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Enhancing Mathematical Connection Ability through Scratch-Assisted Problem-Based Learning: A Mixed-Methods Study in Exponent Topics

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Abstract: This study aims to investigate the role of Scratch multimedia in enhancing junior high school students' mathematical connection skills related to the topic of exponents. This study employed a mixed-methods design, integrating quantitative and qualitative approaches, with 25 ninth-grade students as participants. Six students were purposively selected for in-depth interviews. Quantitative data were collected through pre-tests and post-tests and analyzed using paired-samples t-tests. In contrast, qualitative data were obtained from observation and interview results, and were analyzed thematically to identify the main themes during the learning process. Quantitatively, the study's results showed a significant increase in each indicator of mathematical connection skills. The indicator of connections between mathematical ideas (M post-test = 78.40, M pre-test = 45.20, $t(24) = 7.43$, $p = 0.002$) with an N-Gain value of 61% showed a fairly good increase. The connection indicator between mathematical representations (M post-test = 93.32, M pre-test = 58.40, $t(24) = 4.89$, $p < 0.001$) with an N-Gain value of 84% demonstrated a significant improvement. The connection indicator of mathematics with real-life problems (M post-test = 74.40, M pre-test = 24.20, $t(24) = 6.18$, $p < 0.001$) showed a significant improvement, with an N-Gain value of 61%, indicating a strong connection. Qualitatively, the study's results revealed three main themes: the use of Scratch multimedia in exponential learning enhances students' understanding of the material, creates a fun learning experience, and strengthens understanding through games. This study shows a positive impact of Scratch multimedia on improving students' mathematical connection abilities. Future research can utilize longitudinal studies to determine whether learning improvements are sustained in the long term.

Keywords: mathematical connection, mathematics learning, scratch multimedia.

▪ INTRODUCTION

Mathematical connection skills are an essential component of mathematics learning, as they meaningfully link mathematical concepts to real-life situations. According to the NCTM (2020), mathematical connection skills refer to students' ability to connect various mathematical concepts and relate them to real-life situations. Mathematical connection skills are a crucial aspect that makes learning easier and more meaningful because mathematics is a structured and interconnected science (Rahmi et al., 2020). Mathematics plays a crucial role in helping individuals and communities solve everyday problems and preparing students to face challenges through interactions with real-world contexts (Jawad, 2022). The ability to solve various mathematical problems, including real-world problems, is a key indicator of successful mathematics learning because it requires students to connect and apply mathematical concepts appropriate to the conditions they face (Putri & Wutsqa, 2019). Mathematical connection skills are a fundamental competency that students must possess because the strong interconnections between concepts in mathematics make this ability encompass and relate to other aspects of mathematics (Siregar & Siagian, 2019). Previous research shows that most students have poor mathematical connection skills (Khairunnisak et al., 2020). Therefore,

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strengthening the connection between mathematics and students' real-life experiences needs to be continuously pursued (Rafiepour & Faramarzpour, 2023).

Exponential learning is a crucial topic in mathematics, requiring logical and analytical thinking skills. However, it still faces various conceptual and pedagogical challenges that impact its understanding and application in real-world contexts. Furthermore, mathematics is closely related to science, as both require analytical and logical thinking skills, as demonstrated by research examining students' understanding of the concept of exponential numbers and their application in science (Faizah et al., 2024). One of the challenges in mathematics learning, particularly in exponential learning, is the lack of teacher training and the development of HOTS questions, which are still abstract and rarely linked to real-world contexts (Zaki et al., 2020). Students with low mathematical problem-solving skills in exponentiation have difficulty understanding the questions due to a lack of mastery of exponential concepts and properties (Juliana et al., 2024). Misconceptions about exponential learning stem from a lack of understanding of mathematical symbols, limited variety and practice, and a low willingness to ask questions or review lessons at home (Halim et al., 2021). Students' difficulties in relating the concept of exponents when solving problems can be the basis for designing appropriate exponential function learning and encourage teachers to use learning media that help students better understand the concept (Oktavihari & Priatna, 2023).

