strategies.

As a work in the realm of art education, this design focuses not only on the pedagogical aspect, but also on the visual and material dimensions as part of the learning experience. The modular board design is hexagonal in shape, three-dimensional characters in the style of cartoonist illustrations, and functional color systems are designed to support attention, affective, cognitive, and compensatory functions in learning media. The integration between visual strategies, game mechanics, and numeracy content is the main foundation in the creation of the Ekspedisi Numerasi as a collaborative and immersive learning medium. The design of the Ekspedisi Numerasi game board is also produced from a SWOT analysis consideration, here is how the designer's analysis is the answer to why he chose to create a numeracy game board.

Table 1. SWOT analysis of a board game

No	Factor	Description
1	Strengths	Being a facilitation of face-to-face social interaction, unlike digital media that tends to isolate players in individual screens, board games require direct verbal and non-verbal communication. It is essential to enable a cooperative learning model and there is a positive dependency, where the strategy of solving the numeracy puzzle must be discussed collectively before it is executed on the board.
2	Weakness	The main limitation of physical board games is the risk of loss or damage to small components such as tokens and pawns.
3	Opportunities	Analog mediums offer refreshing sensory novelty, improve focus retention (attention), and reduce visual stress during high cognitive processes. Being a solution to screen saturation. In addition, there is alignment with the Independent Curriculum which emphasizes project-based learning, character formation of mutual cooperation (collaboration), and critical reasoning. The cooperative mechanism in board games provides a

		practical platform for teachers to implement those values without being tied to conventional lecture methods.
4	Threats	The limited initial time for the introduction of the game board during students' learning hours. Educators who are familiar with classical methods may be reluctant to adopt this medium if it is considered to take up the duration of lesson hours just for the understanding of the rules of the game.

The SWOT analysis was conducted as a preliminary design reflection based on observations of existing board-game characteristics, the intended classroom context, and considerations arising during the early design process. It was used to identify potential strengths, weaknesses, opportunities, and threats of the proposed medium rather than as an independent empirical analysis. After making a SWOT analysis, the designer believes that the game board has great potential to be presented again as a numeracy learning medium for high school students in class X, adopting a cooperative game style is an added value for other benefits that students will receive later. The game board is therefore positioned as an alternative physical learning medium that provides opportunities for face-to-face interaction in an increasingly digital learning environment.

Stepping into the world of digitalization, almost all social interactions involve the internet and gadgets, even though students are in the same room, there is a lack of media that can be the reason for their discussion and socialization to be an obstacle in learning. Various studies show that educational board games are able to increase learning engagement, social interaction, and concept understanding through contextual and experiential activities. However, most math learning board games still use competitive mechanics and a roll and move system that relies on dice or luck factors. This kind of game structure limits strategic decision-making space and has the potential to create a participation gap between students, especially for students with lower levels of confidence. On the other hand, the cooperative learning approach emphasizes the principle of positive interdependence, which is that learning success is achieved through cooperation and shared responsibility (Fonseca Franco et al., 2023). Although this concept has been widely applied in classroom learning models, its implementation in educational board game design, especially in high school numeracy materials, is still limited and generally still leaves elements of competition between players or between groups.

Based on this, the novelty of this research lies in the design of a numeracy board game with a purely cooperative mechanism that puts all players in one team to achieve a common victory. This game does not use dice or luck factors as determinants of the course of the game, but is entirely based on strategic decision-making, communication, and collaboration between players (Othman et al., 2025). Numeracy is intrinsically integrated into the game's mechanics through a mathematical resource processing system that must be assembled collectively to complete missions.

Thus, the design of the Ekspedisi Numerasi not only contributes to the development of mathematics learning media, but also offers an educational game design approach that puts strategy, cooperation, and content integration at the core of the learning experience. This position distinguishes this research from previous educational board game developments that are still dominated by competitive and luck-based mechanisms.

The study involved three main sources of data: an interview with the curriculum coordinator and mathematics teacher at SMAN 6 Semarang, observations during the limited implementation trial, and a post-trial questionnaire administered to Grade X students. The interview was conducted online via Zoom on May 18, 2026, and focused on the availability of mathematics learning media, students' learning characteristics, and the suitability of the proposed numeracy content. The limited trial was conducted on June 8, 2026, involving 25 students from class X-A. Participants were selected using purposive sampling based on their status as Grade X students and their relevance to the intended target users of the learning medium.

Prior to data collection, the researchers explained the purpose and procedures of the study to the school and participants. Participation in the questionnaire was voluntary, and the reported data were presented in aggregate form without identifying individual students.

