Enhancing Student's Reasoning in Number Patterns through NumPuzzle Mathigon: A Study Based on Mathematical Disposition

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Article history: received 14-04-2025, revised 24-06-2025, accepted 26-06-2025

Abstract

Mathematical reasoning abilities are essential in math learning to help students analyze patterns, understand concepts, and solve problems logically. The importance of mathematical reasoning ability is not in line with the reality at SMA Negeri 2 Surakarta, which shows that mathematical reasoning abilities are still relatively low. To overcome this problem, the researcher applied NumPuzzle Mathigon to build students' reasoning on number patterns. This study aims to examine the impact of NumPuzzle Mathigon on mathematical reasoning ability from the level of mathematical disposition. This study is a quasi-experimental research with a population of all grade 10 students at the school. The sample was selected using a cluster random sampling technique. The data collection technique is to gather questionnaires to obtain data on mathematical disposition and use tests to obtain data on mathematical reasoning ability. Data were analyzed using a two-way analysis of variance (ANOVA) for unequal cells ($\alpha = 5\%$). The results showed that classes that used NumPuzzle Mathigon produced better mathematical reasoning ability than classes that did not use NumPuzzle Mathigon. In addition, students with high and medium math dispositions show the same and better mathematical reasoning abilities than students with low math dispositions. The results also showed an interaction between NumPuzzle Mathigon and mathematical disposition, indicating that its effectiveness varies across different levels of student disposition. This finding contributes to mathematics education by highlighting the importance of aligning learning media with students' mathematical disposition to improve reasoning skills.

Keywords

NumPuzzle Mathigon, mathematical reasoning skill, mathematical disposition

Introduction

Mathematics is a science that helps individuals understand and solve problems across various fields, including real-life situations (Mytra et al., 2023). Among the essential mathematical abilities that students must acquire is mathematical reasoning, which plays a

vital role in equipping students to face real-world challenges (NCTM, 2000). Mathematical reasoning refers to the ability to construct arguments, justify answers with evidence, and reflect on the problem-solving process, including selecting appropriate strategies (OECD, 2023). According to Tum (2024), mathematical reasoning ability are crucial for students because they enable them to analyze, generalize, and think logically when solving mathematical problems. This ability is essential not only for academic achievement but also for making logical and informed decisions in daily life (Drupadi & Mumu, 2018).

Despite its importance, many students still struggle with mathematics due to its abstract nature and the abundance of complex formulas. As noted by Acharya (2017), "Students were feeling mathematics has an abstract subject and has several formulas. Many students are not ready to learn this formula causing student's fear in learning mathematic." These challenges indicate the need for effective strategies to make mathematics more accessible and meaningful for students.

At the global level, students mathematical reasoning abilities are a concern, as reflected in Programme for International Student Assessment (PISA). According the PISA 2022, Indonesia scored 345 on the reasoning subscale, significantly below the average PISA score. Alarmingly, almost no Indonesian students achieved levels 5 and 6, where students use strategic thinking with broad reasoning ability. Similarly, Nababan (2020) founf that 73.66% of Indonesian students exhibit very low mathematical reasoning ability based on indicator-based assessments.

This issue is also evident at the school level, including in SMA Negeri 2 Surakarta, where many students experience difficulties in mathematical reasoning tasks. Classroom observation revealed that teachers rarely use worksheets and learning media, so they do not support students in finding concepts independently. Consequently, students often have difficulties when facing problems that require reasoning. To overcome these problems, a learning approach is needed that can help students develop mathematical reasoning ability.

One proposed solution is the use of game-based learning, such as NumPuzzle Mathigon. This game leverages the Polypad feature in Mathigon to engage students in completing number pattern puzzles, providing a playful yet meaningful learning experience. The choice of number patterns is strategic, as they lay the foundation for algebraic thinking and reasoning by training students to identify, analyze, and generalize pattern. Research supports the benefits of such interactive media, with Richardo & Kholifah (2023) showing

increased student interest and reasoning ability, and Siregar, Harahap, & Simbolon (2024) demonstrating the effectiveness of game-based learning in enhancing mathematical reasoning. Moreover, NumPuzzle Mathigon stands out for its combination of visual, interactive, and problem-solving elements that help students grasp abstract mathematical concepts through concrete representations (Widodo & Wahyudin, 2018).

