

## The Impact of Using Interactive Digital Media on Students' Mathematical Reasoning Abilities in Derivative Material

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### Abstract

*Mathematical reasoning is a vital competency to cultivate in 21st-century mathematics education. Nonetheless, preliminary findings reveal that students' reasoning abilities remain at a moderate level, particularly weak in mathematical manipulation. This study investigates the effect of interactive digital media on enhancing students' mathematical reasoning and identifies the most significantly affected indicators. Employing a pre test–post test design, the research involved six sixth-semester students from the Mathematics Education Program at Universitas Muhammadiyah Parepare. The instrument was an open-ended test assessing three reasoning indicators: proposing conjectures, expressing mathematical statements, and performing manipulations. Descriptive analysis showed that the mean score rose from 58.33 (moderate) to 80.09 (high), with a normalized gain of 0.52 (medium). The reduction in standard deviation from 7.86 to 5.67 indicates greater consistency in performance after the intervention. Among the indicators, the highest improvement was observed in proposing conjectures (27.78 points), followed by expressing mathematical statements (23.61 points), while mathematical manipulation showed the least gain (13.89 points). These results suggest that interactive digital media effectively enhances higher-order reasoning skills involving visual and conceptual representations, whereas procedural fluency still benefits from manual practice. Thus, balanced integration of digital and conventional strategies is essential for developing comprehensive mathematical reasoning.*

**Keywords:** *mathematical reasoning; interactive digital media; proposing conjectures; mathematical statements; mathematical manipulation.*

### 1. Introduction

Mathematical reasoning is one of the basic competencies in mathematics, along with understanding, communication, and problem solving. Mathematical reasoning is a fact-based thinking process that plays a vital role in helping students understand mathematical concepts and solve various problems in their personal, social, and educational lives. (Dollo, 2018) . Mathematical reasoning not only serves as a tool for solving problems, but also as a basis for developing critical and analytical thinking required in various disciplines (Mulyani & Siregar, 2025) . However, a number of studies reveal that the level of students' mathematical reasoning abilities is still relatively low, which is reflected in less than satisfactory learning achievements in basic materials such as the concept of derivatives (Haura Putri Fortuna et al., 2024) .

Derivatives are an essential part of learning calculus because they have numerous applications in various fields of science (Nie, 2024) (Mishra, 2024) . However, based on field observations, many students experience difficulty in understanding the basic concept of derivatives. This difficulty often impacts students' low ability to perform mathematical reasoning related to the concept. Several studies show that students tend to memorize derivative formulas without understanding the meaning behind the process, resulting in weak and underdeveloped reasoning.

Amidst these challenges, technological developments have opened up new opportunities in designing more innovative and meaningful learning (Melati et al., 2023) , one of which is through the use of interactive digital media (Annisa Gita Cahyani & Setyadi, 2023) . Learning media is one of the learning resources that can stimulate students' interest and enthusiasm for learning (Rofinus Badung & Asdar Dollo, 2024) . Interactive digital media allows students to explore concepts visually and dynamically, which has great potential in helping students understand mathematical concepts more deeply. With its manipulative and interactive features, it has the potential to improve their reasoning skills.

Although the use of interactive digital media has been widely studied in the context of understanding mathematical concepts or solving mathematical problems, there is little research specifically highlighting how this media can be used to develop mathematical reasoning skills, particularly in the context of derived materials at the tertiary level. In fact, with its characteristics that support visualization and concept exploration, interactive digital media is highly suitable for encouraging higher-order thinking processes such as reasoning (Siregar et al., 2024) .

Based on these conditions, the following problems are formulated: (1) How great is the mathematical reasoning ability of students in studying derivative material? and (2) Does the use of interactive digital media affect students' mathematical reasoning ability in derivative material? This research is important to be carried out as an effort to contribute to technology-based mathematics learning strategies that are not only oriented towards understanding concepts, but also towards strengthening students' logical and systematic thinking processes.