2. Results and Discussion

2.1 Conceptual Framework of Cooperative Game Design

The design of the Ekspedisi Numerasi is based on the synthesis of three main foundations, namely game-based learning, cooperative learning, and intrinsic integration in educational game design. These three frameworks become the conceptual foundations that determine the aesthetic direction, mechanisms, and pedagogical strategies in the creation process. Game-based learning places games as a system that has goals, rules, feedback, and challenges that are able to trigger motivation in students (Plass et al., 2015). In the context of learning media, the meta-analysis carried out by (Tokac et al., 2019) shows that board games have a positive impact on the achievement of learning outcomes. However, such effectiveness depends largely on the quality of the design and the degree to which the learning content is integrated into the game mechanics.

On the other hand, cooperative learning as explained by Slavin (2014) emphasizes the importance of positive dependency between group members (Slavin, 2014). The success of the group is determined by the contribution of each individual, so social interaction becomes an integral part of the learning process. This approach is relevant to reduce math anxiety because students are not in a situation of beating each other, but rather supporting each other.

The concept of intrinsic integration put forward by (Habgood & Ainsworth, 2011) emphasizing that learning content should be an integral part of the core mechanics of the game. If the material is omitted, the game should no longer be able to run. This principle is what distinguishes Ekspedisi Numerasi from conventional educational board games that generally only add questions as external elements. By combining these three frameworks, the Ekspedisi Numerasi is

designed not as a mathematically charged game, but as a game system that can only take place through the numeracy activity itself.

Despite the advantages of cooperative gameplay, cooperative game systems may also create challenges such as player dominance and free-riding, in which one participant may control decision-making while another contributes minimally. These risks are relevant to the present design because the game requires collective decision-making. The use of asymmetric character roles provides a potential mechanism for distributing responsibilities among players, as each character has a different ability that can contribute to mission completion. However, the present trial did not systematically measure player dominance or free-riding behavior. Future studies should therefore examine participation patterns and decision-making distribution during gameplay.

2.2 The Planning Process Using the ADDIE Model

The design of the cooperative game board of the Ekspedisi Numerasi uses the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model as a systematic framework in the development of learning media (Branch & Varank, 2009). This model was chosen because it provides a structured flow that allows integration between pedagogical analysis, artistic exploration, and technical realization of design products. The following is the flow of designing numeracy learning media for the Ekspedisi Numerasi game board.

2.2.1. Analysis

The analysis stage revealed that the numeracy ability of high school students in Indonesia is still far below the international average (OECD), especially in the aspect of context-based problem solving in numeracy. This problem is exacerbated by math anxiety that arises due to an overly competitive learning environment and fixation on the end result. Therefore, a shift in a more supportive approach is needed to maintain students' psychological well-being while improving their academic achievement. Given the characteristics of grade X students who are in their early adolescence, social interaction factors and group recognition are the main keys in building motivation. Which usually uses a competition system, this game system deliberately adopts a purely cooperative mechanism to accommodate their collaboration needs. In this way, math learning is no longer a burdensome individual burden, but rather an inclusive and empowering group activity.

In addition, it is very important in designing this game board that it is based on the four functions of learning media. The framework put forward by Levie & Lentz (1982) provides a strong theoretical foundation for designing and allowing the use of learning media (Sapriyah, 2019). There are four main functions that can be fulfilled by media, especially visual media such as game boards. The following table synthesizes how the four media functions are applied concretely in the design of the Ekspedisi Numerasi game board.

Table 2. Main Functions of Learning Media According to Levie & Lenz Implemented in the Ekspedisi Numerasi

No	Media Functions	Theoretical Description (Levie & Lenz)	Application to Ekspedisi Numerasi
1	Attention	Attract and direct students' attention	The board design is unique because it is hexagonal in shape that forms arranged tiles, unique character designs have their own visual characteristics, and various other elements that have interesting visuals (cards, and tokens).
2	Affective	Evoke emotions and positive attitudes	Fun game mechanics, expedition adventure narratives, and group rewards that build a sense of community and a positive attitude towards numeracy.
3	Cognitive	Improves comprehension and memory	Mission cards that are diverse and have their own challenges can help students represent problem-solving steps flexibly in remembering previous obstacles and understanding the next steps to take.
4	Compensatory	Helping students who are struggling	The group discussion mechanism before taking turns, allows weaker students to learn from their peers and visually understand the context of the problem before trying mathematical solutions.

Source: Sapriyah, 2019.

