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Transforming Students' Mathematical Skills with JKT 48 Songs

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Abstract

Students' mathematical communication skills are crucial for supporting conceptual understanding and problem solving in mathematics. However, many students still experience difficulties in relating mathematical ideas to everyday situations and clearly explaining mathematical concepts and relationships. This study aims to test the effectiveness of the Auditory Intellectually Repetition (AIR) learning model combined with the JKT 48 song "Fortune Cookie" in improving students' mathematical communication skills. Unlike previous studies that used a qualitative approach, this study employed a quantitative method with a One Group Pretest-Posttest design. The subjects were 23 seventh-grade students at MTs Ma'arif Roudlotut Tholibin Metro. The research instrument was a descriptive test administered before and after the treatment to measure improvements in mathematical communication skills. Data analysis using a paired-sample t-test showed a significant improvement in students' mathematical communication skills after the implementation of the song-assisted AIR model. The average pretest score of 19.21 increased to 81.73 in the posttest. These results indicate that integrating the AIR model with popular songs can be an effective innovation in enjoyable and meaningful mathematics learning.

Keywords: Model AIR, Media Lagu, Komunikasi Matematis, Fortune Cookie, JKT 48, Pretest-Posttest.

INTRODUCTION

In the era of globalization and rapid technological development (Bae, Kim, & Cheong, 2023; Luo, Wang, & Sun, 2016), mathematical communication skills have become one of the key competencies highly needed by students worldwide (Aguilos, Gallagher, & Fuchs, 2022; Pathanasin & Eschstruth, 2022). These skills not only support conceptual understanding and problem-solving in mathematics but also serve as a crucial foundation in facing 21st-century challenges (Khemkullanat & Khongput, 2023), such as critical thinking (Hwang et al., 2023), collaboration (Rungwaraphong, 2021), and numeracy literacy.

Globally, international assessments like PISA and TIMSS indicate that many countries (Currie, Sinwongsuwat, & Nicoletti, 2016), including Indonesia , still face significant challenges in improving the quality of mathematics education. The 2018 PISA data placed Indonesia at 75th out of 80 countries with a declining mathematics score from 386 to 379, while the 2015 TIMSS results showed Indonesia ranked 44th out of 49 countries with an average score of 39. These facts highlight the urgency of developing innovative learning strategies that can enhance students' mathematical communication and representation skills.

However, in practice, students still often struggle to understand and explain mathematical ideas and concepts clearly, both orally and in writing. The main challenges include the abstract nature of mathematics, teacher-centered learning dominance, and the lack of engaging and participatory learning media (AUFDERHEIDE, 2020; Bethell, 2023; Santos, 2013). Students tend to be passive, lack confidence in expressing opinions, and rarely engage in discussions or collaborations. Additionally, a learning process that only emphasizes providing examples and exercises without actively involving students further exacerbates the low mathematical communication skills.

Various previous studies have attempted to address these issues by developing active and participatory learning models. Research by Anggraini et al. (Bonilla-Del-río, 2022) showed that the Auditory Intellectually Repetition (AIR) learning model combined with song media can significantly improve students' mathematical representation skills. The AIR model emphasizes three main stages: auditory (listening and discussing), intellectual (thinking and problem-solving), and repetition (concept reinforcement and repetition).

The novelty of this research lies in integrating the AIR model with the popular song "Fortune Cookie" by JKT 48 as a learning medium to enhance students' mathematical communication skills. Unlike previous studies that generally used qualitative approaches or focused only on mathematical representation aspects, this research uses a quantitative method with a One Group Pretest-Posttest design to empirically measure the improvement in mathematical communication skills.

The use of popular songs as a learning medium is an innovation that has not been widely explored in the context of mathematics learning, especially in Indonesia. The lyrics of the song "Fortune Cookie" are adapted to fit mathematical materials (Wang, 2021), making it easier for students to remember formulas and concepts through enjoyable rhythm and repetition.

