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The Development of Scratch-Based Interactive Mathematics Learning Media to Enhance Understanding of Exponents

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Abstract: This study addresses the need for interactive mathematics learning media to improve students' understanding of the concept of exponents. The objective of this research is to develop and evaluate Scratch-based learning media using the ADDIE model. This study employed a Research and Development (R&D) method consisting of five stages: analysis, design, development, implementation, and evaluation. Data were collected through expert-validation questionnaires, User Acceptance Test (UAT) questionnaires, and conceptual-understanding tests administered before and after the implementation of the media. The validation results indicated that the developed media and learning materials were highly valid, with validity scores of 0.90 and 0.95, respectively. In addition, the conceptual understanding test instrument was validated by a mathematics education expert and was deemed suitable for assessing students' understanding of exponent concepts. The User Acceptance Test (UAT) was conducted with prospective mathematics teachers to evaluate the usability and practicality of the developed media. In contrast, the implementation and learning outcome assessments were conducted with students. The UAT results showed that the developed media was positively evaluated by users, obtaining a score of 82.9%, which falls within the very good category. The developed media provided interactive learning activities that encouraged students to actively engage with concepts of exponents throughout the learning process. The results showed that students achieved better learning outcomes, as evidenced by increases in their pretest and posttest scores. The average N-Gain score of 0.84 was categorized as high, indicating an improvement in students' understanding of exponent concepts after using the developed media. The study resulted in a Scratch-based multimedia learning media that was evaluated as highly valid and positively received by users. The findings indicated improvements in students' understanding of exponent concepts, while several usability aspects, particularly related to device compatibility, may be further refined in future development.

Keywords: ADDIE, exponent, learning media, Scratch.

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INTRODUCTION

The use of technology in education has spurred the development of interactive, student-centered learning media. Currently, various interactive learning media have developed rapidly and can support students' thinking processes and conceptual understanding. Even though many digital learning media have been developed to support mathematics learning (Arifin et al., 2021), students' understanding of the topic of exponents remains a significant challenge (Salwadila & Hapizah, 2024). Many students seem to struggle to grasp the properties of exponents and then apply those ideas when solving problems (Bakar et al., 2023). These findings indicate that existing instructional practices have not fully supported the development of students' conceptual understanding. Furthermore, active student engagement plays an important role in supporting conceptual understanding (Bond & Bedenlier, 2019). However, some learning media provide limited opportunities for students to actively construct their understanding of mathematical concepts. Therefore, learning media that support active interaction and create meaningful learning experiences are needed to strengthen students' conceptual understanding. Scratch functions as one possible educational platform. Scratch functions as a visual programming language that enables users to learn programming basics through its block-based coding system, which beginners and educators from different fields can use (Chuang & Lee, 2020; Kwon et al., 2018).

Interactive platforms, such as Scratch, help educational institutions create effective learning tools to teach specific mathematical concepts, as evidenced by research (Yulianisa & Sudihartinih, 2022). Scratch engages students by presenting educational content through its interactive visual system, helping them understand the material through direct experience. The use of interactive multimedia content on the Scratch educational platform creates new possibilities for teachers to employ more effective methods for teaching difficult mathematical subjects (Iskandar et al., 2023). Advances in technology in the 21st century enable educators to create new educational resources that help students learn more effectively and solve their academic problems (Yulianisa & Sudihartinih, 2022).

Iskandar et al. (2023) showed that the interactive learning environments of the Scratch educational platform help students learn mathematics more effectively through their learning activities. Scratch is a tool for creating game-based mathematics learning materials, allowing students to master abstract mathematical concepts through hands-on experience and leading to increased student participation and excitement (Pradja & Saputra, 2023). Scratch provides users with an interactive learning platform to create animations, games, and stories, allowing them to learn directly through visual interaction and thereby improve their mathematical skills (Puteri et al., 2024; Sudihartinih & Rachmatin, 2024).

Many students still do not understand complex mathematical concepts, such as exponents (Perbowo & Anjarwati, 2017). Previous studies have reported that students continue to experience difficulties understanding exponent concepts, as evidenced by persistent misconceptions and learning obstacles related to exponent properties and operations (Dewi et al., 2024; Pramasdyahsari et al., 2024). Problem-solving becomes more challenging when students merely memorize rather than build a conceptual grasp of mathematical ideas (Hiebert & Lefevre, 1986; Skemp, 1976). That kind of issue also shows up in algebra learning, where students' mastery of algebraic content remains rather low. In a study using Minimum Competency Assessment (AKM) content analysis, it was reported that students' control of algebraic material only reached 46.44%. The problems, especially in understanding and using algebra concepts, arise when students solve questions (Susanto et al., 2023). Since concepts of exponents are fundamental to algebra, difficulties in algebraic understanding may also affect students' ability to grasp the properties of exponents and apply them appropriately. Previous studies have found that students often have misconceptions and conceptual difficulties in exponentiation, which can hinder their understanding of more advanced mathematical concepts (Zilfikri et al., 2026).

The educational system needs new teaching resources because current methods create problems that hinder students' effective learning of mathematics. Based on interviews with mathematics teachers at a junior high school in Jakarta. Exponent teaching is done mostly by giving a direct explanation of the exponent rules, followed by routine practice exercises. Teachers reported that students often end up memorizing exponent formulas and their properties but do not really grasp the underlying concepts. Because of that, when students have to use exponent rules in real problem-solving, they struggle a lot. Similar results have also been reported in earlier studies, showing that students still face difficulties understanding exponent concepts and applying exponent properties during mathematical problem solving (Retnawati et al., 2017). All of these findings imply that current teaching methods have not yet effectively supported students' conceptual understanding of exponents. Scratch serves as an educational platform that provides users with free programming resources developed by the MIT Media Lab to create interactive educational content using multiple media elements (Pratiwi et al., 2025).