The Ekspedisi Numerasi game board has met the standards in designing the game board based on the four functions of the learning media Framework proposed by Levie & Lenz (1982). So that the design of the Ekspedisi Numerasi game board will be optimal in building a fun learning atmosphere for students.

2.2.2 Design

The design stage is the phase of formulating the mechanical, visual, and narrative concepts of the game. The game's systematic approach is inspired by modern cooperative games such as Pandemic and Forbidden Island by Matt Leacock (Leacock, 2008), Especially in the aspect of role distribution and collective threats. At this stage, a cooperative game system based on the role of asymmetrical characters inspired by previous mathematicians was designed, where each player has different special abilities. This approach aims to create a positive interdependency between team members, so that the success of the game can only be achieved through collaboration.

Mechanically, the game is designed with a system of collecting and assembling numerical resources. Numbers and mathematical operations are not presented as separate subjects, but rather as elements that must be assembled into solutions to achieve victory. The procedure for playing the Ekspedisi Numerasi Game begins by assembling 22 game tiles, then the players place character pawns on the Base Camp tiles. When the game starts the movement mechanism is not determined by the dice, but players are given 3 Turning Action Points, these points can be used to move pawns, take tokens in the bank, give tokens to friends, use character skills, and complete missions. After the player has exhausted the 3 Action Points allotment the player is required to take 1 Obstacle Card and run the effect, the turn is continued by the next player.

Players have a goal which is to complete 2 Mission Cards to achieve

victory, in the Mission Card there is a number that must be achieved by the players by exploring how to solve it looking at the game conditions, for example if the number on the Mission Card is 24, then players can choose to use the 6×4 , 8×3 , $8+8+8$ and so on. Players have to look for the number tokens and operation tokens needed on each tile that provides, for example if the Forest Tile is Even Numbers then the player can pick up even numbers such as 4,6,8, and 10. Likewise, there are Odd and Prima Number Forest Plots. To find an operation token, players can find it in the River Plot. Likewise with other token acquisitions.

After successfully obtaining resources and maintaining them, one of the player representatives must head to the Research Center Tile to complete the Mission Card. Players are required to complete 2 Mission Cards to achieve victory, before the Disaster Mark on the Great Disaster Marker Board reaches the game over column.

For a more exciting gaming experience and added variety, the Ekspedisi Numerasi Game also provides 6 unique characters who have different skills to make the game easier, for example Euclid's character who has a skill of 4 Action Points in each turn so that Euclid can be more free and has extra points that can be used to make decisions. In addition to having special skills, each character is also inspired by the famous mathematician Euclid, Ada Lovelace, Pythagoras, Blaise Pascal, Fibonacci, and Archimedes.

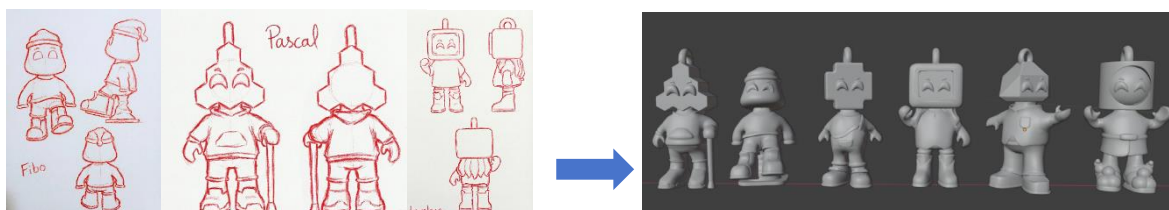


Figure 2. Character sketches and 3D designs using Blender

In terms of space structure, a modular hexagonal board is designed that can be rearranged in each game session, totaling 22 pieces with different variables and players can use a minimum of 16 pieces to play. This modular design aims to increase the flexibility of strategy as well as prevent players from memorizing certain patterns. The visual design adopts the cartoonist's illustration style with cel-shading techniques to maintain the readability of the form and reinforce the identity of the characters. Color selection uses a color coding approach to differentiate the categories of numeracy material, thus helping various cognitive aspects of the player when playing.

