



HALMATIKA: A Halma-Based Board Game for Learning Logarithm Concepts in Secondary Mathematics

Leonard^{1*} & Galih Budi Prasetyo Suryo Nugroho²

¹Universitas Media Nusantara Citra, Jakarta, Indonesia

²Universitas Indraprasta PGRI, Jakarta, Indonesia

Abstract

This study aimed to develop HALMATIKA, a Halma-based board game for learning logarithm concepts in secondary mathematics, and to examine its feasibility for classroom use. The study employed a research-and-development design using the ADDIE model, which comprises analysis, design, development, implementation, and evaluation. The needs analysis was conducted at SMA 2 Perguruan “Cikini” in South Jakarta through interviews with teachers and expert consultation. As a learning medium, HALMATIKA was designed by integrating the movement mechanics of the Halma board game with logarithm question cards, enabling students to engage in concept practice through interactive, collaborative gameplay. Material experts, media experts, and students evaluated the product. A field trial was conducted with 27 tenth-grade students. The findings showed that HALMATIKA achieved a high level of feasibility. Student responses also yielded a positive mean score, suggesting that the medium was well accepted in the classroom. These findings indicate that HALMATIKA is a feasible learning medium for teaching logarithm concepts. The study implies that board game-based media can provide a more engaging learning environment and support the presentation of abstract mathematical concepts more interactively.

Keywords:

Logarithm concept, board game, game-based learning, learning media, secondary mathematics

(*) Corresponding Author: leo.eduresearch@gmail.com

How to Cite: Leonard, L., & Nugroho, G. B. P. S. (2026). HALMATIKA: A halma-based board game for learning logarithm concepts in secondary mathematics. *Formatif : Jurnal Ilmiah Pendidikan MIPA*, 16(1), 229-240. <https://doi.org/10.30998/qdaptt30>

INTRODUCTION

Logarithms are a fundamental topic in secondary mathematics as they support students' understanding of exponential relationships and function as foundational ideas for further study in mathematics and science. However, research on the teaching and learning of logarithms remains relatively limited, and existing studies consistently show that students often struggle to develop coherent meanings for logarithmic notation, logarithmic properties, and the relationship between exponential and logarithmic representations. These difficulties are not merely procedural; they are conceptual, particularly when students are required to coordinate multiplicative growth, interpret exponents meaningfully, and view a logarithm as a number rather than as a memorised rule. Therefore, learning environments for logarithms need to support conceptual sense-making, not only symbolic manipulation. (Gruver, 2018; Kuper & Carlson, 2020; Birgin & Acar, 2022).

One promising approach to supporting such learning is game-based instruction. Research on game-based learning suggests that well-designed games can increase engagement, sustain students' time-on-task, and create opportunities for repeated practice, peer interaction, and mathematical discussion. In mathematics education, however, the educational value of games depends on more than enjoyment alone. Games are most

productive when their mechanics are explicitly aligned with mathematical goals and when classroom use encourages students to think strategically and discuss ideas, rather than merely complete drill-and-practice tasks. Reviews of game-based learning in mathematics further indicate that many existing studies still emphasise routine practice, while conceptually demanding topics receive much less attention (Plass et al., 2015; Bragg, 2012; Stohlmann, 2023; Russo et al., 2024).

This limitation is important for the present study. Although mathematics games and board games have been widely discussed in prior literature, the accessible literature still offers limited evidence on non-digital board games specifically designed to support the learning of logarithm concepts in secondary classrooms. In addition, previous game-based studies have rarely explained in sufficient detail how the game structure is modified to address the conceptual demands of logarithms. As a result, at least three gaps remain. First, there is still limited development of non-digital board game media for logarithm learning at the secondary level. Second, existing mathematics game studies often prioritise motivation or practice outcomes without clearly articulating how game mechanics support conceptual understanding. Third, reviews suggest that research on mathematics games has focused heavily on number and operations, leaving conceptually challenging content comparatively underrepresented (Stohlmann, 2023; Russo et al., 2024).