According to the Cognitive Theory of Multimedia Learning, students learn better when educational content is delivered through animated videos that combine text and visual elements with audio tracks because these materials make explanations more accessible to students who use basic educational resources (Mayer, 2024). The block-based programming interface of Scratch enables students to create programs by eliminating the need for programming syntax, allowing them to focus on mathematical logic rather than programming details (Guzdial, 2022; Iskrenovic-Momcilovic, 2020). The use of interactive digital resources has proven to be an effective solution for overcoming mathematics learning challenges, leading to better educational outcomes (Lutfi et al., 2021; Satria et al., 2023).

The educational environment fails to utilize interactive multimedia tools to their full potential because teachers do not use these resources to help students learn abstract mathematical concepts such as exponents. Thus, Scratch serves as a bridge between these two worlds; it must be investigated by providing students with interactive educational resources that help them understand mathematical concepts.

The Exponent Bites Math multimedia tool was created through Scratch to help students learn about exponents through interactive activities. The development of the media was aligned with the Learning Outcomes in the *Merdeka* Curriculum for Phase D, especially in the Number element. The students are expected to understand and apply integer exponents and roots, not just know the symbols. To operationalize these learning outcomes, the developed media was designed to help students recognize exponent notation, understand the properties of exponents, perform operations with exponents, and solve exponent-related problems. Accordingly, the Scratch-based media was designed to support students' conceptual understanding of exponent concepts through interactive learning activities, rather than relying too heavily on memorization. A gap exists in current research, as the use of Scratch-based interactive multimedia for teaching exponents remains unexplored. To address this, "Exponent Bites Math" was developed as a Scratch-based interactive multimedia tool. The primary objective is to support students who struggle with this topic by providing assistance builds their understanding of exponents through various methods, ultimately leading to higher academic performance.

Based on the identified problems and the need for learning media that support students' conceptual understanding of exponents, this study focuses on developing Scratch-based multimedia learning media. Accordingly, the research questions addressed in this study are: (1) How can Scratch-based multimedia learning media on exponent concepts be developed using the ADDIE model? (2) How valid is the developed media based on expert evaluations? (3) How do users evaluate the developed media in terms of usability and practicality? and (4) To what extent does the implementation of the developed media indicate improvements in students' understanding of exponent concepts?

METHOD

Research Design and Procedure

The research method employed in this study is Research and Development (R&D), specifically the ADDIE model, which encompasses analysis, design, development, implementation, and evaluation phases (Branch, 2009; Dick et al., 2015). 1) The Analysis phase consisted of obtaining a clear picture of students' needs and learning conditions, so that the problems which, in turn, would lead to the development of the interactive multimedia tool could be identified. The intention, however, was to ensure that the product could satisfactorily cope with the detected difficulties. 2) The Design phase was when a storyboard for the interactive learning media was made. Working on the design were five people: three students and two lecturers. The whole thing took place at a university in West Java and lasted for four months. 3) During the Development phase. The interactive learning media were developed using Scratch, adding captivating features. Also, validation tests were conducted by content and multimedia experts to ensure accountability and readiness for the product's implementation. 4) The Implementation phase is made up of the product trial, which starts with functionality testing through User Acceptance Testing (UAT) on the maths teaching students in a university in West Java. The implementation phase consisted of two stages. The first stage involved a small-scale trial through User Acceptance Testing (UAT), with pre-service mathematics teachers at a university in West Java. This stage was conducted as a formative evaluation to assess the technical functionality, usability, content accuracy, and pedagogical appropriateness of the developed media before its implementation with the target users. Pre-service mathematics teachers were chosen because their mathematical content knowledge, alongside their pedagogical knowledge, enabled them to spot potential issues, both technical and content-related. The way the instruction is set up might affect the quality of the media. The User Acceptance Testing results were collected through questionnaires to provide detailed feedback, and three participants were selected for thorough follow-up interviews. Afterward, the second stage focused on using the developed media with junior high school students as the target users. The product's effectiveness was tested on eighth-grade students at a junior high school in Jakarta. A pre-test was administered to assess students' prior knowledge before the media was used, and a post-test was administered afterward to assess their understanding. 5) The Evaluation phase concentrated on the product's functionality evaluation based on the User Acceptance Testing (UAT) results and the corresponding improvements to be made in order to achieve optimum performance.

Participants

The analysis involved two mathematics teachers from a junior high school in Jakarta. The interviews were conducted in 2025 using a semi-structured format. The study involved eighth-grade students from Jakarta. The participants consisted of 21 junior high school students. Purposive sampling was employed to select the participants. The class was chosen because the students had previously studied exponents, making them suitable participants for evaluating the developed Scratch-based learning media. All students in the class participated in implementing the developed Scratch-based learning media.

Instruments

The study employed both test and non-test instruments to collect the required data. The test instrument was used to measure students' conceptual understanding of exponent concepts. In contrast, the non-test instruments were used to identify learning needs during the analysis stage and to evaluate the quality, validity, and practicality of the developed Scratch-based learning media. The instruments consisted of a Semi-Structured Interview Guide, the Exponent Conceptual Understanding Test, the Media and Material Validation Questionnaire, and the User Acceptance Testing (UAT) Questionnaire.