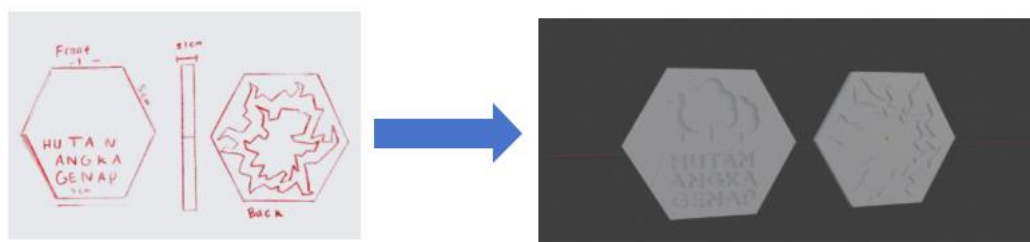


Figure 3. Tile sketches and 3D designs using Blender

Visual quality in media design is positioned as a very crucial element, especially in carrying out the attention function to attract students' attention as well as the affective function to build a positive emotional response as stated by Levie & Lentz. Therefore, the illustration approach used leads to a lighthearted and communicative cartoonist style. The choice of this style is adjusted to the demographic characteristics of high school students who tend to need a fresher and less rigid learning atmosphere, as a counterbalance to conventional learning patterns that often feel monotonous. Technically, the illustrations were processed using the cel-shading technique, which is coloring with a flat color field and a firm shadow border without fine gradations. This approach not only strengthens the visual characters to look more lively and has volume, but also maintains the readability of the form so that the visual elements remain clear and easy to understand in the context of the game.

In terms of color psychology, visual design utilizes color palettes inspired by tropical natural landscapes and transitions to desert shades, such as sand beige, stone gray, and water blue as the backdrop of the game board. The color combination was chosen to create a calming impression while minimizing visual fatigue when students are thinking intensely. In addition, a color coding system is also applied as a strategy for organizing materials on the board and game tokens, where each category of tokens is distinguished by consistent colors such as red for prime numbers, green for even numbers, and yellow for odd numbers so as to help students mentally group information and speed up the decision-making process while playing. The typographical aspect is also carefully designed using Sans Serif font families such as Font Inter and Freedoka One to ensure optimal readability, especially on small media such as cards and guidebooks.



Figure 4. Color coding system in game board tiles oriented towards token colors

The selection of physical and material structures in the design of this media is carried out through careful consideration by balancing aspects of the playing experience, visual quality, and long-term durability of use in the classroom environment. The game board is designed in a modular format in a hexagonal shape, in contrast to conventional boards that are foldable and static like in Monopoly. Each part of the board is a separate hexagonal tile so that it can be rearranged according to the needs of the game scenario. From a technical perspective, each tile is produced using a filament with a thickness of approximately 1 cm so that it is sturdy and stable enough when used repeatedly. Pedagogically, this hexagonal shape allows for high flexibility in building dynamic game maps and does not confuse the direction of students' movements. The ever-changing configuration of the board increases high replayability, prevents students from memorizing fixed patterns, and encourages them to continuously adjust strategies and develop adaptive thinking and problem-solving skills.

Other components such as cards and tokens are also designed with material standards that support durability and comfort of use. The game cards use Ivory paper at least 310 gsm so that it is thick enough and does not warp easily when shuffled frequently. The corners of the cards are cut into rounds using a 4 mm radius corner cutter to prevent premature damage while reducing the risk of injuring students' hands.



Figure 5. a card design that also takes player comfort

Furthermore, the most important part of designing a Ekpedisi Numerasi game board is integrating numeracy materials with games. In accordance with the learning outcomes specified in the Independent Curriculum, phase E of mathematics subjects at the end of phase E students can solve problems related to algebra in the linear equation system (Kanginan, 2023). In addition, integrating and ensuring the content of numeracy content in the presentation requires players to think fluently procedurally in solving narrative problems in the form of mission cards. The numeracy material presented in the game, especially in the mission card section, has also received recognition that it is in line with the learning achievements of High School Class X students by Mr. Selamat as the head of the curriculum and mathematics teacher of SMAN 6 Semarang. He argued that the questions or challenges presented in the mission card have harmony or similarity to algebraic material, especially the linear equation system.

2.2.3 Development

The development stage is the realization of the concept into a functional physical prototype. This process involves the production of digital assets, three-dimensional modeling, as well as the printing of game components. Player characters are modeled in Blender 3D software and printed using resin-based stereolithography (SLA) techniques to produce fine, high-precision visual details. According to Kim Ji-min, a sculpture artist, 3D printing can realize identical results in creating various forms of expression with a very fast processing time (Sae-mi, 2023). Meanwhile, game tokens are produced using PLA+ filaments through FDM techniques to ensure the durability and mobility of components. In addition to physical production, the development phase also includes refining the rules of the game and adjusting the difficulty level of the numeracy challenge to maintain a balance between the educational elements and the playing experience.