To address these gaps, this study develops HALMATIKA, a Halma-based board game for learning logarithmic concepts in secondary mathematics. The novelty of HALMATIKA lies in how it adapts the strategic movement mechanics of Halma into a mathematics learning medium in which progress in the game is connected to logarithm tasks, timed responses, and rule-based consequences that encourage students to remain cognitively engaged during play. In this way, HALMATIKA is not positioned merely as a recreational activity added to instruction, but as a structured medium that combines concept practice, peer interaction, and strategic gameplay within a single learning environment. This design also responds to the needs analysis conducted through teacher interviews and expert consultation at SMA 2 Perguruan “Cikini,” which motivated the development of a more interactive learning medium for logarithm instruction.

Accordingly, this study aims to develop HALMATIKA and examine its feasibility for classroom use. The study's contribution is twofold. In practice, it offers a non-digital board game medium to support the teaching of logarithm concepts in secondary mathematics. Theoretically, it extends the discussion of game-based mathematics learning by showing how a traditional strategy board game can be pedagogically redesigned to support concept-oriented learning rather than merely repeating tasks. Since the present study focuses on product development and feasibility, its claims are limited to validity, feasibility, and student responses, rather than to proving increased mastery or learning effectiveness.

METHODS

Research Design

This study employed a research and development (R&D) design to develop and evaluate the feasibility of HALMATIKA, a Halma-based board game for learning logarithm concepts in secondary mathematics. The development process was organised using the ADDIE framework, which comprises five stages: analysis, design, development, implementation, and evaluation. In the present study, ADDIE was used as an operational framework to guide the systematic development of the product, rather than as a single fixed graphical model. Accordingly, the figure presented in this study should be understood as

the authors' adaptation of the generic ADDIE sequence used to structure the research procedures. ADDIE is widely recognised as a flexible instructional design framework that can be represented in various visual forms while retaining the same core stages. This use of ADDIE as a flexible, iterative development framework is consistent with prior descriptions of instructional design in which ADDIE is treated as a general procedural model rather than a single fixed visual representation (Branch, 2009; Molenda, 2003).

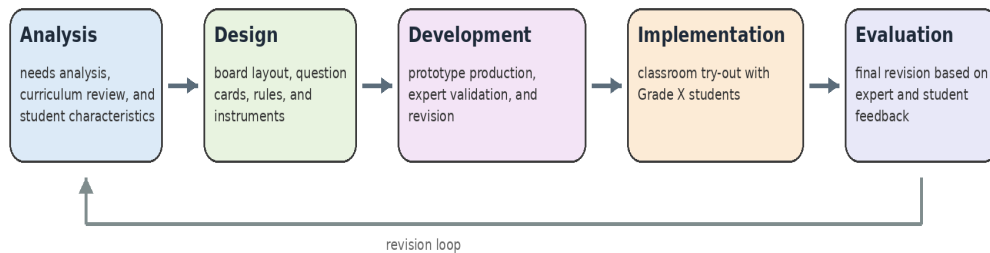


Figure 1. Operational stages of the ADDIE model used in this study

Research Context and Participants

The study was conducted at SMA 2 Perguruan “Cikini,” South Jakarta. Participants were selected purposively based on their roles in each stage of the development process.

In the analysis phase, the participants consisted of two senior mathematics teachers from the school and two university lecturers in mathematics education. They were involved in identifying instructional needs, examining the suitability of logarithms as the content focus, and reviewing curriculum alignment.

In the development phase, the prototype was evaluated by two subject-matter experts and two media experts. In addition, six Grade 10 students participated in a small-scale preliminary tryout to assess the clarity of the rules, the readability of the cards, and the usability of the prototype.

In the implementation phase, the revised product was piloted in one intact Grade 10 class of 27 students. This stage was designed as a limited field trial to examine product feasibility and student responses in an authentic classroom context. Accordingly, this study was not designed as a true experimental or quasi-experimental study and did not include a comparison group or a pretest-posttest design.

Rationale for Topic Selection

Logarithms were selected as the content focus for two main reasons. First, the needs analysis indicated that teachers perceived logarithms as one of the more abstract and challenging topics for Grade 10 students. Second, the topic is well-suited to game-based reinforcement as it requires repeated practice in applying definitions, properties, and symbolic transformations. Therefore, HALMATIKA was designed not only as a substitute for teacher explanation but also as a learning medium to support guided practice, collaborative interaction, and concept reinforcement in classroom learning.

Research Procedures

The study followed five operational stages in accordance with the ADDIE framework.