1. Semi-structured interview guide

The semi-structured interview guide was used during the analysis stage to identify learning needs related to concepts of exponents. The interviews were conducted with two mathematics teachers from a junior high school in Jakarta in 2025. The interview protocol focused on students' difficulties in learning exponent concepts, commonly used teaching methods in exponent instruction, learning media currently used in the classroom, obstacles encountered during exponent learning, and the need for interactive learning media. The information obtained from the interviews was used to support the design and development of the learning media.

2. Exponent conceptual understanding test

Students' conceptual understanding of exponent concepts was measured using an Exponent Conceptual Understanding Test consisting of eight essay questions. The test was developed based on the conceptual understanding framework proposed by the National Council of Teachers of Mathematics (2000) and adapted to the learning objectives for Grade VIII students on exponent concepts. The indicators assessed in the test included: (1) explaining exponent concepts and providing examples, (2) applying the multiplication property of exponents, (3) applying the division property of exponents, (4) applying the power-of-a-power property, (5) applying the power of a product property, (6) applying the power of a quotient property, (7) solving problems involving zero exponents, and (8) solving problems involving negative exponents. An example item is: "Dita states that($2^3 \times 2^5 = 2^8$). Do you agree with her statement? Explain your reasoning". The test consisted of eight essay questions, with each question corresponding to one indicator. The content validity of the test was evaluated by two mathematics education experts using a four-point Likert scale and Aiken's V, yielding a coefficient of 0.96, indicating very high content validity. In addition, the Percentage of Agreement (PA) between the two validators was 99.84% according to Borich (1994), indicating a very high level of agreement regarding the instrument's suitability. Therefore, the instrument was considered appropriate for measuring students' conceptual understanding of exponent concepts.

3. Media and Material Validation Questionnaire

The media and material validation questionnaire was developed based on educational media evaluation principles, including content appropriateness, language clarity, multimedia design, and usability. The questionnaire consisted of 12 items and was evaluated by 2 experts using a 4-point Likert scale. The material validation indicators included alignment with learning outcomes, systematic organization, suitability for students' needs, clarity of the material presented, and the appropriateness of exercises, illustrations, and games. The media validation indicators included multimedia instructions, background design, animation quality, and ease of use. Example items include "The material is aligned with the learning outcomes" and "The multimedia is easy to use". The content validity analysis using Aiken's V yielded coefficients of 0.95 for material validation and 0.90 for media validation, indicating very high validity. Therefore, the developed media was considered appropriate for implementation.

4. User acceptance testing (UAT) questionnaire

The User Acceptance Testing (UAT) questionnaire was developed based on usability and user acceptance principles to evaluate the practicality of the developed media. The questionnaire consisted of seven closed-ended items and five open-ended items. There are five aspects: appearance, media operation, material content, language, and usefulness. The items assessed aspects such as image and text visibility, audio quality, ease of operation, content suitability, effectiveness of practice questions, language clarity, and visual attractiveness. The open-ended items elicited users' opinions on the overall design, interactivity, usefulness, language use, and the media's contribution to learning. An example item is: "The media was easy to operate". The overall practicality score obtained from the UAT was 82.9%, indicating that the developed media was highly practical and acceptable for mathematics learning.

Since this study focused on educational media development, instrument quality was established through expert judgment and content validity analysis using Aiken's V prior to implementation. All instruments were reviewed and revised based on experts' recommendations before being administered in the study.

Data Analysis

Data analysis techniques for test and non-test instruments were applied differently to align with the characteristics of the collected data. Prior to the analysis of learning improvement, a Shapiro–Wilk normality test was conducted to examine the distribution of the pretest and posttest scores. The test instrument was used to assess how much students understood exponents better after their learning process. The test results were evaluated through the N-Gain formula, which measures learning effectiveness by assessing how much students improved their conceptual understanding. The N-Gain formula (Hake, 1999) calculates the difference between the initial score (pre-test) and the final score (post-test), then normalizes it to the maximum possible score. The level of progress is determined to be low, medium, or high based on the N-Gain result. The analysis of non-test instruments included an assessment of questionnaires used in the material expert test, media expert test, and User Acceptance Test. The User Acceptance Test (UAT) consisted of seven closed-ended items and five open-ended items. Responses to the closed-ended items were measured using a four-point Likert scale ranging from 1 (strongly disagree) to 4 (strongly agree) and analyzed quantitatively to obtain the practicality score of the developed media. In contrast, responses to the open-ended items were analyzed qualitatively through thematic analysis to identify common patterns, suggestions, and users' perceptions of the media's appearance, usability, language, interactivity, and usefulness. The study achieved accurate and valid findings using multiple data sources, including User Acceptance Test results and semi-structured interview responses. The study first examined user responses to identify consistent patterns that showed how users interacted with the learning media. The interview data were used to deepen their understanding of user experiences, drawing on direct quotes from users. The advantages and disadvantages of the learning media were identified by analyzing data from multiple sources.

RESULT AND DISCUSSION

Analysis

The needs assessment conducted during the analysis stage identified the difficulties and needs that students encounter when learning about exponents. The analysis required an examination of Junior High School mathematics teachers in Jakarta through both observation and interview methods. The learning topic of "exponents" is an essential component of the Phase D curriculum. The mathematics teacher demonstrated two main methods for presenting the material. The teacher taught basic content through PowerPoint presentations he created using standard learning media. Despite these efforts, students can only pay attention to mathematics material after it has been taught. The study demonstrates that students require learning resources that will boost their interest and motivation while helping them understand mathematical concepts. The teachers had basic knowledge about multimedia options that could make learning more exciting through interactive educational games that let students learn at their own pace. The existing difficulties have shown that educational institutions need to develop interactive multimedia solutions to benefit their organizations.