Contextual problem solving and mathematical connection skills are important focuses in mathematics learning, requiring conceptual mastery, real-life application, and the active role of teachers in effectively integrating them. Problem solving and mathematical connections are the primary goals of mathematics learning (Pambudi et al., 2020). Research over the past 50 years has shown that contextual problems have been the subject of extensive research (Verschaffel et al., 2020). Contextual problems are among the most challenging types of problems for mathematics learners (Haser et al., 2022). Therefore, it is essential to emphasize the ability to formulate problems from various mathematical contexts (Herman et al., 2022). However, although problem solving is a crucial component of mathematics learning, many students have not yet mastered the basic concepts and specific criteria needed to understand and solve problems in everyday life (Pratiwi & Widjajanti, 2020). Teachers still face difficulties integrating real-world contexts into mathematics learning at the junior high school level, underscoring the need for adequate understanding and training to help educators assist students in connecting mathematical concepts to everyday life and fostering student-centered learning (Montesdeoca, 2023). Furthermore, teacher professional development should emphasize aspects of implication, reversibility, and part-whole relationships in mathematical connection practices to enhance students' logical reasoning (Banjo & Luneta, 2025).

The integration of technology-based learning media is one way to build students' mathematical connections. Technology-based mathematics education is becoming increasingly important because it reflects a fundamental shift in the paradigm of mathematics learning (Das, 2021). The use of digital technology in mathematics learning is crucial for improving students' understanding, knowledge, and visualization, particularly through applications, games, simulations, and digital devices (Nurulaini Jaafar et al., 2022). Learning using technology can be a way to improve science and mathematics teaching while building confidence in STEM (Furner, 2024). The implications of technology utilization indicate significant changes in students' learning

habits (Septian, 2022). Interactive technologies such as Scratch can facilitate students' thinking in a free graphical programming environment and provide space for creative problem-solving (Calder, 2019). Scratch can also be used to develop students' mathematical ideas and computational thinking (Rodríguez-Martínez et al., 2020) and is a meaningful and applicable alternative in building experiential learning scenarios in the classroom (Mo et al., 2021).

Problem-Based Learning (PBL), which utilizes technologies such as Scratch multimedia, has been proven effective in helping students overcome difficulties in making mathematical connections. PBL is an approach that emphasizes active student engagement through real-world scenarios to develop critical thinking, collaboration, and problem-solving skills (Fang et al., 2023). The implementation of PBL has a more significant positive impact than conventional learning because students are faced with problems relevant to everyday life (Aisyah & Usdiyana, 2022). The PBL method encourages exploration and in-depth understanding of concepts through technology-assisted critical analysis (Liu & Mu, 2022). PBL activities enhance students' collaboration and problem-solving skills through active participation and effective cooperation during the learning process (Rehman et al., 2023). Furthermore, Realistic Problem-Based Learning (RPBL), as an innovative approach that connects mathematics to real-world contexts, makes learning more engaging and meaningful, and significantly improves students' ability to understand and apply mathematical concepts compared to traditional methods (Anugraheni et al., 2025). The mathematical problem-solving skills of students who participated in technology-based problem-solving learning were higher than those who participated in conventional problem-based learning (Amin et al., 2021). The implementation of PBL significantly influenced students' mathematical connection skills, with significant differences in the achievement of connection skills indicators between high-, medium-, and low-ability students across the three indicators of mathematical connection skills (Tohir et al., 2021).

The purpose of this study was to determine how Scratch multimedia can help junior high school students improve their mathematical connection skills on the topic of exponents. Based on this objective, the research questions were formulated as follows:

1. How does the use of Scratch in Problem-Based Learning (PBL) affect junior high school students' mathematical connection skills on the topic of exponents?
2. How do the quantitative results demonstrate the effect of Scratch use on improving junior high school students' mathematical connection skills on the topic of exponents?
3. How do the qualitative results describe the effect of Scratch assistance on junior high school students' mathematics learning on the topic of exponents?