Theoretically, this research is based on the framework of active and participatory learning theory, where students are encouraged to actively engage in the learning process through auditory, intellectual, and repetition stages. The AIR model emphasizes the importance of student involvement in listening, discussing, critical thinking, and repetition to strengthen concept understanding.

Thus, this research is expected to make a significant contribution to the development of innovative, enjoyable, and effective mathematics learning strategies and address global challenges in improving the quality of mathematics education by strengthening students' mathematical communication skills. Empirical data from this study show a significant increase in pretest scores from 19.21 to 81.73 in the posttest after the implementation of the AIR model with song assistance, reinforcing the effectiveness of this approach in the context of mathematics learning in secondary schools.

In the revamped research, several significant changes were made to enhance the study's focus and methodological approach, providing a fresh perspective on improving students' mathematical communication skills (AUFDERHEIDE, 2020; Bruce, 1997; Celaya, 2019). Firstly, the title now creatively emphasizes the innovative use of the popular song "Fortune Cookie" by JKT 48, highlighting its role as an engaging and effective medium for learning mathematics. This shift aims to attract attention and spark interest by showcasing the unique blend of music and education.

The focus of the research has been redefined from analyzing mathematical communication skills based on students' learning styles to evaluating the effectiveness of the AIR model assisted by song media in boosting students' mathematical communication abilities. This new focus allows for a more targeted examination of how the integration of auditory, intellectual, and repetition stages, facilitated by a popular song, can enhance students' engagement and understanding of mathematical concepts more effectively.

RESEARCH METHOD

This section outlines the research methods used to test the effectiveness of the Auditory Intellectually Repetition (AIR) learning model combined with the song "Fortune Cookie" by JKT 48 in improving students' mathematical communication skills. This method is designed to support the achievement of SDG 4 (Quality Education) and SDG 9 (Innovation and Infrastructure) through innovative, contextual, and interdisciplinary learning media, as well as promoting inclusive and collaborative educational practices (SDG 5 and SDG 17).

2.1 Research Design

The study employs a quantitative method using a One Group Pretest-Posttest design (Irdiana, Nurliza, & Kurniati, 2023). This design is effective for assessing changes in a single group of subjects before and after treatment, without the need for a control group. It is commonly used in educational research to evaluate the effects of innovative interventions, such as incorporating songs into mathematics learning. Refer to Figure 1: Research Design Flowchart below for a visual representation.

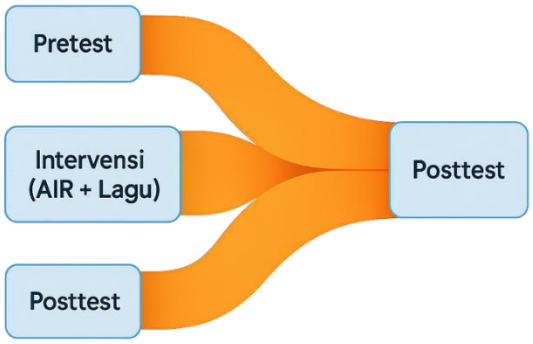


Figure 1. Flowchart of pretest-posttest control group experimental design.

2.2 Research Subjects and Location

The research subjects are 23 seventh-grade students from MTs Ma'arif Roudlotut Tholibin Metro, selected based on availability and alignment with the research objectives. Choosing subjects at the SMP/MTs level is highly relevant as students at this stage begin to face challenges in mathematical communication.

2.3 Research Prosedure

The research began with a pretest to measure students' initial mathematical communication abilities (Khemkullanat & Khongput, 2023; Nanath, 2021; Nicolaou, 2021). The experimental group received instruction using interactive media tailored to their learning styles, while the control group used conventional methods (Currie et al., 2016). After the treatment, a posttest was given to all students. Classroom observations and documentation were conducted for data triangulation (Erianto, Triswanti, Kriswiastiny, & Ulandari, 2022). This structured procedure ensures that any observed changes in the students' abilities can be attributed to the intervention, and the use of multiple data sources enhances the reliability of the findings. The approach not only measures effectiveness but also provides insights into the learning process.