In addition to external factors, internal factors also influence mathematical reasoning ability. One of the factors that affect students' mathematical reasoning ability is the mathematical disposition of students (Lestari, Zamzaili, & Haji et al., 2022). Mathematical disposition is an affective ability or tendency of a person to view mathematics as something that can cultivate good, such as confidence, high interest in learning, persistence, earnestness in solving problems, flexible thinking, and reflection after learning mathematics (Fairus, Fauzi, & Sitompul, 2023). Based on the results of class observation at SMA Negeri 2 Surakarta, the mathematical disposition of each student varies. The diversity in students' mathematical dispositions should be a key consideration in mathematics learning at school.

Given the persistent challenges in developing students' reasoning skills and the significant variation in mathematical dispositions, it is essential to explore learning interventions that can simultaneously address both aspects. Therefore, this study aims to examine the impact of NumPuzzle Mathigon on students' mathematical reasoning ability, considering their varying levels of mathematical disposition.

Mathematical Reasoning Ability

Reasoning is a logical thinking process that begins with sensory observation so that it produces a concept and idea to be generalized and finally reaches a conclusion (Citra, Ambarwati, & Sampoerno, 2021). Mathematical reasoning ability can be defined as a student's ability to think and solve problems by detecting regularities, formulating generalizations from conjectures and evaluating them, and building and evaluating arguments to reach logical conclusions. Students with good reasoning ability tend to be more capable of analyzing and understanding patterns, ideas, or concepts in problem-solving (Wau, Harefa, & Sarumaha, 2022).

NCTM (2000) stated that there are four indicators of mathematical reasoning ability for secondary schools, namely analyzing patterns and structures to detect regularity, formulating generalizations from conjectures about observed regularity, evaluating

conjectures, and constructing and evaluating mathematical arguments. In this study, the mathematical reasoning ability indicators used are based on the opinion of the NCTM.

Mathematical Disposition

Mathematical disposition can be interpreted as a person's tendency to view mathematics positively, which involves confidence, perseverance, flexibility, interest, reflection, assessment of mathematical applications, and appreciation of the role of mathematics. Mathematical disposition is one of the essential aspects of mathematics learning. By having a positive attitude toward mathematics, students can increase their motivation to solve a mathematical problem (Mayratih, Leton, & Uskono, 2022). Mathematical disposition encompasses a willingness to take risks, perseverance in solving problems, responsibility to reflect on work, appreciation of the power of mathematical language, a desire to find solutions and propose new mathematical ideas, and includes belief in one's ability to see problems as challenges (Putra, Budiyono & Slamet, 2017).

In this study, the indicators of mathematical disposition are based on the opinions of Fairus, Fauzi, & Sitompul (2023), who identify seven indicators of mathematical disposition: confidence, curiosity, perseverance, flexibility, reflectiveness, application, and appreciation.

NumPuzzle Mathigon

Mathigon is a mathematics learning application first developed by Philipp Legner. Better known as a mathematics playground, Mathigon is a tool or course that can be easily manipulated and accessed for free for digital mathematics learning (Hidayat, 2022). In addition, Mathigon also helps students visualize the mathematical concepts they learn (Muharram et al., 2023). This Mathigon allows students to explore, discover, be creative, solve problems, and think critically. Mathigon, as an innovative learning provides several features, one of which is Polypad. Polypad contains interactive math tools that allow users to create, manipulate, and visualize various mathematical concepts. NumPuzzle is designed to train students' ability to recognize and compose number patterns. In this game, students are given a series of numbers that form a number pattern with several empty squares in it. The student's task is to fill the blank box with the appropriate number so that the number pattern still meets specific rules. The NumPuzzle game can be viewed at bit.ly/PolypadNumPuzzle.