1. Analysis

At this stage, the researchers conducted a needs analysis through interviews with teachers and consultations with mathematics education experts. The analysis focused on three

aspects: (a) learning difficulties related to logarithms, (b) curriculum alignment for Grade 10 mathematics, and (c) student characteristics relevant to the use of a board game medium. The output of this stage was a decision to develop a non-digital board game medium for learning logarithms.

2. Design

In the design stage, the researchers prepared the conceptual and visual design of HALMATIKA. This included determining the learning objectives, mapping logarithm content into question-card formats, designing the board layout and movement system, drafting game rules, and planning how the medium would be used in small-group collaborative learning. At this stage, the relationship between the medium and the learning strategy was explicitly defined: HALMATIKA was intended to support cooperative practice and concept reinforcement through structured gameplay.

3. Development

In the development stage, the HALMATIKA prototype was produced, including the board, pawns, question cards, and game instructions. Material experts and media experts then reviewed the prototype to evaluate content accuracy, language clarity, presentation, design quality, and attractiveness. The experts' comments were used to revise the product. After expert review and revision, the revised prototype was tested with six students in a small-scale try-out to identify practical problems before classroom implementation.

4. Implementation

The revised HALMATIKA medium was implemented in one Grade 10 classroom involving 27 students. During this phase, students used the board game in small groups under teacher supervision. The purpose of implementation was to examine whether the product could be used appropriately in actual classroom conditions and to gather student responses regarding its feasibility, attractiveness, and usability.

5. Evaluation

Evaluation was conducted both formatively and summatively. Formative evaluation took place throughout the development process, incorporating expert feedback and preliminary student response. Summative evaluation was conducted following a limited field trial, based on expert validation results and student response data. The final version of HALMATIKA was subsequently revised in light of these findings.

Instruments

Three types of instruments were employed in this study. First, a semi-structured interview guide was used in the analysis phase to identify instructional problems, curriculum needs, and students' learning difficulties related to logarithms. Second, expert validation forms were used in the development phase to evaluate the feasibility of the product. Third, a student response questionnaire was administered in the implementation phase to examine students' perceptions of the product following classroom use.

Table 1. Research Instruments Used in Each Stage

Stage	Participants	Instrument	Main indicators measured
Analysis	2 mathematics teachers; 2 mathematics education lecturers	Semi-structured interview guide	learning difficulties in logarithms; curriculum alignment; need for interactive media; student characteristics
Development	2 material experts	Material validation sheet	content accuracy; alignment with objectives; language clarity; presentation; attractiveness

Stage	Participants	Instrument	Main indicators measured
Development	2 media experts	Media validation sheet	design quality; readability; layout; presentation; usability; attractiveness
Development	6 students	Preliminary try-out sheet/observation notes	clarity of rules; readability of cards; ease of use; playability
Implementation	27 Grade X students	Student response questionnaire	content usefulness; language and display; presentation/usability

Validity and Reliability of the Instruments

Content validity was established through expert judgment, a procedure widely recommended in instrument development studies to ensure that the items are relevant, clear, and appropriate for the intended construct (Polit et al., 2007; Zamanzadeh et al., 2015). The interview guide and questionnaires were developed to align with the objectives of each research stage. The student response questionnaire was examined using Cronbach's alpha, a commonly used measure of internal consistency for questionnaire-based instruments (Tavakol & Dennick, 2011). The internal consistency of the student response questionnaire yielded a coefficient of 0.88, indicating good reliability.

Data Collection

Data collection was carried out according to the stage of development. Interview data were collected in the analysis phase. Expert validation data were collected in the development phase after the prototype had been produced. Student response data were collected in the implementation phase after students had used HALMATIKA in classroom learning. Thus, different instruments were used for different stages of ADDIE, and the Likert-scale questionnaire was not used in every stage.

Data Analysis

Interview data were analysed descriptively and used to justify the product's development. The expert validation sheets and student response questionnaire were analysed using descriptive statistics based on a five-point Likert scale, with response options ranging from 1 = strongly disagree to 5 = strongly agree. Mean scores were calculated using the following formula:

$$\bar{X} = \frac{\sum X}{N}$$

where \bar{X} is the mean score, $\sum X$ is the total score obtained, and N is the number of ratings. The use of mean scores to summarise Likert-type responses is common in educational research when the purpose is to provide a descriptive interpretation of grouped responses. For practical interpretation, the mean scores were converted into qualitative categories using equal intervals on the 1.00–5.00 scale, as presented in Table 2.