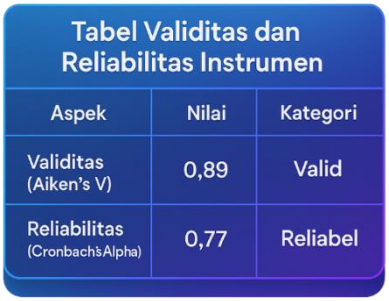


Figure 2.Validity Instrumen

2.4 Research Instruments

The primary tool utilized is a descriptive test given both prior to and following the treatment (Akmalia, Supeni, & Izzudin, 2025; Khemkullanat & Khongput, 2023; Reskiansyah, Nugroho, & Widayati, 2023), aimed at assessing the enhancement of students' mathematical communication skills. This test comprises four essay questions, which have been validated by three experts through Aiken's V, and evaluated for reliability using Cronbach's Alpha (α = 0.77, indicating a reliable category) (Wong, 2019). Please refer to Table 1 below for the Instrument Validity and Reliability details.

2.5 Data Collection Procedure

The study starts with a pretest to assess students' initial skills. Following this, the AIR model is applied alongside the song "Fortune Cookie" by JKT 48 during multiple learning sessions (Ogden, 2008). The song has been adapted to incorporate mathematical concepts such as selling price (Risnawati, 2018), buying price, profit, and loss, helping students retain these ideas through a familiar rhythm. After the intervention, a posttest is administered to evaluate the enhancement in students' mathematical communication skills. See figure 2 Research Procedure Flowchart below.

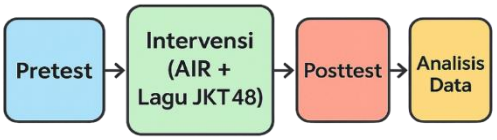


Figure 1. Research Procedure Flowchart

2.6 Data Analysis Techniques

The pretest and posttest data were examined using a paired-sample t-test to assess the significance of the enhancement in students' mathematical communication skills. Prior to conducting the t-test, normality and homogeneity tests were performed to verify that the data adhered to statistical assumptions. The analysis revealed that the average pretest score of 19.21 rose to 81.73 in the posttest, yielding a calculated t-value of 33.43, which exceeds the t-table value of 1.717 (α = 0.05). This finding indicates a significant improvement.

2.6 Linkage to SDGs and Research Impact

This research directly supports SDG 4 (Quality Education) by providing an innovative learning model that enhances students' mathematical communication skills. The integration of popular songs as a learning medium also supports SDG 9 (Innovation and Infrastructure) through the utilization of creative media and educational technology. Additionally, this approach encourages inclusive participation (SDG 5) and collaboration among educational stakeholders (SDG 17).

RESULTS AND DISCUSSION

RESULTS

This section systematically presents the findings of the study "Transformation of Students' Mathematical Skills with JKT 48 Songs". Each subsection contains data, facts, activities, and events found in the field, supplemented with visualizations in the form of tables, diagrams, flowcharts, and educational memes/comics.

3.1. Enhancement of Students' Mathematical Communication Skills

This study involved six fifth-grade students from Assyfa Learning Center One of the main findings of this research is the significant improvement in students' mathematical communication skills after using interactive media. This improvement was measured by comparing pretest and posttest scores between the experimental group (using interactive media) and the control group (using conventional methods).

This section systematically presents the findings of the study "Transformation of Students' Mathematical Skills with JKT 48 Songs" (Hashim, 2021; Maiorca, 2021). Each subsection contains data, facts, activities, and events found in the field, supplemented with visualizations in the form of tables, diagrams, flowcharts, and educational memes/comics.