The needs assessment conducted during the analysis step revealed several challenges students face in learning exponent concepts. From interviews with math teachers at a junior high school in Jakarta, instruction on exponents was mostly delivered through direct explanations of the rules of exponents, followed by routine practice exercises. One teacher said that "students often memorize exponent formulas and their properties but do not really understand the underlying concepts". The same teacher added that "when students are asked to apply exponent rules in real problem-solving situations, they frequently encounter difficulties." These results suggest that learners need learning resources that support conceptual understanding and encourage active involvement. As a result, the development of an interactive Scratch-based learning medium was deemed necessary to address these learning obstacles.

The learning media is designed to integrate exponent materials through an engaging, contextual approach. Its development focuses on several key indicators: (1) explaining the concept of exponent numbers, (2) finding the properties of exponents, and (3) solving contextual problems related to determining the value of exponent numbers. The learning media stages are structured progressively to strengthen students' conceptual understanding. The activities require students to match pairs of data, which helps them learn about exponential numbers through their respective properties.

The learning component of the media was built with a drag-and-drop mechanism that lets students interact with concepts of exponents in real time. In that activity, students have to match, sort, and recognize the correct exponent representations and properties. Instead of just taking information passively, students engage with the material and, through that guided back-and-forth, build their understanding. This approach aligns with the Cognitive Theory of Multimedia Learning (Mayer, 2021), which holds that meaningful learning occurs when learners actively select, organize, and connect information from verbal and visual sources. By combining text, pictures, animations, and drag-and-drop tasks, the media supports active mental processing and should help students gain a deeper grasp of concepts involving exponents. Through these interactions, students are pushed to uncover connections among properties of exponents and develop conceptual understanding rather than merely memorizing formulas.

In addition to the learning part, the media also has a separate game section with a shark-themed activity. The idea here is simple: it is not really about introducing brand-new concepts, but rather about reinforcing, testing, and checking the concepts that have already been learned. Students have to solve exponent-related tasks and get immediate feedback, which helps them solidify their understanding and correct misconceptions. The shark character serves as a gamification device, intended to boost motivation, sustain attention, and increase learner engagement as they work through the activities. Therefore, though the learning section aims at conceptual understanding through active knowledge building, the game section serves more as a reinforcement activity, encouraging practice, engagement, and improved retention of exponent concepts.

Design

The design team developed multimedia content through their research, which established fundamental concepts based on the game and its exponent component. The multimedia project was titled "Exponent Bites Math". A team of five people developed a storyboard outlining each scene and the game flow. The materials aligned with the basic competencies on exponents. The game Exponent Bites Math begins with an attractive visual display at a resolution of 1024x768 pixels. The title "Exponent Bites Math" is displayed with a dynamic animation that immediately captures the player's attention. After clicking the Start button, players are introduced to the main menu. The main menu displays several sections, including the profile menu, which contains the multimedia developer's identity; the indicator menu, which outlines the expected learning objectives; and the material menu, which includes interactive materials and a game. The game requires players to solve contextual questions by consuming small fish that contain correct answers. The topic of functions requires materials from textbooks and online sources, which were used to create visual design elements using Canva.

Audio elements play a significant role in enhancing the gaming experience. The background music creates a cheerful atmosphere that engages listeners. The materials provide audio instructions on how to perform tasks correctly. The game provides instructions on what players should do when the game begins. The game's educational content is delivered through audio, which keeps students engaged while building their understanding of exponents.

Development

The development team created game-based learning media using the Scratch application. The Scratch-based game development project for exponent research has reached this stage.

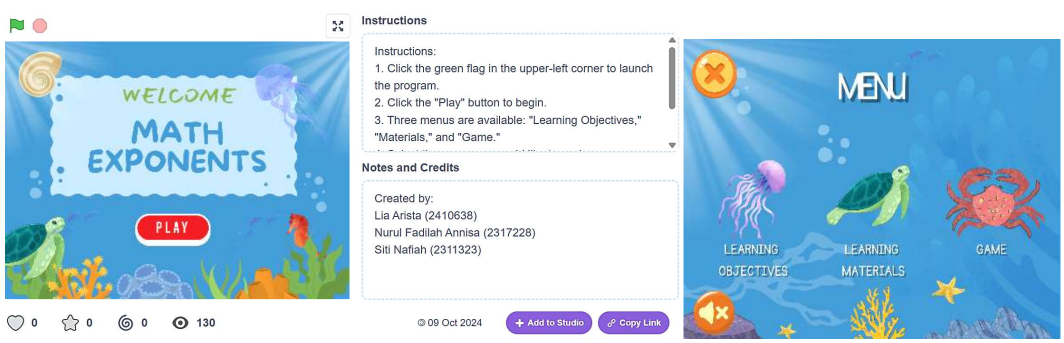

Figure 1. Initial display and menu

The video demonstration of the developed media can be accessed on YouTube at [https://youtu.be/asPU_cBfWHU], allowing users to review its features, learning activities, and functionality. The game's initial display appears in Figure 1. Users need to click the green flag button to start the game, which shows the game title and start button. The initial screen displays a main menu. The media creator presents a greeting and introduction to the audience through the initial screen, which activates when viewers press the play button. The menu screen displays a selection of indicator buttons, materials, and a game. Each screen provides users with sound effects for its functional buttons.