▪ METHOD

Research Design

This study employed a mixed-methods approach with an Explanatory Sequential design, involving quantitative data collection to assess junior high school students' mathematical connection abilities in mathematics learning assisted by Scratch multimedia on the topic of exponents. This was followed by qualitative data collection through observation and interviews to explain the quantitative findings. The choice of this research design was made to evaluate significant changes in students' mathematical

connection abilities after the intervention, and is strengthened by findings related to the factors that influence these changes.

Participant

This research was conducted at a junior high school in Bandung, West Java. The subjects were 25 ninth-grade students participating in learning activities. Based on their learning outcomes and active participation during the learning process, six students from the high-scoring group were purposively selected through interviews to obtain in-depth information from previous findings. This selection was conducted to explore how students build the mathematical connections expected in learning.

Research Instruments

The instrument used to measure mathematical connection skills is a test that refers to the mathematical connection indicators as outlined by the NCTM (2000). The test instrument in this study consisted of three essay questions. The indicators used in this study are as follows: 1) Connections between mathematical ideas; 2) Connections between mathematical representations; 3) Connections between mathematics and real-life problems (Diana et al., 2020). The content, construct, and language validity of this instrument were assessed through expert judgment by two mathematics education lecturers. The instrument grid in this study is presented in the following table.

Table 1. Blueprint for mathematical connection test instrument

No	Mathematical Connection Indicator	Question Indicator	Question	Question No
1	Connection between mathematical ideas	Explaining the concept of exponents	Explain the general concept of exponents, including the meaning of zero exponents and negative exponents.	1
2	Connection among mathematical representations	Identifying the properties of exponents	Determine the result and properties of exponents based on the following operations: $(2^2)(2^3)$ $(3^2)^3$	2
3	Connection between mathematics and real-life problems	Solving contextual problems related to determining the value of exponents	A farmer owns a square plot of land with a side length of 8 meters. He wants to double the area of the land to make it 2^3 times the original area. What is the new area of the land?	3

This study utilized Scratch multimedia as a learning medium. Scratch multimedia is a platform for creating interactive simulations and learning media games. This platform was chosen because its features support creativity and conceptual understanding through a visual and interactive approach. The Scratch multimedia used in this study can be viewed at the following link: https://bit.ly/Multimedia_Scratch. The display of the Scratch multimedia used is shown in the following illustration.

Figure 1. Scratch multimedia interface

Research Steps

The research steps followed refer to general procedures in qualitative research (Fraenkel et al., 2012) to identify and analyze the phenomena that occur, namely: Phase 1: Instrument development and validation. In this phase, the essay test instrument and interview guide were developed based on the mathematical connection indicators proposed by NCTM (2000). Both instruments were validated by two mathematics education lecturers to review the content, construct, and language aspects. Revisions were made in response to the feedback provided. Phase 2: Pre-test implementation. Before the intervention, a pre-test was administered to 25 ninth-grade students to gather initial data on students' mathematical connection abilities related to the topic of exponents. Phase 3: Intervention implementation. Learning was carried out using the PBL model assisted by Scratch multimedia. In this phase, classroom observations were conducted to observe student learning behavior. Phase 4: Post-test implementation: A post-test was given to the same 25 ninth-grade students to identify changes in mathematical connection abilities. Phase 5: Qualitative data collection. Qualitative data were collected through classroom observations during the intervention and interviews with six students from the high-ability group to obtain more in-depth information. Phase 6: Data analysis. Quantitative data were analyzed using statistical tests to observe changes in students' mathematical connection skills, while qualitative data were analyzed through coding techniques to identify patterns and relationships between categories.

Data Analysis

The quantitative data in this study were analyzed using paired-samples t-tests on pre-test and post-test scores. Qualitative data were analyzed using inductive coding techniques, where themes emerged directly from the data without the use of predetermined categories. The coding process was conducted independently by three coders (the researcher and two mathematics education lecturers) to ensure inter-coder reliability. Analysis was conducted by systematically identifying data units, assigning initial codes, comparing and refining these codes, grouping codes into categories, and

synthesizing these categories into main themes that explain how students develop their mathematical connections (Oun & Bach, 2014).