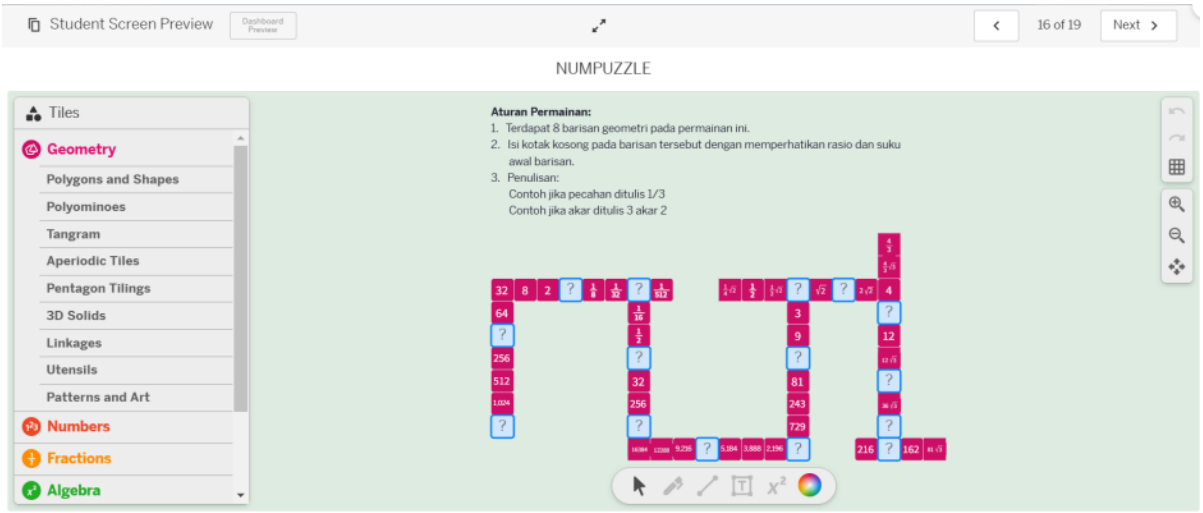

Figure 1. NumPuzzle Mathigon

Using Mathigon's Polypad feature, NumPuzzle allows students to interact directly with numbers visually, manipulate numbers, and try out various possible answers until they find the correct pattern. This approach not only enhances students' understanding of number patterns but also makes learning more engaging and exploratory.

Methodology

The research method used in this study was a quasi-experimental design with a 2×3 factorial structure. This design aimed to examine the effects of learning media and mathematical disposition on students' mathematical reasoning ability. The two independent variables consisted of learning media and mathematical disposition, while the dependent variable was mathematical reasoning ability. Learning media in this study referred to two approaches: NumPuzzle Mathigon and PowerPoint. NumPuzzle Mathigon is an interactive, game-based learning tool that utilizes the Polypad feature to engage students in completing number pattern puzzles designed to enhance reasoning skills. In contrast, PowerPoint served as conventional presentation-based media used in the control class. Mathematical disposition was defined as students' tendencies, attitudes, and habits when learning mathematics, including their confidence, interest, perseverance, and reflective thinking. In this study, mathematical disposition was categorized into three levels: high, medium, and low.

The population of this study consisted of all Grade X students of SMA Negeri 2 Surakarta in the academic year 2023/2024. The sample was selected using a cluster random sampling technique, where intact classes were considered as clusters. All available Grade X classes were listed, and two classes were randomly selected through a lottery process. As a result, class X-E4 was assigned as the experimental group, which received learning with NumPuzzle Mathigon, while class X-E2 served as the control group, receiving learning through PowerPoint. Each class consisted of 32 students.

Students' mathematical disposition was measured using a validated questionnaire. The categorization of disposition followed the guidelines from Budiyono (2015) by applying score conversion rules with ideal standard deviation calculations. Students were grouped as follows: high disposition if their score exceeded the mean plus one ideal standard deviation, medium disposition if their score fell within one ideal standard deviation above or below the mean, and low disposition if their score was below the mean minus one ideal standard deviation. This standardized categorization ensured objectivity and replicability.