Table 2. Feasibility categories used to interpret the mean scores

Mean interval	Category
4.21–5.00	Very feasible
3.41–4.20	Feasible
2.61–3.40	Moderately feasible
1.81–2.60	Less feasible
1.00–1.80	Not feasible

The use of mean scores to summarise Likert-type responses is common in educational research when the purpose is to provide a descriptive interpretation of grouped responses (Sullivan & Artino, 2013). These categories were used consistently to interpret the results of the material validation sheet, media validation sheet, and student response questionnaire.

Scope of the Findings

As this study used interview data, expert validation, preliminary try-out feedback, and student response data, the findings support claims related to content validity, media feasibility, and classroom acceptability. The study did not employ an achievement test, a mastery instrument, a pretest-posttest design, or a comparison group. Therefore, it does not measure mastery of logarithm concepts or the medium's effectiveness in improving learning outcomes.

RESULTS & DISCUSSION

Results

This section presents the results of the development and limited field trial of HALMATIKA based on the ADDIE framework. In line with the scope of the study, the findings focus on the development outputs, expert validation results, and student responses to classroom use.

Analysis Phase

The analysis phase indicated the need for a more interactive learning medium for teaching logarithm concepts in Grade 10 mathematics. Based on teacher interviews and curriculum review, logarithms were identified as a topic that students often perceive as abstract and difficult, particularly when applying logarithmic properties and symbolic transformations. In addition, the analysis suggested that students required more opportunities for guided practice in a structured, engaging learning environment. These findings supported the decision to develop HALMATIKA as a non-digital board game medium for logarithm learning.

Design and Development Phase

Based on the results of the analysis phase, HALMATIKA was designed as a Halma-based board game consisting of a board, pawns, question cards, and game instructions. The board measures 30 cm × 30 cm and contains 37 circles, several of which are marked with the word “log.” When a player lands on one of these circles, the player must draw a logarithm question card. The question-card set comprises 65 items on logarithm concepts and operations. The game also includes feedback elements in the form of special cards that affect player movement, thereby integrating mathematical practice with strategic gameplay.