The urgency of this research lies not only in the academic need to improve students' mathematical reasoning skills but also in line with the Independent Learning-Independent Campus (MBKM) policy, which encourages innovation in learning methods. Through this research, it is hoped that practical solutions can be found that can be implemented in higher education settings to improve the quality of mathematics education in Indonesia.

In an effort to strengthen the quality of technology-based mathematics learning, several studies have been conducted to evaluate the effectiveness of digital media in teaching various mathematical materials. Several studies have shown that the use of digital media can help students understand concepts visually and increase learning interest (Azzahro & Subekti, 2022) . Other studies have also shown that digital media is effective in improving problem-solving skills (Mahuda et al., 2021) , conceptual understanding (Halim & Hadi, 2023) , and visual representations in geometry materials (Manik et al., 2024) . However, most of these studies still focus on aspects of conceptual and procedural understanding, rather than on aspects of mathematical reasoning that involve higher-order thinking processes.

Furthermore, research using digital media generally focuses on the secondary school level, while studies examining the integration of these media into mathematics learning in higher education are still limited. More specifically, studies analyzing the relationship between the use of interactive digital media and the development of students' mathematical reasoning skills in derivatives are scarce. Yet, derivatives in calculus are a complex topic with significant potential for analysis from a reasoning perspective (Amalia & Fathurrohman, 2020) and (Pandey & Singh, 2021) , as they involve understanding the relationship between changes in function values and their rates of change in various representations.

This study aims to fill this gap. Unlike previous studies that only assessed final learning outcomes, this study seeks to examine students' thinking processes while using interactive digital media to learn derivatives. The study focuses not only on improving learning outcomes but also on students' mathematical reasoning processes in developing an understanding of the concept of derivatives. This is an important contribution because reasoning is a crucial indicator of higher-level mathematical thinking in higher education.

The novelty of this research lies in three main aspects. First, in terms of research focus, this study focuses on the context of higher education in Indonesia, where research on the use of interactive digital media in mathematics learning, particularly in derivatives, is still limited. Second, in terms of approach, this study uses an indicator-based analysis of mathematical reasoning to evaluate the extent to which interactive digital media contributes to students' mathematical reasoning processes.

## 2. Method

This research is an quantitative descriptive research. This research will use Pre-Experimental Design with *One-Group Pre test-Post test Design approach*. This research is a study on the material of *function derivatives* with the research subjects being students of the Mathematics Education Study Program, Universitas Muhammadiyah Parepare who have programmed the Differential Calculus course, namely semester VI of the 2024/2025 Academic Year. Subjects were taken purposively, taking into account students who have basic experience in using interactive digital media. The instruments used in this study are: (1) Mathematical Reasoning Test, to measure students' reasoning abilities before and after using interactive digital media.

### 2.1 Research Procedures

This research will use Pre-Experimental Design with *One-Group Pre test-Post test Design approach*. The data used in this study were quantitative, and the research instrument was a mathematical reasoning ability test. The data collection technique consisted of two stages. First, a pre-test was administered to students before learning using interactive digital media to measure their initial abilities. Second, a post-test was administered after all learning activities were completed to determine improvements in mathematical reasoning ability following the treatment.

This research was conducted through several stages as follows: (1) Preparation: (a) Compiling research instruments (mathematical reasoning tests and interview guides), (b) Validating instruments through expert assessment, and (c) Compiling interactive digital media (interactive digital modules) that will be used in learning the concept of derivatives. (2) Implementation of the Experiment: (a) Providing an initial test (pretest) to measure students' initial mathematical reasoning abilities, (b) Implementing learning using interactive digital media that has been designed, implemented in several meetings, and (c) Providing a final test (posttest) to determine changes or improvements in students' mathematical reasoning abilities. (3) Evaluation: analyzing research data to measure research objectives

### 2.2 Data Analysis Techniques

The data analysis techniques used are quantitative descriptive statistical analysis: Quantitative data from the results of the mathematical reasoning ability test were analyzed using descriptive statistics (average, standard deviation, and score gain).