The learning indicator display and material menu show learning materials for both the learning indicator and the material display, as shown in

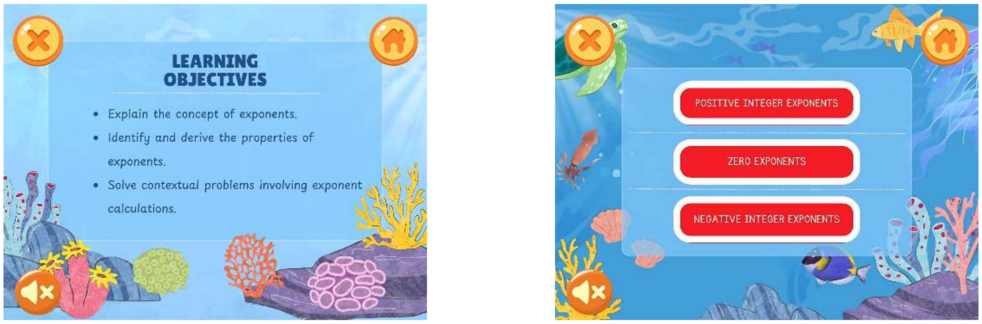

Figure 2. Indicator display and material menu

Figure 2. The material menu display contains buttons for positive, zero, and negative integer exponents, which perform their respective functions when clicked.

Figure 3 shows the five properties of positive integer exponents through an interactive drag-and-drop activity. In this task, students must examine expressions with exponents, identify

Figure 3. Display of positive integer powers

recurring ideas, and drag the correct answer choices into the labeled spaces. Instead of just getting the exponent rules, students discover how the pieces connect through the guided interaction. The activity still fosters conceptual understanding, since students build knowledge themselves and notice the patterns that arise when performing operations with exponents. To support the learning process, audio prompts guide students through what to do in each step and why the properties of exponents work as they do.

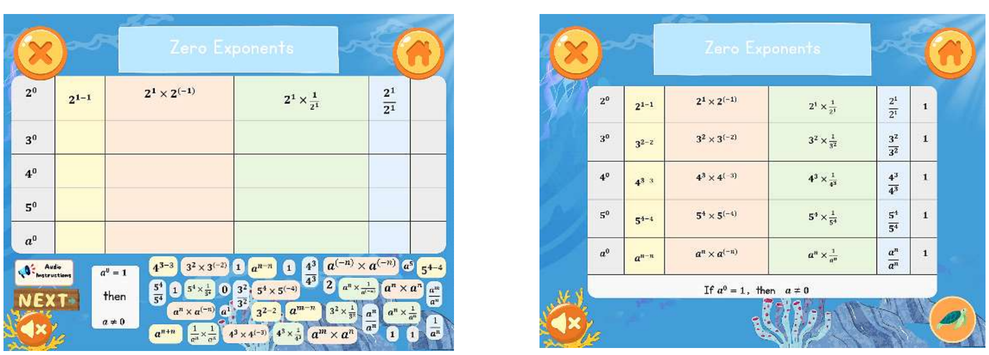

Figure 4. Display of integers to the power of zero

Figure 4 then shifts to the concept of zero exponents, illustrated in a structured table in which several expressions with exponents are left unfinished. Students need to fill in the missing entries by observing numerical patterns and comparing exponents. Through this activity, students are guided to examine how repeated exponentiation leads to the rule that any nonzero number raised to the power of zero equals 1. After students finish the table, the media displays the correct answers in the following scene. This feedback enabled students to compare their responses with the expected answers and reinforce their understanding of the zero exponent rule. Audio prompts are also present and support students throughout the process, not just at the end.

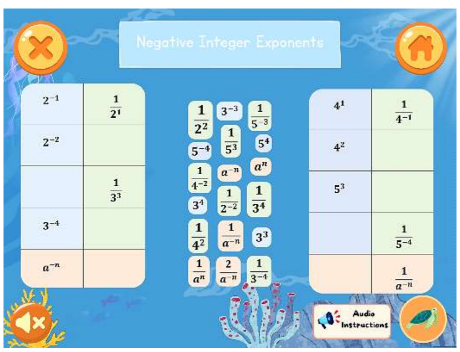

Figure 5. Display of integers to negative integer powers

Figure 5 shows negative integer exponents using this interactive table activity. Students fill in the blank entries by looking at how positive and negative exponents align, and they also match exponent expressions to their fractional forms. While doing so, students are prompted to notice patterns and understand that a negative exponent can be written as the reciprocal of a positive exponent. As with the earlier activities, there is audio guidance and quick feedback, so students stay on track and really build the concept rather than just guessing.

Figure 6 shows the game section of the media; it serves as a reinforcement activity after the learning section. The game starts with brief instructions that explain the gameplay steps and how scoring is handled. Once the start button is pressed, students are shown exponent-related questions and must pick the correct option from a set of fish. The shark then follows the cursor and "eats" the fish the student selects. When answers are correct or incorrect, different sound effects play, and scores and remaining lives are shown throughout the session.

Unlike the learning section, which aims to build conceptual understanding through guided discovery. This game section is designed to reinforce and check students' understanding of exponent concepts. To move ahead in the game, students must use the exponent properties that were learned earlier during the instructional part. With immediate feedback through sound effects, scores, and life indicators, students can track their progress and catch mistakes while they are still

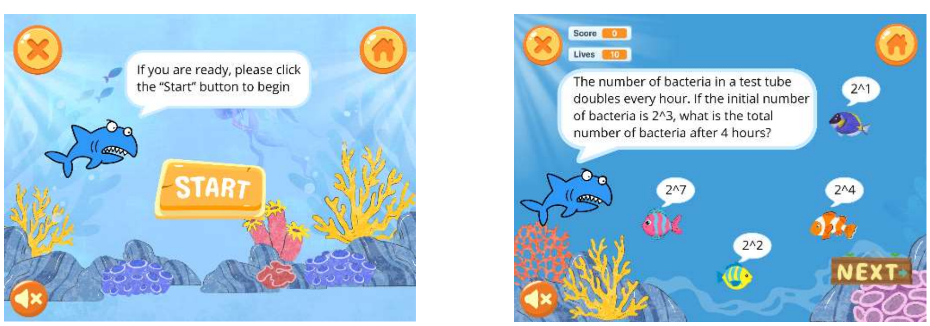

Figure 6. Game view

learning. This feedback structure supports self-assessment and strengthens understanding by prompting students to reflect on their answers and why.