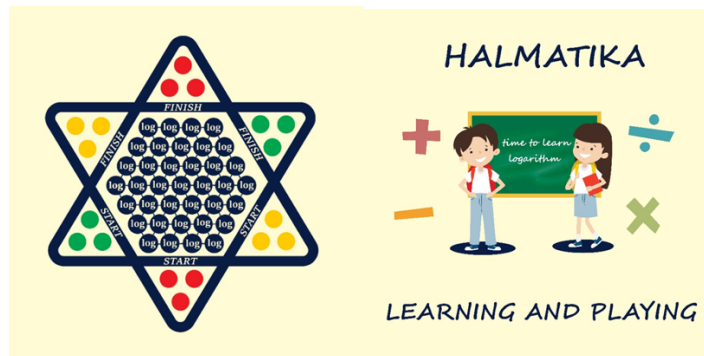


Figure 2. Front and Back Views of the HALMATIKA Board

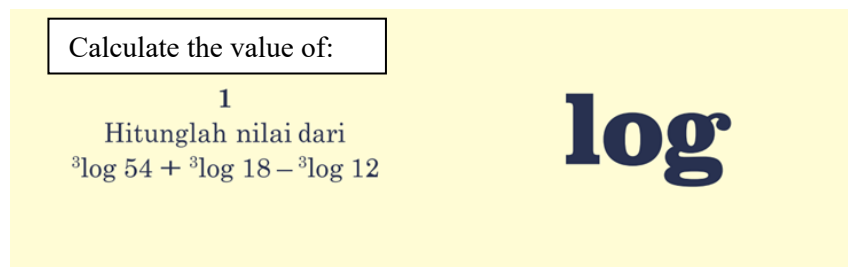


Figure 3. Front and Back Display of the HALMATIKA Question Cards

HALMATIKA GAME RULES

- Players are divided into 3 groups.
- Each group consists of 3 people.
- Players provide paper to answer the questions on the drawn question cards.
- Each group must move all of their pawns from start to finish.
- Each group can jump over pawns (either opponent's or their own) in front of it to move farther and reach the finish line faster.
- To determine which group goes first, a rock-paper-scissors game (or a draw) is held, with a member from each group.
- Players will move to the “log” circle and take a card.
- Out of the 37 circles, there will be 65 questions, and some of these questions may contain joy cards with a laughing emoji and sadness cards with a crying emoji.
- Players must answer the questions correctly to remain on the chosen circle. If the answer is incorrect, the player must move back 1 step.
- Each group that gets a fun card does not need to answer a question and is entitled to move 1 step forward from the chosen circle. Conversely, if they get a sadness card, they must answer a question; if they cannot, the player will move back 2 steps.
- The 65 questions on the question cards are easy-level questions.
- For each question, 90 seconds are given to work on it.
- The supervisor checks the completed answer sheets.
- The first group to successfully move all three of their pawns to the finish is declared the winner in the HALMATIKA (Mathematics Halma) game.

PERATURAN PERMAINAN HALMATIKA

- Pemain dibagi menjadi 3 kelompok.
- Setiap kelompok terdiri dari 3 orang.
- Pemain menyediakan kertas untuk menjawab pertanyaan dari kartu soal yang diambil.
- Setiap kelompok harus memindahkan semua pion miliknya dari start sampai ke finish.
- Setiap kelompok bisa melompati pion (baik pion lawan ataupun pion sendiri) yang ada di depannya untuk melangkah lebih jauh dan agar lebih cepat mencapai finish.
- Untuk menentukan kelompok yang mulai pertama, dilakukan dengan hompimpa yang diwakilkan oleh perwakilan setiap kelompok.
- Pemain akan melangkah ke lingkaran yang terdapat kata “log” dan mengambil kartu.
- Dari banyaknya 37 lingkaran akan ada 65 soal dan kemungkinan di dalam soal tersebut berisikan kartu kesenangan dengan emoji tertawa (😄) dan kartu kesedihan dengan emoji menangis (😭).
- Pemain harus mengerjakan soal dengan tepat untuk tetap berada di lingkaran yang dipilih. Apabila jawabannya tidak tepat maka pemain harus mundur 1 langkah.
- Setiap kelompok yang mendapatkan kartu kesenangan tidak perlu mengerjakan soal dan berhak maju 1 langkah dari lingkaran yang dipilih. Sebaliknya jika mendapatkan kartu kesedihan maka harus mengerjakan soal dan apabila tidak bisa mengerjakannya maka pemain akan mundur 2 langkah.
- 65 soal pada kartu soal merupakan soal yang tingkatannya mudah.
- Pada setiap pertanyaan diberikan waktu 90 detik untuk mengerjakannya.
- Pengawas memeriksa lembar jawaban yang telah dikerjakan.
- Kelompok pertama yang berhasil memindahkan ketiga pionnya menuju finish dinyatakan sebagai pemenang dalam permainan HALMATIKA (Halma Matematika).

Figure 4. HALMATIKA Game Instructions

The development phase produced the HALMATIKA prototype, including the board's visual design, the question cards, and the game guide. Material and media experts

then reviewed the prototype before it was revised for classroom use. Overall, the development process resulted in a learning medium that combined concept practice, peer interaction, and rule-based game mechanics within a single instructional product.

Media Expert Validation

The results of the media expert validation are presented in Table 3. The overall mean score was 4.70, placing it in the “very feasible” category. Across all assessed aspects, the scores ranged from 4.62 to 4.83, indicating consistently strong evaluations of the product’s design quality.

Table 3. Results of Media Expert Validation

No.	Assessment Aspect	Total Score	Mean Score	Category
1	Content	29	4.83	Very Feasible
2	Language and Display	65	4.64	Very Feasible
3	Presentation	57	4.75	Very Feasible
4	Interest	37	4.62	Very Feasible
	Overall	188	4.70	Very Feasible

The high content score suggests that the media components were considered appropriate and relevant to the intended instructional purpose. Similarly, the strong presentation score indicates that the organisation of the board, cards, and rules supported the medium's usability. The high interest rating also suggests that the visual and structural features of HALMATIKA were perceived as capable of capturing students’ attention. Taken together, these findings indicate that the game format was not only visually acceptable but also instructionally coherent for classroom use.

Material Expert Validation

The results of the material expert validation are presented in Table 4. The overall mean score was 4.55, which also falls into the “very feasible” category. Three aspects, such as content, presentation, and interest, were rated as very feasible, while language and display obtained a mean score of 4.16, which falls into the feasible category.