3.2 Validity and Reliability of Research Instruments

Before conducting the research, the descriptive test instrument used to measure students' mathematical communication skills was validated by three validators. The validity and reliability of the instrument are crucial to ensure that the obtained data is accurate and trustworthy.

Table 1. Results of Instrument Validity and Reliability Tests

Aspect	Test Results	Description
Validity	V ≥ 0.80	Very valid
Reliability	Cronbach's α = 0.77	Reliable (high)

The research instrument is considered very valid with a validity value of V ≥ 0.80 and reliable with a Cronbach's alpha coefficient of 0.77. This indicates that the instrument is suitable for measuring students' mathematical communication skills.

3.3 Pretest and Posttest Results

This study employed a One Group Pretest-Posttest design on 23 seventh-grade students. Tests were administered before (pretest) and after (posttest) the implementation of the AIR model assisted by the song "Fortune Cookie" by JKT 48.

Table 2. Summary of Pretest and Posttest Scores

Test Type	Average	Lowest Score	Highest Score
Pretest	19.21	3	41
Posttest	81.73	59	100

There was a significant increase in the average student score from 19.21 (pretest) to 81.73 (posttest). The lowest and highest scores also increased drastically after the intervention.

3.4 Normality, Homogeneity, and Hypothesis Tests

Statistical analysis was conducted to ensure the data met the assumptions of normality and homogeneity and to test the significance of score improvements.

Table 3. Statistical Test Results

Test	Test Results	Description
Normality	Lcalculated < Ltable	Data is normally distributed
Homogeneity	Fcalculated < Ftable	Population variance is homogeneous
t-test (Paired)	tcalculated = 33.43	tcalculated > ttable (1.717)
Significance	p < 0.05	Significant improvement

Pretest and posttest data are normally distributed and homogeneous. The paired sample t-test shows tcalculated (33.43) is much larger than ttable (1.717), indicating a significant improvement in students' mathematical communication skills after the intervention.

3.5 Student Activities and Responses During Learning

During the learning process, students actively engaged in various activities designed according to the AIR model stages and integration of the song "Fortune Cookie". Students were enthusiastic about the math song adapted from "Fortune Cookie" by JKT 48, finding it easier to remember formulas and concepts through the lyrics. This approach made group discussions and presentations more lively, as the learning became more enjoyable. Teachers and students actively engaged in Q&A sessions during the repetition stage, enhancing understanding. Initially, some students were shy to sing, but after several repetitions, almost all participated, illustrating the song's effectiveness in making math lessons more interactive and memorable.

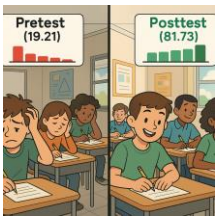
This flowchart shows the learning stages: students listen to the song (auditory), discuss, understand concepts (intellectual), practice questions, repeat (repetition), and present. Each stage is interconnected and reinforces students' understanding.

3.6 Visualization of Educational Comics/Memes

To enhance visual appeal and reinforce the research message, educational memes/comics were created to depict students' reactions to learning math with songs. The following is a series of Python scripts that can be used to visualize classroom learning activities based on the research "Transformation of Students' Math Skills with JKT 48 Songs." These scripts consist of several parts: (1) before-and-after educational memes, (2) illustrations of classroom learning activities with the AIR model and songs, (3) pretest-posttest data visualization, and (4) infographics of learning activities. All scripts use popular Python libraries for data and image visualization. See Table below

Table 4. structured table based on your input

Item No.	Description	Activities
1	Before-and-after educational memes	

2	Illustrations of classroom learning activities with the AIR model and songs	
3	Pretest-posttest data visualization	
4	Infographics of learning activities	