The game design incorporates gamification elements, such as challenges, scoring, lives, and small rewards, to boost motivation, attention, and overall engagement. According to the Cognitive Theory of Multimedia Learning (Mayer, 2021), meaningful learning increases when learners actively process information and receive feedback on their performance. Therefore, the game works as more than just entertainment; it becomes an interactive learning activity that encourages concept application, practice, retention, and active cognitive engagement with exponent concepts.

After the media was developed, multiple tests were conducted, resulting in several editions before implementation testing began. Validity testing was executed to verify the accuracy and operational capacity of the multimedia. Both the media content and design elements were validated by two Mathematics Education lecturers from a university in Bandung, West Java. Following this assessment, the multimedia tool was approved as viable educational material, requiring only minimal revisions before further testing could proceed. Furthermore, functional tests were administered to undergraduate Mathematics Education students at a university in Bandung, West Java, followed by limited-effectiveness tests with junior high school students. The feasibility of the multimedia game was established through assessments conducted by subject-matter and instructional-media experts. Based on these findings, the developed multimedia meets the criteria for use in educational settings, both in terms of content and media quality.

Implementation

The development of the Scratch-based learning media was completed, and functionality and effectiveness testing were then conducted. Functional testing aimed to ensure that all application features operated according to predetermined specifications. This testing was conducted using User Acceptance Testing (UAT) to assess user responses to the learning media. A total of 17 Mathematics Education students at a university in West Java participated by completing open-ended and closed-ended questionnaire statements distributed via Google Forms.

The closed statements and open-ended questions were coded to facilitate response analysis. The closed statements included: the quality of the images and text on the media were clearly visible (Q1); the quality of the sound and background sound on this media was good and pleasant to listen to (Q2); the media was easy to operate (Q3); the material presented in the learning section of this media aligned with the concepts in the exponent material (Q4); the practice questions in the game section were able to measure student understanding (Q5); the use of language in this media was straightforward and easy to understand (Q6); the design of this media attracted students' interest in learning the material (Q7). Open-ended questions include: "What is your opinion of the overall design of this media display?" (Q8); Can this media be used interactively? Why? (Q9); Is this game able to build students' conceptual understanding of the material studied in this media? Give your opinion! (Q10); What is your opinion regarding the use of language in this media as a whole? (Q11); What is your opinion regarding the usefulness of this media for the parties involved, such as students, teachers, or other parties? (Q12). The results from the user acceptance testing are summarized in Table 1.

Based on the data in Table 1, prospective mathematics teachers had a very positive perception of the developed media's practicality and usability, with an average score of 82.9%. The results suggest that the media was viewed

Table 1. Results of the user acceptance

No	Indicators	Percentage	Category
1	Visual and Audio Design	79%	Very Good
2	Media Operations	61%	Good
3	Content and Conceptual Understanding Support	88.5%	Very Good
4	Language	94%	Very Good
5	Usefulness	92%	Very Good

favorably for its design, content, language, helpfulness, and operational aspects. The User Acceptance Test (UAT) was carried out with prospective mathematics teachers to get feedback on how practical, usable, and instructionally suitable the developed media feels, from the perspective of future educators. The thing is, prospective teachers are expected to contribute useful insights. Since they have both mathematical content knowledge and pedagogical understanding, they should be able to offer more or less constructive opinions to improve the media. The feedback from the UAT was then used to adjust the media before implementation. Overall, the results suggested that the developed media was well received, particularly for its practicality and usability, which is encouraging.

Participants' responses regarding various aspects of the game revealed both positive feedback and areas for improvement. Regarding question 8 on the game's appearance, P1 considered the design attractive despite some shortcomings, such as the bubble layer being located beneath the answer layer. P3 agreed that the design was attractive, although somewhat difficult to use because some answers were difficult to drag and drop. P8 also mentioned that the design was very attractive, but some of the number images were blurry.

The Media Operation aspect received the lowest score (61%) among the UAT indicators, though it was still categorized as good. Responses from participants indicated that the drag-and-drop feature felt harder to use on smaller screens. P3 mentioned the media design was attractive, but that certain answers were difficult to grab and position in the right place. Meanwhile, participants on larger screens or those with touchscreen devices seemed to have less trouble with the drag-and-drop activities. This finding suggests that the media operations worked were shaped not only by the interface design, but also by the device traits themselves. Therefore, future updates should aim to optimize the drag-and-drop part so the experience remains more usable across different screen sizes and device types.

In response to question 9, which discussed the media's operation, P1 stated that the media could be used interactively because it offered many options to explore. According to P3, this media was quite interactive because students were directly involved in working on the practice questions. P8 also mentioned that it was interactive because it provided communication through instructional features.

In response to question 10, which addressed the material's content, P1 stated that the instructions were sufficient for understanding the concepts. P3 stated that the material helped build understanding because the explanations were easy to follow. P8 added that the content helped build understanding because it was easy to follow and included examples and exercises.

Regarding the language used in question 11, P1 stated that it was easy to understand and did not readily lead to misunderstandings. P3 and P8 also stated the same thing: the language used in this medium was easy to understand.