## 3. Results and Discussion

In an effort to provide a comprehensive overview of students' mathematical reasoning abilities before and after LMS implementation, descriptive statistical analysis was used based on pre-test and post-test results. The complete analysis results are shown in Table 1.

**Table 1. Descriptive Statistical Analysis of Pre-test and Post- test**

|                    |         | Pre-Test Score | Test Value | Gain Value |
|--------------------|---------|----------------|------------|------------|
| N                  | Valid   | 6              | 6          | 6          |
|                    | Missing | 48             | 48         | 48         |
| Mean               |         | 58.3333        | 80.0926    | .5221      |
| Standard Deviation |         | 7.85674        | 5.67012    | .10882     |
| Minimum            |         | 47.22          | 72.22      | .42        |
| Maximum            |         | 66.67          | 88.89      | .67        |

The results of the descriptive analysis showed that before the treatment, students' mathematical reasoning abilities were still at an intermediate level. The average pre-test score was 58.33 with a score range of 47.22 to 66.67. The standard deviation of 7.86 indicates relatively small variation in abilities between students. Individual categorization showed that five students were in the intermediate category, while one student was in the low category. These findings indicate that the majority of students have sufficient basic understanding, although there are still weaknesses, especially in the indicator of *performing mathematical manipulation*, which obtained the lowest average score (55.56).

After learning with interactive digital media, there was a significant improvement. The average post-test score reached 80.09, which is included in the high category, with a score range of 72.22 to 88.89. The standard deviation decreased to 5.67, indicating that student achievement is increasingly homogeneous. The distribution of categories shows that five students successfully achieved the high category, while one student was in the medium category. This condition indicates that the use of interactive digital media can elevate almost all students to a higher level of mathematical reasoning.

Furthermore, the *normalized gain analysis* showed an average value of 0.52, which is considered moderate. Individual gains ranged from 0.42 to 0.67, with all students consistently falling within the moderate category. Thus, it can be concluded that interactive digital media has a positive impact on improving students' mathematical reasoning abilities.

If we look at the indicators of mathematical reasoning ability, this can be seen in table 2 below.

Table 2. Data on mathematical reasoning ability based on reasoning indicators

|                    |         | Filing Allegations (Pre Test) | Filing Allegations (Post Test) | Presenting Mathematical Statements (Pre Test) | Presenting Mathematical Statements (Post Test) | Presenting Mathematical Statements (Pre Test) | Presenting Mathematical Statements (Post Test) |
|--------------------|---------|-------------------------------|--------------------------------|---|--|---|--|
| N                  | Valid   | 6                             | 6                              | 6   | 6  | 6   | 6  |
|                    | Missing | 48                            | 48                             | 48  | 48   | 48  | 48   |
| Mean               |         | 62.5000                       | 90.2778                        | 56.9444                                       | 80.5556  | 55.5556                                       | 69.4444  |
| Standard Deviation |         | 11.48671                      | 3.40207                        | 9.74204                                       | 6.80414  | 11.38550                                      | 8.60663  |
| Minimum            |         | 50.00                         | 83.33                          | 41.67   | 75.00  | 41.67   | 58.33  |
| Maximum            |         | 83.33                         | 91.67                          | 66.67   | 91.67  | 75.00   | 83.33  |

Based on the indicators, there were differences in the level of improvement. The indicator *for making conjectures* showed the highest increase, from an average of 62.50 in the pre-test to 90.28 in the post-test, or an increase of 27.78 points. This substantial increase reflects the effectiveness of interactive digital media, particularly in the form of graphic visualizations and dynamic animations (for example, with GeoGebra), which help students discover patterns and make logical conjectures.

For the indicator *of presenting mathematical statements*, the average score increased from 56.94 to 80.56, a 23.61-point increase. These results indicate that interactive digital media can support students in converting conceptual understanding into more structured mathematical models, such as deriving equations or modeling contextual problems.