Two instruments were utilized in this research: the mathematical disposition questionnaire and a mathematical reasoning ability test. The reasoning test was designed to measure students' ability to construct logical arguments, identify patterns, justify answers, and make generalizations. Both instruments underwent validation and reliability testing prior to use. Content validity was assessed by three experts in mathematics education to ensure alignment with learning objectives and mathematical reasoning indicators. Empirical validity was tested using Pearson's product-moment correlation, retaining only items with correlation values exceeding the critical threshold. Reliability testing was conducted using Cronbach's Alpha, with a coefficient value above 0.7 considered acceptable, indicating sufficient internal consistency of the instruments.

The research was implemented over four meetings for both experimental and control groups, with equal instructional time to ensure fairness. Both groups were taught by the same mathematics teacher to control for teacher-related influences on learning outcomes. The data collection procedure began with administering the mathematical disposition questionnaire to all students. Based on the results, students were categorized into high, medium, and low disposition groups. Following the categorization, learning interventions were conducted in each group according to the assigned learning media. After the learning process, a post-test was administered to assess students' mathematical reasoning ability.

Data analysis was conducted using two-way ANOVA for unequal cells to examine the main effects of learning media and mathematical disposition, as well as their interaction effect on mathematical reasoning ability. Prior to conducting ANOVA, assumptions of normality and homogeneity of variances were tested using the Shapiro Wilk test and Levene's test, respectively. All statistical analyses were performed using SPSS version 26, with a significance level set at $p < 0.05$. If significant effects were found, a post-hoc test using Tukey's HSD was conducted to further explore specific group differences. This research also adhered to ethical principles, with approval obtained from the relevant institutional ethics committee, and informed consent secured from all participating students and their parents.

Result

Learning activities with NumPuzzle Mathigon were conducted in the experimental class over a single session with a total duration of 2 x 45 minutes. During the learning activity, the teacher introduced the concept of number patterns, which served as foundational material for the reasoning tasks. Next, students in each group consisting of 6-7 students collaborate on worksheets that guide them to discover independently the concept of number patterns.

After understanding the concept, students engaged with the NumPuzzle Mathigon activity as a form of concept application. In this interactive activity, students analyzed number patterns both horizontally and diagonally, identified regularities, formulated conjectures about the numbers in the empty boxes, and evaluated the validity of their conjectures. These processes align with the core indicators of mathematical reasoning, which include making logical generalizations, providing justifications, identifying patterns, and evaluating conclusions.

Following the implementation of the intervention, this section presents the results of the study regarding the influence of NumPuzzle Mathigon and students' mathematical disposition on reasoning ability. The data from this study is in the form of quantitative data obtained from the mathematical reasoning ability test instrument and the mathematical disposition questionnaire instrument of students in the experimental and control classes. Based on the calculation of the ANOVA test of two unequal cell pathways, the results were obtained as presented in Table 1.

Table 1. Result of Two-way Analysis of Variance (ANOVA) for Unequal Cells

Source	F_{obs}	F_{α}	Test Result	Conclusion
Learning Media (A)	10.127	4.007	H_{0A} rejected	There is an influence
Mathematical Disposition (B)	63.5592	3.156	H_{0B} rejected	There is an influence
Interaction (AB)	3.6642	3.156	H_{0AB} rejected	There is an influence

Note.
F_{obs} = Observed F-value
F_{α} = Critical F-value

The test results showed that there was a significant difference in mathematical reasoning ability between students in the experimental class and the control class ($F_{obs} = 10.127 > F_{\alpha} = 4.007; p < 0.05$), suggesting that students who learned with NumPuzzle Mathigon outperformed those in the control group. These findings support the opinion of Maisarah & Prasetya (2023), who argue that learning media affects students' reasoning ability.