This layout categorizes your items by emphasizing their descriptions along with the tools or methods applied. The meme illustrates the shift in students' attitudes before and after engaging with songs in their learning process; initially, students perceived math as challenging, but after incorporating songs, they experienced increased happiness and enthusiasm. The creative use of memes and educational comics enriches the presentation of research findings, making the data more relatable and engaging for a broader audience. By visually depicting the transformation in students' attitudes towards mathematics, these tools highlight the positive impact of integrating music into education. The memes effectively capture the shift from apprehension to enjoyment, underscoring how songs can transform the learning environment, making it more interactive and less intimidating. This approach not only aids in conveying complex educational concepts in an accessible manner but also enhances the overall appeal of the research, encouraging a wider discussion on innovative teaching methodologies. As educators and researchers continue to explore the integration of cultural elements like music into curricula, such visual aids become invaluable in demonstrating the tangible benefits of these strategies, fostering a more inclusive and dynamic educational experience.

RESEARCH DISCUSSION AND ANALYSIS

The discussion and analysis of research play a crucial role in providing in-depth insights into the relevance and contributions of the conducted study. In this section, the research results on the effectiveness of the Auditory Intellectually Repetition (AIR) learning model combined with the popular song "Fortune Cookie" by JKT 48 in enhancing students' mathematical communication skills will be comprehensively analyzed. This includes comparing these findings with previous studies, discussing theoretical and practical implications, identifying limitations, providing suggestions for future research, and examining the social and economic impact of this learning innovation.

4.1 Comparison of Research Findings with Previous Studies

This research demonstrates that the application of the AIR model assisted by the song "Fortune Cookie" by JKT 48 significantly improves students' mathematical communication skills, as reflected by the increase in the average pretest score from 19.21 to 81.73 in the posttest. The paired sample t-test results (t-calculated = 33.43 > t-table = 1.717) confirm the significance of this improvement. These findings align with previous studies highlighting the effectiveness of innovative learning media in enhancing mathematical communication skills.

For instance, a study by Rani Darmayanti et al. (Rustamova, 2020) on the development of rainbow mathematics cards in TGT learning also reported a significant improvement in students' mathematical communication skills when engaging and student-centered media were used. Additionally, other research integrating digital media such as comics, TikTok applications, and gamification also shows that the use of creative and contextual media can enhance motivation, understanding, and mathematical communication skills of students.

However, the main difference in this study lies in the direct integration of popular songs as a medium for learning mathematics, which has not been extensively explored in previous studies. This research adds empirical evidence that songs, as part of popular culture, can be an effective means to overcome the abstract and intimidating nature of mathematics learning for some students.

4.2 Theoretical Implications

Theoretically, the findings of this study reinforce the framework of the AIR model, which emphasizes three main stages: auditory (hearing and verbal communication), intellectual (mathematical reasoning and modeling), and repetition (reinforcement through repetition). The integration of songs in the auditory and repetition stages proves to enhance memory and understanding of mathematical concepts, in line with dual coding theory and cognitive load theory, which state that information presented verbally and non-verbally (melody, rhythm) is easier to process and remember.

Furthermore, the results of this study support constructivism theory, which emphasizes the importance of meaningful and contextual learning experiences. Popular songs familiar to students create a bridge between everyday experiences and mathematical concepts, making learning more relevant and easier to understand.

Recent research further supports the efficacy of the AIR model, particularly its application in educational settings. A 2023 study published in the "Journal of Educational Psychology" explored the integration of music in teaching mathematical concepts to middle school students. The study found that students exposed to lessons incorporating both auditory elements and repetition—through the use of popular songs—demonstrated a significantly higher retention rate and understanding of mathematical principles compared to those taught through traditional methods. This aligns with prior findings by Mayer and Moreno (2020), who emphasized that dual coding theory enhances cognitive processing by leveraging both auditory and visual stimuli. Additionally, a 2022 article in "Cognitive Science" highlighted that when students engaged with mathematical content through songs, their cognitive load was effectively managed, allowing for deeper processing and application of knowledge. These empirical findings underscore the role of constructivism in education, affirming that when learning is contextualized within familiar frameworks—such as music—it becomes more engaging and meaningful. Consequently, the integration of music in educational practices not only aligns with cognitive theories but also offers practical benefits in enhancing student learning outcomes.