Meanwhile, the *mathematical manipulation indicator* experienced the lowest improvement. The average pre-test score of 55.56 increased to 69.44 in the post-test, representing a 13.89 point increase. Despite the improvement, this indicator's performance was still lower than the other two indicators. This indicates that students' procedural and manipulative skills have not been fully supported by interactive digital media. Procedural errors were still found, so the mathematical manipulation aspect requires additional practice beyond interactive technology support.

Considering your research findings, which show an increase in average scores from 58.33 to 80.09 after using interactive digital media, these data align with the previous studies. For example, (Muhamad Yunus et al., 2022) found that students who used Macromedia- based digital media Flash showed significant improvements in mathematical reasoning skills compared to conventional learning. Similarly, research by Rahmawati et al., 2024, reported that interactive media had a positive effect on mathematical reasoning in the pre-test and post-test .

In addition, research using GeoGebra in discovery learning by (Fatahillah et al., 2023) supports that visual and interactive media not only increase average scores, but also show a reduction in variability between students—in line with your finding of a decrease in standard deviation from 7.17 to 5.18. Likewise, the *Enhancing Learning study Mathematical Reasoning through the Integration of Realistic Geometry with Interactive Multimedia Learning Applications* report significant effects of

interactive media in strengthening mathematical representation and reasoning. (Alim et al., 2024) , which matches the indicators in your research.

These studies together reinforce that interactive digital media have two main effects: significantly increasing students' average scores in pre-post measurements, and also making results more uniform across students — supporting that these media not only improve performance but also reduce learning variation (homogeneity of learning outcomes).

When viewed based on indicators, *proposing conjectures* experienced the largest increase, with a difference of 27.78 points. This indicates that interactive digital media is highly effective in facilitating students' initial conjecture development through dynamic visual representations. Graphic and animated visualizations allow students to observe patterns of change, form hypotheses, and test their validity more directly. This finding aligns with a study by Medina Herrera et al., 2024, which reported that spatial visualization tools support the development of mathematical conjecture or hypothesis-making skills and deeper mathematical understanding. Similarly, Rif'at et al., 2021 reported that the combination of visual and algebraic representations facilitates students' development of more accurate mathematical conjectures.

International research also supports these findings. (Muzangwa & Ogbonnaya, 2022) showed that students were better able to connect symbolic functions with graphical representations after engaging in visual matching activities, making it easier for them to form patterns and conjectures. A study (Zulu & Mudaly, 2023) also showed that iconic and symbolic visualizations helped prospective mathematics teachers construct mathematical conjectures in complex problem-solving and effectively use visual representations. Furthermore, a study (Yurmalia & Jupri, 2021) found that visual imagination skills play a significant role in helping students see arithmetic patterns and propose valid hypotheses.

Thus, the results of this study are consistent with previous findings that visual representations presented through interactive digital media significantly contribute to the ability to make conjectures. Therefore, it can be asserted that this indicator is most impacted due to the nature of interactive media, which encourages exploration, pattern observation, and hypothesis formation, which are at the core of higher-order mathematical reasoning.

The indicator *for presenting mathematical statements* also showed a substantial increase, reaching 23.61 points. This indicates that interactive digital media helps students convert conceptual ideas into systematic mathematical symbols, equations, or models. Media such as GeoGebra and interactive e-modules provide space for students to test and validate their mathematical representations. (Elfariana et al., 2024) confirmed that interactive e-LKPD supports students in constructing clearer mathematical statements, while (Marsitin & Sesanti, 2023) found that mathematical literacy- based digital modules can improve the accuracy of mathematical model formulations in various contexts.