The test results also showed a significant influence of mathematical disposition on students' reasoning ability ($F_{obs} = 63.5592 > F_{\alpha} = 3.156; p < 0.05$), consistent with the findings of Fauzan et al. (2022), which highlighted the positive impact of mathematical disposition on reasoning ability.

Importantly, a significant interaction effect was observed between learning media and mathematical disposition ($F_{obs} = 3.6642 > F_{\alpha} = 3.156; p < 0.05$). This indicates that the effectiveness of NumPuzzle Mathigon in improving reasoning ability is influenced by students' levels of mathematical disposition.

Discussion and Conclusion

Discussion

Learning Media

The ANOVA test shows that the learning media affects students' mathematical reasoning ability. By analyzing the marginal average of each class, it was found that students who used NumPuzzle Mathigon as a learning medium achieved higher mathematical reasoning scores than those who used PowerPoint. The interactivity of NumPuzzle Mathigon enables students to actively engage in discovering number patterns and testing their conjectures, thereby enhancing their mathematical reasoning ability. This result is in line with the results of research by Khaerani, Ismail, & Oroh (2022), who concluded that interactive multimedia is more effective than PowerPoint in improving students' mathematical reasoning ability. Rahmadi et al. (2015) also noted that learning media supporting the visualization of

mathematical concepts can enhance students' reasoning abilities. The effectiveness of NumPuzzle Mathigon can be explained through the lens of constructivist learning theory, where students actively construct knowledge through hands-on exploration and pattern recognition. Its interactive and game-based nature increases student engagement and provides scaffolding that supports logical reasoning development.

The manipulative features in NumPuzzle Mathigon allow students to explore concepts dynamically, making it easier for them to understand the regularity of patterns and make generalizations. Nursyahidah & Saputra (2015) argue that media exploration helps students experiment, observe, reason, and generate mathematical ideas.

In contrast, PowerPoint media in the control class primarily serves as a tool for creating presentations and displaying content attractively (Haliza, 2022). However, it offers limited opportunities for dynamic exploration, which impedes the development of students' mathematical reasoning ability, leading to less optimal outcomes in this area.

Mathematical Dispositions Factor

The ANOVA test shows that the level of mathematical disposition affects students' mathematical reasoning ability. Furthermore, an ANOVA test was carried out to see the difference in each level of mathematical disposition. The results of the Post ANOVA test showed significant differences between each level. By analyzing the marginal average of each level, it was obtained that students with high mathematical dispositions had better mathematical reasoning ability than students with medium dispositions. Meanwhile, students with low dispositions have the worst mathematical reasoning ability.

In the learning process, students with high mathematical dispositions tend to be persistent, diligent, and interested in exploring new things (Trisnowali, 2015). On the other hand, students with moderate dispositions sometimes still feel less confident and afraid of making mistakes (Maisaroh, 2019). This condition can hinder deep thinking, preventing the fulfillment of all indicators of mathematical reasoning ability. Meanwhile, students with low mathematical dispositions often face significant limitations, such as a lack of perseverance and easy discouragement when working on problems, leading to an inability to solve problems (Rozi & Afriansyah, 2022).

Learning Media Factor and Mathematical Dispositions Categories

The ANOVA test reveals the interaction between learning media and mathematical disposition on mathematical reasoning ability. Given this interaction, a post-ANOVA test (Tukey HSD) was conducted. The test results are presented as a profile effect of mathematical disposition and learning media, as shown in Figure 2.