▪ RESULT AND DISSCUSSION

Implementation of Learning with Scratch Multimedia

Mathematics learning on the topic of exponents using Scratch multimedia is designed using the Problem-Based Learning (PBL) model, integrated with Scratch multimedia, from problem orientation to evaluation. In the problem orientation stage, the teacher presents a contextual problem related to the development of information on social media. Then, students are asked to understand and examine the given problem. Then, in the organization stage, the teacher divides students into small groups (3-4 people per heterogeneous group) and distributes Student Worksheets containing instructions for exploring the properties of exponents in solving problems. Then, in the group investigation stage, students discuss in groups to find solutions to the given problems, while understanding the concept of exponents through joint exploration of Scratch multimedia. In the presentation stage, each group presents the results of the discussion in front of the class, other groups provide responses, and the teacher provides reinforcement and explanations of the concept of exponents. Finally, in the evaluation stage, the teacher provides practice questions in the form of games in Scratch multimedia to assess individual understanding of the concept of exponents. The following figure illustrates the student learning process that occurs actively and collaboratively using Scratch multimedia.

Figure 2. Student learning process

The results of this study indicate that mathematics learning on the topic of exponents, designed using the PBL model and assisted by Scratch multimedia, effectively strengthens students' mathematical connection abilities. The design of learning materials is arranged based on mathematical connection indicators, which include the relationships between mathematical concepts, the relationships between mathematical representations, and the relationships of mathematics to contextual problems. Problem solving is carried out through PBL syntax steps, starting from orientation to evaluation, where students actively explore the concept of exponents with the support of interactive materials and features in Scratch multimedia.

Quantitative Result

Based on the pre-test results, students' mastery of each indicator was in the moderate to low category. Indicator 1 had an average score of 45.2, indicating that most students did not fully understand the concept being measured. Indicator 2 achieved a slightly higher average score of 58.4, indicating a relatively better initial understanding of the exponent material. Meanwhile, Indicator 3 had the lowest average score, 24.4, indicating significant difficulty in understanding the concept before the learning intervention. After the learning activities, post-test results showed significant improvements in all indicators. The average score for Indicator 1 increased to 78.4, indicating good mastery by most students. Indicator 2 reached 93.3, reflecting very high mastery and optimal learning effectiveness. Meanwhile, Indicator 3 increased to 74.4, indicating a significant improvement in student understanding.

The N-Gain calculation was used to objectively assess the effectiveness of improving learning outcomes. The analysis results showed an N-Gain of 61% for Indicator 1, 84% for Indicator 2, and 66% for Indicator 3. Based on Hake's (1998) classification, the scores of 61% and 66% fall into the moderate category, while the score of 84% falls into the high category. This indicates an increase in students' mathematical connection skills after learning, with varying effectiveness for each indicator. The highest increase occurred in indicator 2, indicating that learning was highly effective in helping students understand related concepts. Indicators 1 and 3 showed good improvement, but still required further improvement to reach the high category. Overall, the average N-Gain score of 70.3% confirms that the learning implemented was effective in improving students' mathematical connection skills.

Furthermore, the results of the paired-samples t-test for indicator 1 showed a significant increase in students' mathematical connection abilities, as the post-test score ($M = 78.40$) was higher than the pre-test score ($M = 45.20$), $t(24) = 7.43$, $p = 0.002$. Thus, it can be stated that there is a statistically significant difference between the pre-test and post-test scores on indicator 1, indicating that mathematics learning, assisted by Scratch multimedia, improves students' mathematical connection abilities on the topic of exponents.

Furthermore, the results of the paired-samples t-test for indicator 2 showed a significant increase in students' mathematical connection abilities, with the post-test score ($M = 93.32$) being higher than the pre-test score ($M = 58.40$), $t(24) = 4.89$, $p < 0.001$. Thus, it can be stated that there is a statistically significant difference between the pre-test and post-test scores on indicator 2, indicating that mathematics learning, assisted by Scratch multimedia, has a positive influence on improving students' mathematical connection abilities.