Finally, in response to question 12, which assessed the usefulness of games in learning mathematics, P1 considered it very useful. Students were not burdened by potential boredom when learning mathematics, and teachers could also focus more on monitoring students' media use. P3 stated that this was useful because it helped teachers convey the material without having to explain at length. P8 also stated that it was very useful because it made it easier for teachers to explain exponent material and kept students from getting bored, as this medium included game-like quizzes.

The "Exponent Bites Math" learning media received very positive feedback from users, who rated all aspects with an average score of 82.9%, as shown in Table 1 and the interview results. Users assessed the media quality as "very good" through their ratings. The user acceptance testing produced functional test results demonstrating media effectiveness in the subsequent testing phase. Students' conceptual understanding was assessed using two assessments administered before and after students' use of the "Exponent Bites Math" multimedia content.

The pretest was administered to assess students' conceptual understanding of exponents before students used the developed media. After completing the learning activities and multimedia game, students were given a post-test to evaluate changes in their understanding. The average pre-test score was 49.55, while the average post-test score increased to 91.67. Prior to the N-Gain analysis, a Shapiro–Wilk normality test was conducted to assess the distribution of the pretest and posttest scores. The output indicated that the pretest scores were normally distributed ($p = 0.179$), whereas the posttest scores were not ($p = 0.013$). Consequently, rather than using a parametric approach, a Wilcoxon Signed-Rank Test was used to assess whether the improvement was real, not merely a coincidence. The results showed a significant difference between the pretest and posttest scores ($p < 0.001$), indicating that the change was not due to chance. Furthermore, the N-Gain analysis yielded a score of 0.84, which falls within the high category. These findings indicate an improvement in students' performance following the implementation of the developed media.

The graph in Figure 6 demonstrates that students achieved better learning outcomes

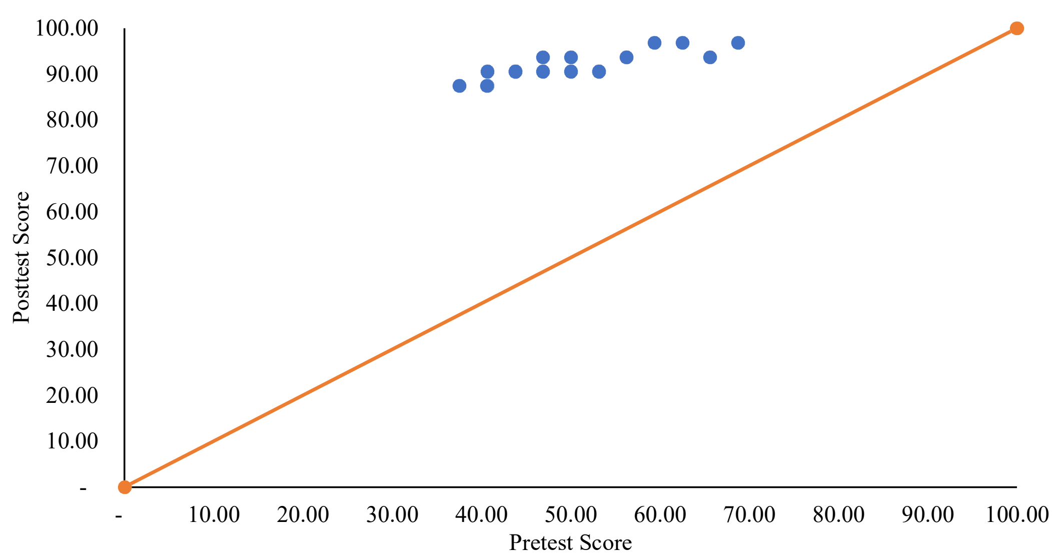

Figure 6. Graph of the increase in students' conceptual understanding

through multimedia learning methods, which enhanced their understanding of the material. The students achieved significant improvements in their conceptual understanding, as evidenced by an N-Gain score of 0.84, which falls in the "high" category.

To complement the quantitative findings, follow-up interviews were conducted with three students (S1, S3, and S5) after the implementation stage. The interviews explored students' perceptions of the developed media, especially its visual design, ease of use, and whether it really helped learning. Regarding the visual design, S1 said the media was visually appealing and helped maintain attention during learning. However, S1 noted that a few sections of the text and some visual elements could be enlarged. It would be easier to read on smaller screens, but without making everything feel crowded. On the other hand, S3 and S5 reported that the visual appearance was clear, engaging, and suitable for learning exponent concepts.

In terms of usability, all three students reported that the navigation was easy to follow and that they did not encounter major problems when switching between activities. They also said the instructions in each section were clear and, honestly, quite supportive. When it comes to learning support, S1, S3, and S5 agreed that interactive activities helped them grasp concepts of exponents better than conventional exercises. They really liked the examples and practice activities because those parts let them verify their understanding and reinforce the key ideas. Overall, the interview results suggest that the developed media was well received by students and supported their understanding of exponent concepts. However, some slight tweaks to improve visual readability might further enhance the user experience.

Evaluation

The assessment process tests all elements that determine how well learning media material was created. The process evaluates the effectiveness of multimedia learning tools in achieving their intended educational outcomes. The evaluation phase assesses the effectiveness of the developed learning media after its implementation with students. The evaluation focused on improving students' understanding of the material on exponents through pretest and posttest assessments. The implementation results show that students obtained an average pretest score of 49.55 and an average posttest score of 91.67. Prior to the N-Gain analysis, a Shapiro–Wilk normality test was conducted. The results showed that the pretest scores were normally distributed ($p = 0.179$), whereas the posttest scores were not ($p = 0.013$). The learning improvement was then analyzed using the N-Gain formula. N-Gain analysis showed that learning outcomes had improved. The N-Gain calculation results showed an average score of 0.84, which falls within the high range. The learning media benefited all students, as evidenced by their high N-Gain scores, indicating that their understanding improved relative to their starting knowledge level. The evaluation findings show that the learning media developed through this project were effective, as they led to improved student learning outcomes. The learning media proved suitable for teaching the material on exponents, yielding effective results during the learning process.