In contrast, the indicator *for performing mathematical manipulation* experienced a relatively small increase (13.89 points) compared to other indicators. Despite this increase, these results indicate that procedural skills , such as symbolic calculation or algebraic manipulation, are not fully facilitated by interactive digital media. This finding aligns with a study (Lampropoulos, 2023) which showed that game-based digital media was more effective in increasing motivation and representation, but had little effect on symbolic manipulation skills. (Jongbloed et al., 2024) and (Sawyer et al., 2022) also found that technology-based procedural simulations are indeed beneficial, but their effectiveness in strengthening manipulative skills tends to be lower than the concept visualization aspect. Thus, it can be concluded that interactive digital media is more effective in supporting the initial stages of mathematical reasoning (proposing conjectures and presenting statements) than the manipulative stage which requires more intensive procedural practice.

These findings have important implications. First, the integration of interactive digital media in mathematics learning needs to focus on strengthening higher-order reasoning skills, particularly conjectures and mathematical representations, which have been shown to be most affected. Second, the weaknesses in the mathematical manipulation aspect indicate the need for a more balanced learning design, where interactive digital media is used in conjunction with manual exercises and problem-solving-based learning strategies to strengthen procedural skills. Third, the decrease in standard deviations among students after the treatment confirms that interactive digital media can be a solution to reduce the achievement gap between students in heterogeneous classes.

#### 4. Conclusion

The results of this study confirm that the use of interactive digital media contributes significantly to improving students' mathematical reasoning abilities. In general, the average score increased from 58.33 (medium category) in the pre-test to 80.09 (high category) in the post-test, with a decrease in the standard deviation from 7.86 to 5.67, indicating increasingly homogeneous student achievement. These findings indicate that interactive digital media is not only able to improve individual performance but also reduce the achievement gap in heterogeneous classes.

Indicator-based analysis showed that the greatest improvement occurred in the ability *to propose conjectures* (27.78 points), followed by *presenting mathematical statements* (23.61 points), while *performing mathematical manipulations* experienced the lowest improvement (13.89 points). These results reveal that interactive digital media is more effective in supporting higher-order reasoning skills based on visual and conceptual representations, compared to procedural skills that require repeated symbolic practice.

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#### Bibliography

- Alim, J. A., Oktaviani, C., & Wijaya, T. T. (2024). Enhancing Mathematical Reasoning through the Integration of Realistic Geometry with Interactive Multimedia Learning Application. *Jurnal Pendidikan Progresif*, 14(3), 1533–1547. <https://doi.org/10.23960/jpp.v14.i3.2024105>
- Amalia, A., & Fathurrohman, M. (2020). Analisis Kemampuan Penalaran Matematis pada Materi Turunan Fungsi aljabar berdasarkan Gaya Kognitif Siswa. *Jurnal Inovasi Dan Riset Pendidikan Matematika*, 1(3), 1–11. <http://www.jurnal.untirta.ac.id/index.php/wilangan>
- Annisa Gita Cahyani, & Setyadi, D. (2023). 10.47435/jtmt.v4i02.1984 Development of Instagram Filters in Interactive E-Books Mathematics Learning Build a Flat Side Space. *JTMT: Journal Tadris Matematika*, 4(02), 158–171. <https://doi.org/10.47435/jtmt.v4i02.1984>
- Azzahro, T. A., & Subekti, F. E. (2022). Systematic Literature Review : Efektivitas Penggunaan Media Evaluasi Digital dalam Pembelajaran Matematika. *Biormatika : Jurnal Ilmiah Fakultas Keguruan Dan Ilmu Pendidikan*, 8(2), 207–213. <https://doi.org/10.35569/biormatika.v8i2.1331>
- Dollo, A. (2018). Mathematical Reasoning Analysis in Solving Limit Functions Problems of Students in Mathematics Education of Pare-pare Muhammadiyah University. *Mathematics Education Journal*, 2(1), 59. <https://doi.org/10.22219/mej.v2i1.5796>
- Elfariana, R., Aisyah, N., & Susanti, E. (2024). Development of Interactive Electronic Student Worksheets on Pythagorean Theorem Material to Support Students' Mathematical Reasoning in Junior High Schools. *Kreano, Jurnal Matematika Kreatif-Inovatif*, 15(1), 306–318. <https://doi.org/10.15294/kvzmp80>
- Fatahillah, A., Yafi, M. A., Monalisa, L. A., Hussen, S., & Wiharjo, E. (2023). Pengembangan Media Pembelajaran Matematika Materi Persamaan Lingkaran berbasis Discovery Based Learning Berbantuan Geogebra Classroom untuk Meningkatkan Keterampilan Berpikir Kreatif Siswa. *Proximal: Jurnal Penelitian Matematika Dan Pendidikan Matematika*, 6(2), 43–54. <https://doi.org/10.30605/proximal.v6i2.2643>
- Halim, A., & Hadi, M. S. (2023). Analisis Efektivitas Penggunaan Media Digital dalam Meningkatkan Pemahaman Konsep Matematika Peserta Didik Kelas VII SMP Negeri 275 Jakarta. *INNOVATIVE: Journal Of Social Science Research*, 3(3), 8333–8341.