Table 4. Results of Material Expert Validation

No.	Aspect	Total Score	Mean Score	Category
1	Content	76	4.75	Very Feasible
2	Language and Display	25	4.16	Feasible
3	Presentation	55	4.58	Very Feasible
4	Interest	26	4.33	Very Feasible
	Overall	182	4.55	Very Feasible

The highest score in the content aspect indicates that the mathematical material embedded in HALMATIKA was considered sufficiently accurate, relevant, and aligned with the learning objectives for logarithms. The strong presentation score further suggests that the mathematical tasks were organised in a way that supported use in classroom activities. However, the slightly lower score for language and display implies that some wording, instructions, or visual details could still be improved for greater clarity. This pattern is crucial as it shows that the product's core mathematical substance was already strong, while minor refinements were still needed to optimise readability and communication.

Student Responses in the Limited Field Trial

Following revision based on expert input, HALMATIKA was implemented in one Grade 10 class involving 27 students. The purpose of this stage was to examine the product's feasibility in an authentic classroom context and to collect students' responses after they used the game. The results are presented in Table 5.

Table 5. Student Response Results

No.	Aspect	Total Score	Mean Score	Category
1	Content	759	4.21	Very Feasible
2	Language and Display	333	4.16	Feasible
3	Presentation	592	4.22	Very Feasible
	Overall	1.684	4.21	Very Feasible

An overall mean score of 4.21 indicates that students responded positively to HALMATIKA, signifying its feasibility for classroom implementation. Both the content and presentation reached the “highly feasible” category, suggesting that students perceived the game as useful and sufficiently clear to support logarithm practice. The linguistic and interface aspect received a slightly lower score of 4.16, which remained within the feasible category. Consistent with the subject-matter expert validation, this result suggests that although the medium was generally well received, some refinement in wording, instructions, or visual presentation may further enhance the student experience.

Importantly, the student response pattern demonstrates that HALMATIKA was not perceived merely as a recreational activity. Instead, students appeared to recognise it as a learning medium that combined practice with participation, strategy, and classroom interaction. This is meaningful for logarithm learning because the topic often requires repeated exposure to symbolic forms and opportunities to discuss procedures and concepts with peers.

Discussion

This study developed HALMATIKA, a Halma-based board game for learning logarithm concepts and found that the product was rated as highly feasible by media experts ($M = 4.70$), material experts ($M = 4.55$), and students in the limited field trial ($M = 4.21$). Taken together, these results indicate that HALMATIKA was considered instructionally appropriate, usable, and acceptable for classroom implementation. More importantly, the convergence of expert validation and student responses suggests that the product functioned not merely as an attractive classroom aid, but as a learning medium whose design, content, and implementation were perceived as coherent and educationally meaningful. Nevertheless, these findings should be interpreted as evidence of validity, feasibility, and classroom acceptability rather than as proof of improved mastery of logarithm concepts, because the present study did not employ an achievement test or an experimental design.

The positive evaluation of HALMATIKA can be understood in light of game-based learning theory. Plass et al. (2015) argue that educational games are effective not simply because they are enjoyable, but because they can simultaneously activate cognitive, affective, behavioural, and sociocultural forms of engagement. In HALMATIKA, progress in the game depended on answering logarithm questions, following explicit rules, managing time limits, and interacting with peers during gameplay. This means that the game mechanics were directly tied to academic tasks rather than functioning as a decorative

motivational layer. Such alignment is important because prior meta-analytic work has shown that the learning benefits of games depend strongly on design features and on how gameplay is integrated with instructional goals, not on the game medium alone (Clark et al., 2016). From this perspective, the high scores in presentation and interest are not incidental; they likely reflect the instructional coherence of a product in which students' participation in the game required sustained attention to mathematical content. This interpretation is also compatible with meta-analytic evidence showing that serious games can support learning and retention, particularly when gameplay is accompanied by instructional support and repeated opportunities for engagement (Wouters et al., 2013).