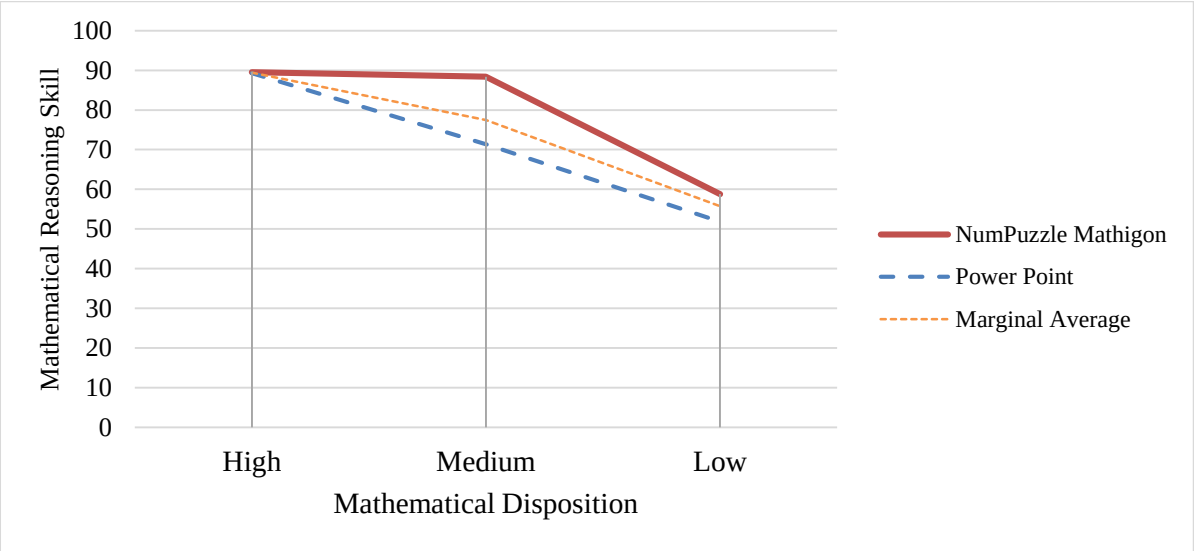

Figure 2. Effect Profile of Mathematical Disposis and Learning Media

Figure 2 illustrates the interaction effect between learning media and levels of mathematical disposition on students' mathematical reasoning ability. In students with high dispositions, using NumPuzzle Mathigon and PowerPoint has nearly the same impact on improving mathematical reasoning ability. This happens because their positive attitude towards mathematics allows them to reason well. This is supported by the results of research by Halawati, Sujata, & Hidayati (2024), which states that students with high interest, confidence, and strong reflection ability tend to have better mathematical abilities.

For students with a medium disposition, the results also showed no significant difference between NumPuzzle Mathigon and PowerPoint in improving mathematical reasoning. Both media have a similar effect. This is thought to be because students with medium mathematical dispositions can understand the material and follow the teacher's directions but are not as encouraged to explore it in depth. Damayanti, Anggraeni, and Tsany (2024) show that students with moderate dispositions still do not have a flexible attitude in learning mathematics. As a result, the use of interactive media features does not affect improving students' reasoning ability.

In the low disposition category, the results showed no significant difference between the two media in improving mathematical reasoning. This is due to the difficulties faced by students with low disposition in understanding the material, whether presented through NumPuzzle Mathigon or PowerPoint, which affects their reasoning and problem-solving. These findings align with Putri et al. (2024), who stated that students with low dispositions often have difficulty understanding problems and can only overcome them with limited analysis.

Conclusion

This study shows that the use of NumPuzzle Mathigon in mathematics learning is more effective in enhancing students' mathematical reasoning ability than conventional media such as PowerPoint, particularly among students with high mathematical dispositions. Although the interaction between learning media and disposition was not statistically significant across all levels, NumPuzzle Mathigon still showed a consistently positive impact. These findings imply that exploration-based and interactive learning media can support students' reasoning development, especially when aligned with their affective traits. However, this study was limited by the sample size and duration of the intervention, which may affect the generalizability of the results. Future research should consider involving larger and more diverse student populations, extending the duration of the intervention, and exploring other moderating variables that influence the effectiveness of interactive media in mathematics education.

Declarations

Competing Interests

The authors declare that they have no competing interests.

Data Availability

The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

Acknowledgement

The author expresses sincere gratitude to God Almighty for His grace and guidance, which made it possible to complete this paper successfully. The author would like to thank the supervisors who have provided direction and support during the research process. The author also expresses heartfelt thanks to all individuals who have assisted, directly or indirectly. Hopefully, this research can contribute to the development of science.

Authors

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