Furthermore, the results of the paired-samples t-test for indicator 3 show a significant increase in students' mathematical connection abilities, as the post-test score ($M = 74.40$) is higher than the pre-test score ($M = 24.40$), $t(24) = 6.18$, $p < 0.001$. Thus, it can be stated that there is an average difference between the pre-test and post-test scores for indicator 3, indicating that mathematics learning, assisted by Scratch multimedia, improves students' mathematical connection abilities in the topic of exponents.

Overall, the results of the paired-samples t-test show a significant increase in students' mathematical connection abilities, as the post-test score ($M = 82.44$) is higher than the pre-test score ($M = 41.28$), $t(24) = 7.16$, $p < 0.001$. Thus, it can be stated that

there is a statistically significant difference between the pre-test and post-test scores, indicating a significant effect of mathematics learning on the topic of exponents when assisted by Scratch multimedia. The scatter plot, which maps the pre-test and post-test scores of each student, is presented in the following figure.

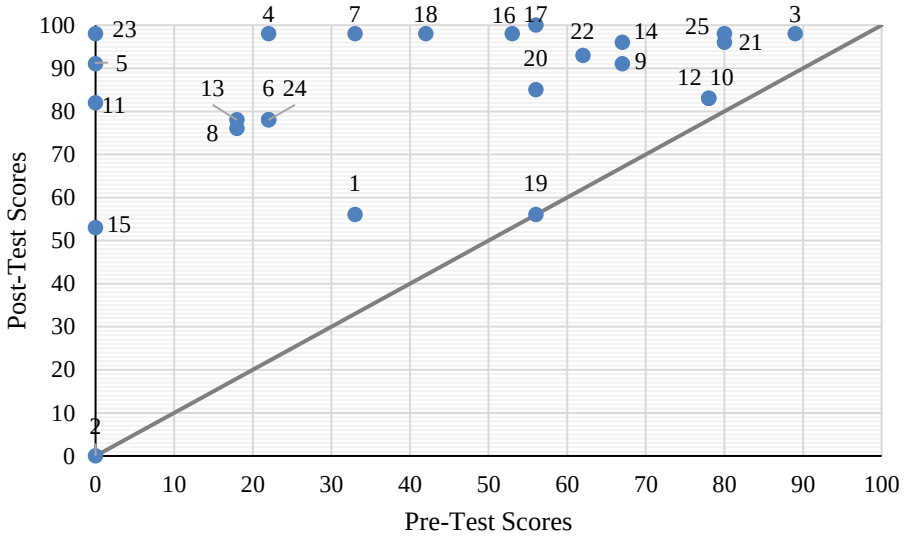

Figure 3. Distribution of pre-test and post-test scores for each student

The figure above shows a scatter plot comparing the pre-test and post-test scores of 25 students. Each dot represents a student, with the horizontal axis showing the pre-test score and the vertical axis showing the post-test score. The diagonal line depicts the point where the pre-test and post-test scores are equal. The graph shows that most of the dots lie above the diagonal line, indicating that the majority of students experienced an improvement in their scores after the learning process. Only two students (students 2 and 19) had scores on the line, indicating no significant improvement. Furthermore, several students with low pre-test scores achieved high post-test scores, indicating significant improvement in their abilities after the learning process. Overall, this graph indicates that the learning method implemented significantly improved the learning outcomes of most students.

The findings of this study are consistent with the results of several previous studies. Ammelia Sari et al.'s (2024) research showed that Scratch-based multimedia for teaching relations and functions was successfully developed using the ADDIE model. Positive feedback from users and a significant increase in student test scores demonstrated the effectiveness of this multimedia in improving conceptual understanding, although several aspects still required improvement (Ammelia Sari et al., 2024). Furthermore, Bernard and Setiawan's (2020) research also showed a positive effect of using Scratch-based media on mathematics learning outcomes. The average pre-test score of 70.74 increased to a post-test score of 82.69, with the results of the paired t-test indicating a significance level of 0.000 (<0.05). Additionally, the use of the Scratch programming language has been shown to improve students' ability to solve contextual mathematical problems by reducing indicators of learning difficulties (Bernard & Setiawan, 2020). Pratiwi et al.'s research (2025) also supports this finding, where the implementation of Scratch

Wabimendu MIL (Multimedia Interactive Learning) resulted in significant improvements in student learning outcomes (I. A. Pratiwi et al., 2025).