The strong ratings from material experts are also pedagogically significant, as logarithms are widely recognised as conceptually demanding. Research has shown that students often struggle to develop meaningful understandings of logarithmic notation, logarithmic properties, and the relationship between exponential and logarithmic representations (Gruver, 2018; Kuper & Carlson, 2020). These challenges are not merely procedural; they involve difficulties in coordinating multiplicative reasoning, interpreting exponents meaningfully, and seeing a logarithm as a quantity rather than as a memorised symbolic rule. In this context, HALMATIKA appears relevant because its question-card system creates repeated encounters with logarithmic tasks in a structured and interactive format. Rather than positioning practice as isolated seatwork, the medium embeds it within a rule-based and socially shared activity, thereby increasing the likelihood that students remain engaged with concept-related tasks for longer periods.

A further strength of the product lies in its contribution to the literature on game-based learning in mathematics. Recent review studies suggest that although educational games are widely used in mathematics, many designs still emphasise drill-and-practice routines and target factual or procedural knowledge more than conceptually oriented understanding (Kacmaz & Dubé, 2022). Likewise, Pan et al. (2022) note that the mathematics game literature still needs richer accounts of how learning mechanics and gameplay mechanics are integrated, especially when the goal is to support deeper mathematical thinking rather than mere repetition. HALMATIKA contributes to this gap by adapting the strategic structure of a traditional board game into a topic-specific, non-digital learning medium for logarithms. Its design integrates movement rules, question cards, time constraints, and peer interaction into one instructional environment, making it a more concept-oriented form of game-based practice than many routine game formats reported in prior literature.

The positive student responses in the limited field trial reinforce this interpretation. Students rated the product as very feasible overall, indicating that HALMATIKA was well received in classroom use. This suggests that the medium sustained student participation while maintaining a clear academic focus. In practical terms, the product may reduce the monotony often associated with repetitive logarithm exercises by transforming practice into collaborative turn-taking, strategic decision-making, and immediate feedback. This matters because conceptually demanding mathematical learning often requires repeated exposure, but repeated exposure is more likely to be productive when students remain cognitively and socially engaged in the activity. Accordingly, the present findings support the broader view that well-designed mathematics games can serve as structured environments for participation and meaning-making, rather than as entertainment added to formal teaching. This interpretation is also consistent with findings that rule-based board game structures can support mathematical participation and competency development when learning tasks are embedded within the mechanics of play (Skillen et al., 2018).

At the same time, the slightly lower scores for language and display from both material experts and students identify an important direction for refinement. These results do not weaken the overall feasibility of HALMATIKA; rather, they indicate that the

product's mathematical core was already strong, while some aspects of wording, visual communication, or instruction clarity could still be improved. For development studies, such a pattern is analytically useful because it shows that feasibility is not a single undifferentiated outcome. Instead, it helps distinguish between strengths in substantive instructional design and areas where technical presentation can still be optimised for first-time users.

Overall, the discussion of these findings supports the view that HALMATIKA has value as a classroom learning medium because it combines structured mathematical practice with strategic and collaborative gameplay. The product appears to support engagement not only through enjoyment but also through the deliberate organisation of tasks, rules, and peer interaction around logarithm content. However, the claims of this study must remain within the limits of the research design. Because the study focused on product development, expert validation, and a limited classroom trial, it does not demonstrate that HALMATIKA improves students' mastery or achievement in logarithms. Future studies should therefore examine its effects on conceptual understanding, achievement, and mathematical discussion using experimental or quasi-experimental designs with broader samples and achievement-based measures.

CONCLUSION

This study developed HALMATIKA, a Halma-based board game for learning logarithm concepts in secondary mathematics, using the ADDIE framework. The findings showed that HALMATIKA was rated as very feasible by media experts, material experts, and students in the limited field trial. These results indicate that the product was considered appropriate in terms of content, presentation, usability, and classroom acceptability. The study also suggests that HALMATIKA has practical value as a non-digital learning medium for teaching logarithm concepts. By integrating question-based practice with strategic and collaborative gameplay, the medium provides an alternative way to support classroom engagement and make abstract mathematical content more interactive for students. In this sense, HALMATIKA contributes not only as an instructional product but also as an example of how a traditional board game can be pedagogically adapted for concept-oriented mathematics learning. However, the conclusions of this study must be interpreted within the scope of the research design. Since the study focused on product development, expert validation, and student responses, it does not provide evidence of improved mastery or learning achievement. Future research is therefore recommended to examine the effectiveness of HALMATIKA in improving students' conceptual understanding of logarithms through experimental or quasi-experimental designs involving broader samples and achievement-based measures.