- Haura Putri Fortuna, Rahma Aulia, Riska Mutia Febriyani, & Eka Rachma Kurniasih. (2024). Analisis Hasil Belajar Matematika Siswa Kelas XI IPS di SMAN 8 Tambun Selatan Pada Materi Turunan. *Bilangan : Jurnal Ilmiah Matematika, Kebumihan Dan Angkasa*, 2(4), 155–165. <https://doi.org/10.62383/bilangan.v2i4.173>
- Jongbloed, J., Chaker, R., & Lavoué, E. (2024). Immersive procedural training in virtual reality: A systematic literature review. *Computers & Education*, 221, 105124. <https://doi.org/10.1016/j.compedu.2024.105124>
- Lampropoulos, G. (2023). Educational benefits of digital game-based learning: K-12 teachers' perspectives and attitudes. *Advances in Mobile Learning Educational Research*, 3(2), 805–817. <https://doi.org/10.25082/AMLER.2023.02.008>
- Mahuda, I., Meilisa, R., & Nasrullah, A. (2021). PENGEMBANGAN MEDIA PEMBELAJARAN MATEMATIKA BERBASIS ANDROID BERBANTUAN SMART APPS CREATOR DALAM MENINGKATKAN KEMAMPUAN PEMECAHAN MASALAH. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, 10(3), 1745. <https://doi.org/10.24127/ajpm.v10i3.3912>
- Manik, S. A. R., Humairoh, A. P., Annisa, S., Mailani, E., & Ketaren, M. A. (2024). Peran Media Visual Dalam Meningkatkan Pemahaman Geometri Siswa Sekolah Dasar. *AR-RUMMAN: Journal of Education and Learning Evaluation*, 1(2), 759–763. <https://doi.org/10.57235/arrumman.v1i2.4425>
- Marsitin, R., & Sesanti, N. R. (2023). Developing an electronic module based on mathematical literacy to enhance students' mathematical reasoning. *Jurnal Elemen*, 9(1), 197–210. <https://doi.org/10.29408/jel.v9i1.6915>
- Medina Herrera, L. M., Juárez Ordóñez, S., & Ruiz-Loza, S. (2024). Enhancing mathematical education with spatial visualization tools. *Frontiers in Education*, 9. <https://doi.org/10.3389/educ.2024.1229126>
- Melati, E., Fayola, A. D., Hita, I. P. A. D., Saputra, A. M. A., Zamzami, Z., & Ninasari, A. (2023). Pemanfaatan Animasi sebagai Media Pembelajaran Berbasis Teknologi untuk Meningkatkan Motivasi Belajar. *Journal on Education*, 6(1), 732–741. <https://doi.org/10.31004/joe.v6i1.2988>
- Mishra, R. (2024). The Profound Nature of Derivatives and Integration: A Comprehensive Examination. *Patan Prospective Journal*, 4(01), 103–109. <https://doi.org/10.3126/ppj.v4i01.70206>
- Muhamad Yunus, Mizan Abrory, Zafrullah, Dedek Andrian, & David Maclinton. (2022). The Effectiveness of Macromedia Flash Digital Media in Improving Students' Mathematics Reasoning. *Mathematics Research and Education Journal*, 6(1), 14–20. [https://doi.org/10.25299/mrej.2022.vol6\(1\).9013](https://doi.org/10.25299/mrej.2022.vol6(1).9013)
- Mulyani, S., & Siregar, R. N. (2025). Analysis of Students' Mathematical Understanding of Derivatives Algebraic Function on Islamic Boarding High School. *(JIML) JOURNAL OF INNOVATIVE MATHEMATICS LEARNING*, 8(1), 173–187. <https://doi.org/10.22460/jiml.v8i1.27159>
- Muzangwa, J., & Ogonnaya, U. I. (2022). Undergraduate Mathematics Education Students' Visual Representations of Multivariable Functions. *Edumatica : Jurnal Pendidikan Matematika*, 12(03), 212–221. <https://doi.org/10.22437/edumatica.v12i03.15712>
- Nie, Z. (2024). The Applications of Derivative and Differential. *Science and Technology of Engineering, Chemistry and Environmental Protection*, 1(10). <https://doi.org/10.61173/sjvhcy05>
- Pandey, A. K., & Singh, S. (2021). Derivatives: A Comprehensive Study of Rate of Change. *Journal*