Qualitative Result

Throughout the learning process, students demonstrated positive learning experiences. Student 1 stated, "It was a pleasant experience. The lessons were fun and engaging," while Student 2 added, "Learning math this time was fun and enjoyable, and I was able to recall the formulas I had learned." Student 3 simply stated, "It was fun and exciting," and Student 5 emphasized, "It was fun and enjoyable because we could play while learning using the material we had learned." Student 6 highlighted the benefits of the activities in clarifying previously confusing concepts: "It was fun and I understood the problem better. I went from being confused and forgetful to understanding." While most emphasized enjoyment and engagement, Student 4 also acknowledged some difficulties, saying, "The fish game was fun, difficult, and frustrating." Based on these students' impressions, the use of Scratch multimedia in mathematics learning can provide a positive and enjoyable learning experience for most students. Game-based activities help students re-understand previously confusing concepts. However, some students still experienced technical difficulties with the game, indicating the need for improvements to ensure effective learning for all students.

Based on the results of interviews with students, three main themes emerged: the ease of understanding the exponent material, the enjoyable experience of using multimedia Scratch, and games as a learning reinforcement. A description of the three main themes found is presented in the following table.

Table 2. Student interview results

No.	Theme	Findings
1	Ease of Understanding Exponent Material	Learning using Scratch multimedia makes it easier for students to understand exponent material. Students 1 and 4 stated that Scratch multimedia helps them understand exponent material more easily. Student 6 also stated that before using Scratch multimedia, there was difficulty in understanding the concept of exponents. However, after using Scratch multimedia, there was an improvement in understanding the process of calculating exponents in a more interactive manner. Students 2 and 5 also experienced similar ease, as the concept of exponents became better understood after using Scratch multimedia. However, there were slight challenges, such as difficulty in following the given instructions.
2	Enjoyable Experience Using Scratch Multimedia	The multimedia features in Scratch provide an engaging and enjoyable learning experience for students. Student 1 stated that the Scratch multimedia game was very engaging and increased enjoyment during the learning process. Student 2 stated the same thing, although there were some challenges, such as the excessive number of fish in the game, which affected the difficulty level. Student 4 stated that Scratch multimedia made him more interested and involved in the learning process. Student 5 also stated that the game was

		fascinating and motivated him to work together and collaborate with friends in a study group.
3	Games as Learning Reinforcement	Scratch multimedia games serve as an effective medium for strengthening students' mathematical understanding of exponents. Students 1 and 4 stated that the games helped them recall the material they had been taught. Student 2 stated that the game provided a fun way to learn the concept of exponents. Student 5 emphasized the importance of the game in strengthening understanding of the material. In contrast, Student 6 stated that the game's answer-dragging feature was very helpful in understanding and clarifying the concept of exponents' properties.

Interview findings in this study indicate that learning mathematics with the aid of Scratch multimedia positively contributes to the development of students' mathematical connection skills on the topic of exponents. Based on the three themes identified, the use of Scratch multimedia in learning exponents improved students' understanding of the material, created a fun learning experience, and reinforced understanding through gameplay. Several students provided feedback for improvements, such as clearer presentation of the material and improvements in the technical aspects of the game.

The themes of the interview results in this study align with the findings of several previous studies. In the first theme, research by Ridho Adi Negoro et al. (2024) showed that the increase in ICT literacy and critical thinking skills of high school students who used Wave teaching materials assisted by Scratch was higher compared to students who used conventional teaching materials (Ridho Adi Negoro et al., 2024). Furthermore, research by Wati et al. (2025) showed that the development of Scratch-based learning multimedia was proven valid, practical, and effective in improving students' mathematical literacy skills (Wati et al., 2025).