REFERENCES

- Birgin, O., & Acar, H. (2022). The effect of computer-supported collaborative learning using GeoGebra software on 11th-grade students' mathematics achievement in exponential and logarithmic functions. *International Journal of Mathematical Education in Science and Technology*, 53(4), 872–889. <https://doi.org/10.1080/0020739X.2020.1788186>
- Bragg, L. A. (2012). The effect of mathematical games on on-task behaviours in the primary classroom. *Mathematics Education Research Journal*, 24(4), 385–401. <https://doi.org/10.1007/s13394-012-0045-4>

- Branch, R. M. (2009). *Instructional Design: The ADDIE Approach*. Springer. <https://doi.org/10.1007/978-0-387-09506-6>
- Clark, D. B., Tanner-Smith, E. E., & Killingsworth, S. S. (2016). Digital games, design, and learning: A systematic review and meta-analysis. *Review of Educational Research*, 86(1), 79–122. <https://doi.org/10.3102/0034654315582065>
- Gruver, J. (2018). A trajectory for developing conceptual understanding of logarithmic relationships. *The Journal of Mathematical Behavior*, 50, 1–22. <https://doi.org/10.1016/j.jmathb.2017.12.003>
- Kacmaz, G., & Dubé, A. K. (2022). Examining pedagogical approaches and types of mathematics knowledge in educational games: A meta-analysis and critical review. *Educational Research Review*, 35, 100428. <https://doi.org/10.1016/j.edurev.2021.100428>
- Kuper, E., & Carlson, M. (2020). Foundational ways of thinking for understanding the idea of logarithm. *The Journal of Mathematical Behavior*, 57, 100740. <https://doi.org/10.1016/j.jmathb.2019.100740>
- Molenda, M. (2003). In search of the elusive ADDIE model. *Performance Improvement*, 42(5), 34–36. <https://doi.org/10.1002/pfi.4930420508>
- Pan, Y., Ke, F., & Xu, X. (2022). A systematic review of the role of learning games in fostering mathematics education in K–12 settings. *Educational Research Review*, 36, 100448. <https://doi.org/10.1016/j.edurev.2022.100448>
- Plass, J. L., Homer, B. D., & Kinzer, C. K. (2015). Foundations of game-based learning. *Educational Psychologist*, 50(4), 258–283. <https://doi.org/10.1080/00461520.2015.1122533>
- Polit, D. F., Beck, C. T., & Owen, S. V. (2007). Is the CVI an acceptable indicator of content validity? Appraisal and recommendations. *Research in Nursing & Health*, 30(4), 459–467. <https://doi.org/10.1002/nur.20199>
- Russo, J., Kalogeropoulos, P., Bragg, L. A., & Heyeres, M. (2024). Non-digital games that promote mathematical learning in primary years students: A systematic review. *Education Sciences*, 14(2), 200. <https://doi.org/10.3390/educsci14020200>
- Skillen, J., Berner, V.-D., & Seitz-Stein, K. (2018). The rule counts! Acquisition of mathematical competencies with a number board game. *The Journal of Educational Research*, 111(5), 554–563. <https://doi.org/10.1080/00220671.2017.1313187>
- Stohlmann, M. S. (2023). Categorization of game-based learning in middle school mathematics: A review. *Middle School Journal*, 54(5), 16–26. <https://doi.org/10.1080/00940771.2023.2254175>
- Sullivan, G. M., & Artino, A. R., Jr. (2013). Analyzing and interpreting data from Likert-type scales. *Journal of Graduate Medical Education*, 5(4), 541–542. <https://doi.org/10.4300/JGME-5-4-18>
- Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education*, 2, 53–55. <https://doi.org/10.5116/ijme.4dfb.8dfd>
- Wouters, P., van Nimwegen, C., van Oostendorp, H., & van der Spek, E. D. (2013). A meta-analysis of the cognitive and motivational effects of serious games. *Journal of Educational Psychology*, 105(2), 249–265. <https://doi.org/10.1037/a0031311>
- Zamanzadeh, V., Ghahramanian, A., Rassouli, M., Abbaszadeh, A., Alavi-Majid, H., & Nikanfar, A.-R. (2015). Design and implementation content validity study: Development of an instrument for measuring patient-centered communication. *Journal of Caring Sciences*, 4(2), 165–178. <https://doi.org/10.15171/jcs.2015.017>