Figure 6. Process of printing tiles and tokens using PLA (Polylactic Acid) with the FDM (Fused Deposition Modeling) method

Meanwhile, character pawns as direct representations of players are given special treatment using SLA (Stereolithography) using the vessel photopolymerization method, which is a liquid photopolymer resin that hardens when exposed to UV or laser light (Sandi et al., 2022) The resin material was chosen because it is able to produce very fine micro-details, especially on the character's face and clothing elements, so that the final look looks neater and more precise than conventional 3D printing. In addition to providing visual advantages, resin also presents a more solid weight so that the pawn feels steady when held and moved. The premium impression that emerges from the quality of detail and weight indirectly increases the perceptual value of media in the eyes of students, encouraging them to appreciate and care more for it as a serious and valuable learning tool, rather than just an ordinary game.

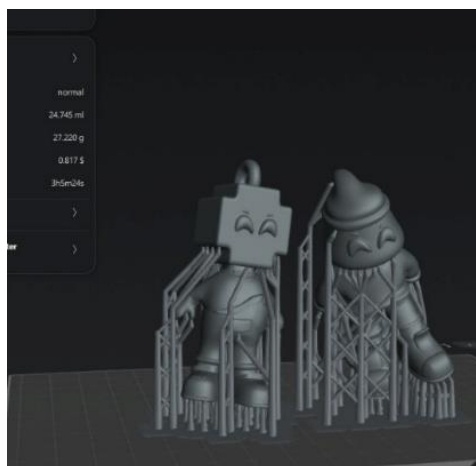


Figure 7. The process of slicing and providing support to the model before printing

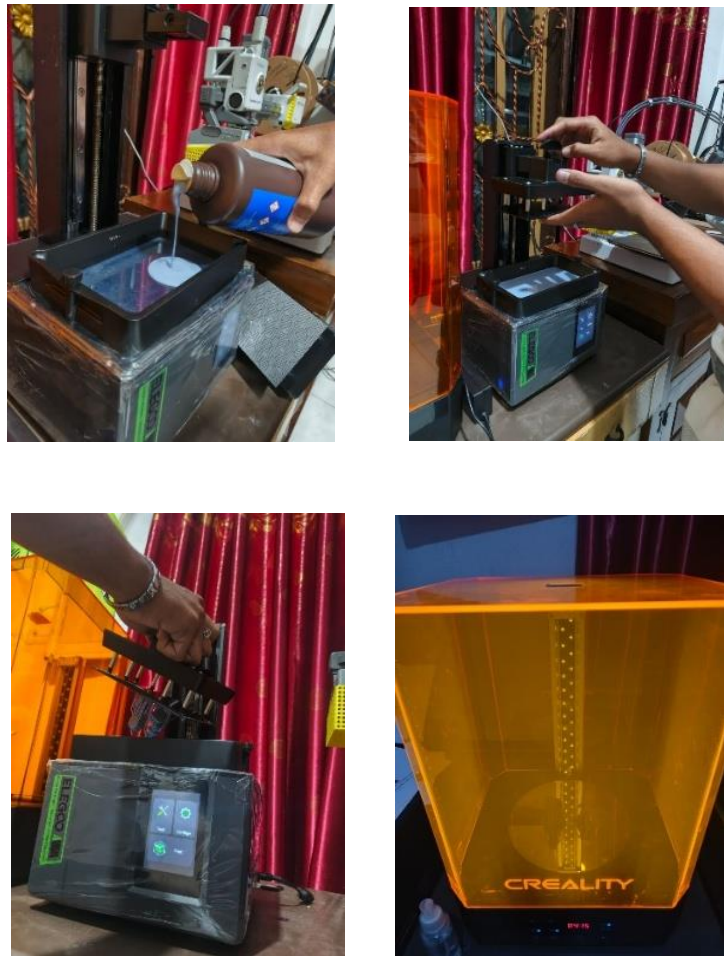


Figure 8. The printing process uses SLA (Stereolithography) using the vat photopolymerization method

At the production stage, after all game components are successfully printed using 3D printing technology, a process is carried out in the form of giving basic colors to the game board and characters. This stage begins with the preparation of the object's surface, such as cleaning the remaining material and the fireplace of less delicate parts, to ensure that the paint can adhere optimally. Furthermore, the basic color coating is carried out using pilox type spray paint with a gray primary color. This color selection is based on its function as a neutral base layer that is able to increase the adhesion of advanced paint while helping to bring out the shape details of the three-dimensional prints.

The spraying process is carried out evenly with controlled distance and pressure to avoid paint buildup at one specific point. Repeated thin layering techniques are applied to produce a smooth surface that does not obscure the details of the object. Once the entire surface is evenly covered, the components are allowed to dry in stable conditions before entering the advanced coloring or detailing stage. This stage is important because the quality of the base coat will greatly affect the visual finish and durability of the paint in subsequent use.