The improvement observed in students' conceptual understanding of exponents may be linked to how the developed media was designed and implemented. Unlike the usual approach, where the teacher mostly explains and uses presentation-type materials. This media was made so students would actually get involved, not just sit and listen, through drag-and-drop tasks, guided exploration, and immediate feedback. These parts seemed to push students to notice recurring patterns, see how exponent rules connect, and develop their own understanding, rather than just memorizing.

This finding is consistent with constructivist learning theory. That theory holds that learning becomes meaningful when students actively construct knowledge rather than merely receive information (Fosnot & Perry, 1996). Through interactive media activities, students had opportunities to explore ideas about exponents and to check their thinking by directly handling the learning objects (Bruner, 1961). Experiences like that may help them develop a more lasting conceptual grasp than passive reception.

Furthermore, it might be that the visuals plus the sound worked together to produce the results. The Cognitive Theory of Multimedia Learning suggests that learning improves when information shows up through both visual and verbal channels in a coordinated way (Mayer, 2021). In the developed media, images, audio directions, and interactive tasks were included to support students' mental processing and help them move toward better concept acquisition. So, the pairing of interactive learning activities with multimedia elements could be one reason for the positive outcomes in this study.

These findings are also supported by previous studies that claim interactive multimedia can enhance student engagement and support conceptual understanding, as it provides learners with opportunities for active participation and immediate feedback (Barnett-Itzhaki et al., 2023; Gaddi et al., 2024; Plodkaew et al., 2025). However, given the limited sample size and the absence of a control group, the findings should be interpreted as preliminary and exploratory. Further studies with larger sample sizes and more rigorous experimental designs are needed to provide stronger evidence of the developed media's effectiveness.

The substantial improvement in student comprehension, evidenced by the high N-Gain score, aligns with research indicating the significant impact of interactive, gamified learning platforms on academic achievement and conceptual retention in STEM subjects (Pratiwi et al., 2025; Weylin et al., 2023). Specifically, the observed N-Gain score of 0.84 indicates a substantial improvement in conceptual understanding, consistent with findings from similar studies that utilize interactive multimedia to enhance learning (Plodkaew et al., 2025; Wirjawan et al., 2020).

This aligns with broader trends in educational technology, where interactive multimedia has consistently demonstrated its capacity to elevate student engagement and facilitate deeper knowledge acquisition, as evidenced by similar successful implementations across various educational contexts (Barnett-Itzhaki et al., 2023). The effectiveness threshold, often set at an N-Gain score exceeding 0.3 for a medium category and 0.7 for a high category, further corroborates the significant impact of the developed media (Pratiwi et al., 2025; Hake, 1999). This high effectiveness is further corroborated by studies showing that N-gain values above 0.7 indicate a substantial increase in learning outcomes, helping avoid misinterpretations of student progress (Nurdiansyah et al., 2025). Such improvements highlight the potential of well-designed, game-based learning environments to significantly enhance computational thinking and overall learning outcomes in mathematics (McMullen et al., 2023).

The observed gains in understanding are consistent with research demonstrating that multimedia-based learning tools effectively enhance mathematical thinking and lead to significant improvements in learning outcomes (Uwineza et al., 2025). Furthermore, the application of game-based learning media has been shown to provide stimuli that activate students' engagement, thereby enhancing their mathematical reasoning and problem-solving capabilities (Hidayat et al., 2023; Hui & Mahmud, 2023). Moreover, the observed student enthusiasm and the perceived ease of use of the learning media align with prior research indicating that accessible and engaging media can significantly facilitate learning anytime, anywhere, thereby fostering enhanced student motivation (Kusuma et al., 2022).

CONCLUSION

The study results demonstrate that mathematics learning media for exponent material, developed using the Scratch application, completed the ADDIE framework but still needs improvement in certain areas. The ADDIE process analysis, design, development, implementation, and evaluation were executed effectively. The media received positive feedback from users, who rated it "very good" after scoring 82.9% in their evaluation of all tested features.

Furthermore, the conceptual understanding test instrument was reviewed and validated by a mathematics education expert to ensure its relevance, clarity, and alignment with the learning objectives. The validation results indicated that the instrument was highly valid and suitable for assessing students' conceptual understanding of exponent concepts. The results showed this kind of increase in students' scores from the pre-test to the post-test, with an average N-Gain score of 0.84, which falls within the high category. In other words, these findings indicate that the developed Scratch-based multimedia might help students' understanding of exponent concepts. However, the findings should be interpreted with caution due to several limitations of this study. First, the User Acceptance Test (UAT) involved prospective mathematics teachers rather than a broader sample of junior high school students, the media's primary target users. Consequently, the UAT findings mainly reflect the perspectives of future educators regarding the practicality and usability of the developed media. Second, the study employed a one-group pretest–posttest design without a control group and involved a relatively limited sample size. Therefore, the findings should be regarded as preliminary and exploratory rather than conclusive evidence of effectiveness. Future studies are encouraged to involve a larger number of target users and employ more rigorous experimental designs, including comparison groups, to provide stronger evidence regarding the effectiveness, usability, and acceptance of the developed media.

DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS

During the writing of this manuscript, the author(s) employed Grammarly to assist with language editing and proofreading. The author(s) have reviewed and edited the content generated by this tool and assume full responsibility for the content of the published article.

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