Furthermore, the second theme in this research is also supported by several previous studies. Research by Noftiana et al. (2019) showed that the use of Scratch animation-based learning media increased students' interest in learning (Noftiana et al., 2019). Meanwhile, research by Voinohovska and Doncheva (2021) found that Scratch can be used as a tool to improve the teaching and learning process in various subjects, for both students with special needs and regular students. Furthermore, students involved in the study used their new skills to interact positively and solve problems interdisciplinary manner (Voinohovska & Doncheva, 2021).

Furthermore, the third theme in this research is reinforced by several previous studies. Research by Grandchamp des Raux et al. (2025) shows that the use of games in learning can improve cognitive processes and problem-solving abilities, especially if designed with appropriate feedback mechanisms (Grandchamp des Raux et al., 2025). Meanwhile, research by Dabbous et al. (2022) found that game-based learning (GBL) is associated with improved learning outcomes. Students demonstrate high motivation in this active learning style, and this motivation is a key factor in achieving learning outcomes (Dabbous et al., 2022).

▪ STUDY LIMITATIONS AND IMPLICATIONS

Based on the research results, there are several limitations: (1) The sample size of only 25 students limits the generalizability of the findings to a broader population; (2) There is the potential for the Hawthorne effect, which is the tendency for students to perform better because they are aware that they are being studied. To effectively integrate Scratch multimedia into mathematics learning, teachers are advised to implement the process gradually, aligning it with the phases of PBL, starting from problem-oriented instruction and progressing toward game-based evaluation. It is crucial for educators to leverage simulations and interactive games created in Scratch to help students understand abstract mathematical concepts and to encourage active group discussions among students. Furthermore, teachers must provide additional guidance and tailored support to students who are less familiar with the technology, ensuring that no learner is disadvantaged. On the other hand, there are critical pitfalls to avoid: teachers must not sacrifice core learning objectives for the sake of mere play activities, ensuring every game used remains highly relevant and strongly linked to the subject matter. Finally, the use of Scratch multimedia should always be accompanied by clear, explicit guidance, as implementing it without proper instruction can confuse students and ultimately reduce the overall learning effectiveness.

▪ CONCLUSION

Based on the data analysis obtained, the findings of this study can be summarized as follows: (1) Implementation of Learning with Scratch Multimedia: The results of this study indicate that mathematics learning on the topic of exponents, designed using the PBL model assisted by Scratch multimedia, effectively strengthens students' mathematical connection skills. The learning materials are designed based on mathematical connection indicators, which include the relationships between mathematical concepts, relationships between mathematical representations, and the relationship of mathematics to contextual problems. Problem solving is carried out through PBL syntax steps, from orientation to evaluation, where students actively explore the concept of exponents with the support of materials and interactive features in Scratch multimedia. (2) Quantitative Results: The results of the statistical test using the paired-samples t-test showed a significant increase in students' mathematical connection skills, where the post-test score ($M = 82.44$) was higher than the pre-test score ($M = 41.28$), $t(24) = 7.16$, $p < 0.001$, with an average N-Gain value of 70.3%. Thus, it can be concluded that there is a statistically significant difference between the pre-test and post-test learning outcomes, indicating that mathematics learning on the topic of exponents, assisted by Scratch multimedia, has an effect. This indicates that the applied learning is effective in improving students' mathematical connection skills. (3) Qualitative Results: The results of observations and interviews indicate that mathematics learning, facilitated by Scratch multimedia, makes a positive contribution to the development of students' mathematical connection skills on the topic of exponents. Overall, the use of Scratch multimedia in learning exponents enhances students' understanding of the material, creates a fun learning experience, and reinforces understanding through engaging games. (4) Unique Contributions and Future Research Directions: This study demonstrates the value of a mixed-methods design, which combines quantitative and qualitative data to provide a comprehensive understanding of the learning process. Future research could use

longitudinal studies to determine whether learning improvements persist over the long term.

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