Figure 9. The process of applying a base coat using remier grey spray paint

Once the base coating stage is completed and the surface of the object is in a perfectly dry condition, the development process continues at the detailing stage. At this stage, coloring is done on the game board with reference to the color coding system that has been designed beforehand. Each area on the board is assigned a specific color according to its function and meaning in the game mechanics, thus not only reinforcing the visual aspect, but also helping the player in intuitively understanding the flow and rules of the game. The coloring process is done manually using brushes to maintain precision in each field, especially in small parts and intercolor boundaries.

In addition to the game board, the detailing process is also applied to the characters by following the visual design that has been developed in the previous stage. Character coloring uses enamel paint that is chosen because it has good closing power, more solid colors, and relatively high resistance to friction. The application technique is carried out in stages by paying attention to color gradation, contrast, and detail of visual elements so that the character looks lively and in accordance with the design concept. This stage is crucial because the final result of the detailing not only determines the aesthetic quality, but also affects the attractiveness and visual experience of the user when interacting with the game media.



Figure 10. Final Result of the prototype product Ekspedisi Numerasi

2.2.4 Implementation

The selection of High School Class X students is the result of consideration from cognitive theories about child psychology. High school kids (ages 15–17) are no longer kids who just play for instant fun, but they have unique cognitive and social characteristics. Objective considerations and scientific facts why the Ekspedisi Numerasi game is very suitable and has advantages if implemented in high school children, based on Erik Erikson's theory of social development, children in the age range are greatly influenced by peer groups. They are able to negotiate, suppress egos to achieve common goals, and divide tasks with reasonable reasons. With cooperative mechanics, high school students' advantages in communicating will emerge and help them in providing topics for discussion (Batra, 2013).

The implementation stage will be carried out through a limited trial on June 8, 2026, for a group of students in class X-A SMAN 6 Semarang as target users. This school was chosen because it meets the criteria of the lack of diversity of learning media available, especially in mathematics subjects. Linear with what was said by Mr. Slamet Riyadi as the head of curriculum as well as a Mathematics teacher at SMAN 6 Semarang in an interview via zoom platform on May 18, 2026. Mr. Slamet also added that some class X students at SMAN 6 Semarang looked anxious or anxious when they were studying or faced with math problems. Based on this foundation, SMAN 6 Semarang school became a test place that was relevant to the learning media of the Ekspedisi Numerasi that had been designed.

The trial aimed to observe students' responses to visual display, material suitability, and the effectiveness of cooperative mechanisms. At this stage, it is observed how students interact in groups, how they distribute roles, and the extent to which discussions take place before decision-making. Implementation is also a moment to evaluate the readability of visual elements and the ease of use of physical components. Observations during implementation provide an initial overview of the game's potential in encouraging collaboration and active participation. This stage serves not only as a test of the product's functionality, but also as a reflection on the successful integration between visual design and pedagogical mechanisms.



Figure 11. Interview with Mr. Slamet Riyadi via Zoom

In the implementation or trial process, the students are very enthusiastic because this is a new thing for them and also quite challenging. When they heard that this was a cooperative game that required them to work together, their response was quite surprised because by imagining a board game with a cooperative mechanism, the question of what they had to fight to achieve victory

must have crossed. But after all the parts of the game aspects were explained, they seemed to get used to it and enjoy how the game was going.



Figure 12. Implementation of the "Ekspedisi Numerasi" for 10th-grade students in Class X-A at State Senior High School 6 Semarang

2.2.5 Evaluation

Evaluation in the development of this media is carried out in a formative and continuous manner throughout the design process. Formative evaluations are conducted at each stage to improve and refine the design before moving on to the next phase, while summative evaluations are conducted after the implementation trial stage to assess the overall effectiveness of the product. The aspects examined include the visual attractiveness and attractiveness of the game, the clarity of the mechanics and rules, the effectiveness of cooperation between players, and the level of student involvement in numeracy activities.