of Applied Science and Education (JASE), 1(1), 1–4. <https://doi.org/10.54060/JASE/001.01.005>

Rahmawati, S., H, N., & Muin, A. (2024). Development of Web-Based Digital Mathematics Modules Grade VII SMPN 1 Watansoppeng. *Inovasi Kurikulum*, 21(2), 647–660. <https://doi.org/10.17509/jik.v21i2.67846>

Rif'at, M., Sudiansyah, S., & Peterianus, S. (2021). Algebraic and Visual Representation in Solving Mathematics Problems Based on Empirical Thinking. *Al-Jabar : Jurnal Pendidikan Matematika*, 12(2), 481–499. <https://doi.org/10.24042/ajpm.v12i2.23567>

Rofinus Badung, & Asdar Dollo. (2024). Pengaruh Penggunaan Aplikasi Wordwall Terhadap Hasil Belajar Matematika Siswa Kota Parepare. *Tautologi: Journal of Mathematics Education*, 2(1), 30–34. <https://doi.org/10.31850/tautologi.v2i1.1910>

Sawyer, T., Bergman, L., & White, M. L. (2022). Simulation for Procedural Skills Teaching and Learning. In *Clinical Education for the Health Professions* (pp. 1–21). Springer Nature Singapore. [https://doi.org/10.1007/978-981-13-6106-7\\_92-2](https://doi.org/10.1007/978-981-13-6106-7_92-2)

Siregar, B. H., Panjaitan, A., Hasratuddin, H., Kairuddin, K., Mulyono, M., & Rahman, A. A. (2024). Digital Media Innovation Based on Multimedia Cognitive and Constructivist Theory in a Cultural Context: Encouraging Students' Higher Order Thinking Skills. *JTAM (Jurnal Teori Dan Aplikasi Matematika)*, 8(1), 269. <https://doi.org/10.31764/jtam.v8i1.16800>

Yurmalia, D., & Jupri, A. (2021). Student Visual Thinking in Solving Realistic Problems: The Case of Arithmetic Sequence. *2021 4th International Conference on Big Data and Education*, 63–68. <https://doi.org/10.1145/3451400.3451410>

Zulu, M. W., & Mudaly, V. (2023). Unveiling problem-solving strategies of pre-service mathematics teachers: A visual and discursive exploration. *Eurasia Journal of Mathematics, Science and Technology Education*, 19(7), em2299. <https://doi.org/10.29333/ejmste/13344>