The summative evaluation of this game involved 25 students of class X-A SMAN 6 Semarang as target users, where data was collected through a post-trial questionnaire, the number of responses was obtained from the number of students who had the opportunity to participate in the 180-minute Ekspedisi Numerasi board game trial which was divided into 6 sessions. The 180-minute trial was organized into six gameplay sessions. Each session involved a group of students playing the same core game system, followed by observation of player interaction and completion of the relevant gameplay activities. After the trial, participants completed the questionnaire individually. Demographically, the participants were dominated by 16-year-old students with a total of 18 students, accompanied by several 15-year-old students with a total of 3 people and 17-year-olds with a total of 4 people. Interestingly, the profile of the playing experience between them was quite varied, as many as 13 students were trying board games for the first time, while 12 students were already familiar with board games. This contrasting composition confirms that the designed media is not only inclusive for students from a variety of backgrounds, but also validated to be friendly and easy to understand for new users.

Table 3. Demographic Profile of Study Participants (N = 25)

Characteristic	Category	Frequency	Presentase
Age	15	3	12%
	16	18	72%
	17	4	16%
Boardgame Playing Experience	Ever been	12	48%
	Never	13	52%

Source: Primary data 2026

The assessment includes 10 aspects of the questions grouped into 3 sections, namely the visual and aesthetic dimensions, the content and learning dimensions, and the gameplay and engagement dimensions. Each aspect is assessed using a Likert scale of 1–5. The overall assessment results showed an average score of 4.55 out of 5.00 with a scale of 1.00–1.79 = Very Poor; 1.80–2.59 = Less; 2.60–3.39 = Sufficient; 3.40–4.19 = Good; 4.20–5.00 = Excellent, which indicates a very positive response from the target user. Details of the results of the assessment per aspect are presented in the following figure and table.

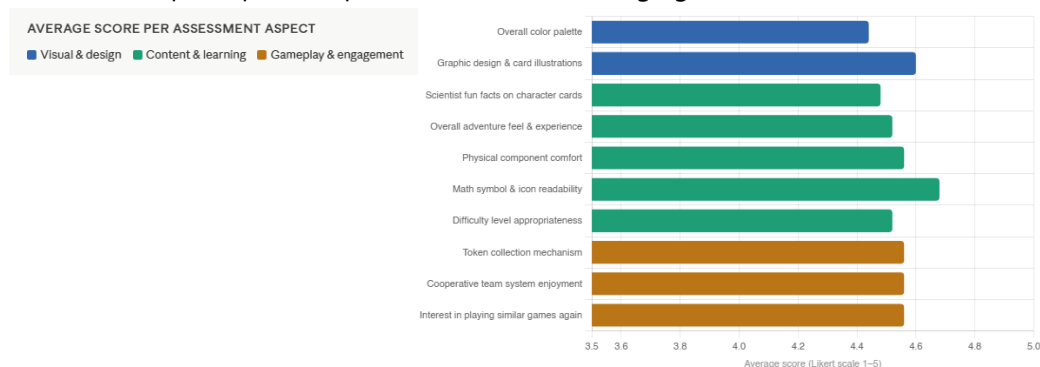


Figure 13. Average Score Assessment Aspect

Table 4. Details of the assessment results by aspect for the Ekspedisi Numerasi

No	Assessment Aspects	Average Score	Category
Visual & Aesthetic Dimensions			
1	Color palette of all game components	4,44	Excellent
2	Graphic design and illustration of character cards and obstacle cards	4,60	Excellent
Content & Learning Dimension			
3	The interesting info of the unique facts of the scientist behind the character cards	4,48	Excellent
4	The overall look and feel of the adventure of the game	4,52	Excellent
5	Convenience of physical components (tokens, cards, tiles) when used	4,56	Excellent
6	Ease of recognition of mathematical symbols/icons on tokens	4,68	Excellent
7	The suitability of the difficulty level of the questions with the material of class X of high school	4,52	Excellent
Gameplay & Engagement Dimensions			
8	The token mechanism supports numeracy-related gameplay	4,56	Excellent
9	The teamwork system makes the game enjoyable	4,56	Excellent
10	Interest in returning to play if a similar game is made	4,56	Excellent
Overall Average		4,55	Excellent

Source: Primary data 2026

Based on the data in the table above, all aspects of the assessment are in the Excellent category with a score range of 4.44 to 4.68. The aspect of ease of recognition of mathematical symbols and icons on tokens obtained the highest score (4.68), which indicates that the application of color coding systems and functional typography in game components successfully supports the player's cognitive processes. These findings are in

line with the principle of cognitive function of learning media as stated by Levie & Lentz (1982), where structured visual elements are able to facilitate understanding and speed up decision-making while playing.

The aspect with the lowest score was the color palette of the entire component (4.44), which, although still included in the Very Good category, indicates that there is room for improvement in the consistency of the color palette between components. This is reinforced by one of the respondents' qualitative suggestions that "the combination of numbers and games must be equal in order to be a more exciting game," which indicates the need for a balance between the visual content and the mechanics of the game. From the gameplay and engagement dimensions, the success aspect of the token mechanism in creating an implicit learning experience earned a score of 4.56. These findings support the principle of intrinsic integration put forward by Habgood & Ainsworth (2011), where numeracy is successfully integrated as an integral part of the core mechanics of the game so that students experience the learning process naturally without feeling like they are doing math practice. The score for interest in returning to play (4.56) indicates positive initial interest among the participating students; however, a longitudinal study would be needed to establish sustained engagement.

Not only that, as an optimizer for the design of the Ekspedisi Numerasi board, the designer was very grateful to get constructive suggestions and input from participants who had the opportunity to try the Ekspedisi Numerasi board game, one student participant suggested that the balance between numerical content and gameplay could be improved to make the game more engaging. In addition, Mr. Selamat provided suggestions for numeracy questions and challenges on the Ekspedisi Numerasi game board that can be redeveloped about the variety of materials and the level of difficulty. The designer realizes that even though the Ekspedisi Numerasi game board respondent data manages to be in the very good category, there will always be a part that can be readjusted as possible from the presentation of numbers and the overall game mechanics. Responding to Mr. Selamat's suggestion, in the next development time, the designer will try to readjust the variety of numeracy questions or challenges presented in the Ekspedisi Numerasi game board.

3. Conclusion

The design received positive initial responses from Grade X students. The findings support the feasibility of the prototype as a mathematics learning medium, but do not establish its effectiveness in improving numeracy outcomes. The main contribution of this medium lies in the application of pure dice-free cooperative mechanics and individual competitions that successfully transform mathematics learning into inclusive, collaborative, and strategic group activities. Through this system, learning objectives, game mechanics, and visual results reinforce each other.

From the perspective of art education, this study confirms that visual and material decisions can support the learning experience. Flexible hexagonal boards, functional color-coding systems, illustration styles, and levels of precision achieved through SLA and FDM 3D printing techniques collectively fulfill the four functions of learning media according to Levie & Lentz (1982), namely attentive, affective, cognitive, and compensatory functions. These design choices prove that art and design practices can contribute directly to the quality and effectiveness of educational media, beyond mere aesthetic aspects.

The summative evaluation involving 25 Class X students at SMAN 6 Semarang resulted in an overall average score of 4.55 out of 5.00, where the ten aspects assessed were included in the "Very Good" category. The interesting thing is that 52% of respondents have never had experience playing board games before, but this game is still positively received in all dimensions. This shows that the game has a strong level of

accessibility for novice users. The aspect with the highest score, namely the readability of mathematical symbols and icons (4.68), was associated with positive student perceptions of the color coding and typography system in supporting students' cognitive processes during the game. Additionally, the teamwork mechanics and interest in continuing to play together earned a score of 4.56, indicating that the game has suggesting positive initial interest in continued use of the medium.

However, this study still has some limitations. The implementation has only been carried out on a limited scale and has not yet used a pre-post test measurement design. Therefore, this study has not been able to provide quantitative evidence of increasing learning outcomes or decreasing the level of math anxiety in a measurable manner. Further research is suggested to test the effectiveness of the "Ekspedisi Numerasi" through large-scale quasi-experimental studies or mixed-methods, focusing on improving numeracy achievement, student engagement levels, and reducing math anxiety. The development of games to accommodate other math topics, different grade levels, or digital-physical hybrid formats is also a very promising direction for future development. The next limitation is that this study does not have enough mathematician validation data to be presented and serve as a basis and benchmark for the quality of the numeracy material presented.

In addition, the numeracy content has not undergone structured validation by mathematics experts, and the game prototype has not been formally validated by educational media or game design experts. The questionnaire also has not undergone formal content validation or reliability analysis. Furthermore, player dominance and free-riding were not systematically measured during the trial, and some questionnaire items may not adequately measure intrinsic learning integration. Finally, the study did not include a comparative condition with competitive games, so claims regarding differences between cooperative and competitive gameplay cannot be empirically established.

In conclusion, the "Ekspedisi Numerasi" became a meaningful meeting point between educational design, visual arts practice, and cooperative learning theory. This research offers a model of how board game design can function as a medium that may support mathematics learning by integrating collaboration, strategic thinking, and visual experience, a medium that places collaboration, strategic thinking, and aesthetic experiences as integrated components towards more friendly mathematics learning.

Declaration of Conflicting Interests

The authors state that there is no conflict of interest in the publication of this article.

Funding Information

None.

Acknowledgement

Thank you to everyone who was involved.

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