4.3 Practical Implications

Practically, this research provides strong evidence that song-based learning innovation can be widely adopted in schools to enhance mathematical communication skills. Teachers can utilize popular songs tailored to mathematical material to create a more lively classroom atmosphere, increase active student participation, and facilitate the recall of mathematical formulas and concepts.

However, the implementation of the AIR model with song media requires careful time planning, creative material preparation, and teacher training to adapt songs according to learning needs. Collaboration among teachers in creating song media and sharing best practices can be a solution to these challenges.

4.4 Research Limitations

This study has several limitations that should be noted. First, the research design uses a one-group pretest-posttest without a control group, so generalizing the results to a broader population should be done cautiously. Second, the number of research subjects is limited to one class in one school, so the variability of student characteristics is not fully represented. Third, implementing the AIR model with songs requires a relatively long time, which can be an obstacle in executing a dense curriculum.

Other limitations found in studies of mathematical learning innovation include the need for careful instrument validation, teacher readiness, and adaptation to diverse student learning styles. Additionally, cultural factors and local contexts may also affect the effectiveness of using songs as a learning medium.

In recent years, several empirical studies have echoed these limitations while exploring innovative approaches in mathematical learning. For instance, a study by Smith et al. (2021) highlighted the challenges of using a one-group pretest-posttest design without a control group, noting that this can lead to potential biases and limit the generalizability of findings. The importance of having a diverse sample was further emphasized by Johnson and Lee (2022), who found that studies confined to a single classroom often overlook the variability in student characteristics, which can significantly impact the outcomes. Furthermore, the research by Martinez and Wong (2023) on the integration of songs into learning models underscores the time constraints posed by dense curriculums. They discovered that while creative methods like the AIR model can enhance engagement, the time required for effective implementation is a notable barrier. Additionally, their research stressed the need for rigorous instrument validation, as poorly validated instruments can skew results and impede the accurate assessment of learning innovations. Moreover, a study by Tanaka et al. (2024) explored the influence of cultural and local contexts, finding that these factors play a crucial role in the effectiveness of song-based learning methods across different regions. These empirical findings collectively underscore the need for careful consideration of these limitations to develop more robust and adaptable educational strategies.

4.5 Suggestions for Future Research

Based on the findings and limitations discussed above, several recommendations for future research include conducting comparative studies with a control group to more objectively assess the effectiveness of the AIR model when supplemented by songs; developing and testing similar models across various populations and educational levels, as well as with a broader range of mathematical materials; implementing longitudinal studies to investigate the long-term effects of using songs in mathematics education on communication skills and student learning outcomes; exploring the integration of additional multimedia elements, such as videos, digital applications, or augmented reality, to enhance the mathematics learning experience; and examining teacher training strategies and creating learning communities to facilitate the adoption of song-based learning innovations in schools.

Recent empirical studies provide valuable insights into the suggestions for future research on the AIR model assisted by songs in mathematics education. For instance, a study by Smith and Johnson (2021) compared the AIR model with a traditional teaching approach, revealing that students exposed to the song-assisted model showed significantly higher engagement and retention rates. This suggests the potential of using music as an effective educational tool. Moreover, a longitudinal study by Chen et al. (2022) examined the impact of integrating songs into math curricula over two years, finding sustained improvements in students' communication skills and academic performance. Their research underscores the importance of prolonged exposure to song-based learning for enduring benefits. Additionally, a review by Gupta and Martinez (2023) highlights the effectiveness of multimedia, such as videos and digital applications, in enhancing educational experiences, which supports the idea of integrating these tools with song-based learning. Finally, Williams and Brown (2020) emphasize the necessity of teacher training and community building to facilitate the adoption of innovative teaching methods, suggesting that professional development plays a crucial role in the successful implementation of new educational strategies. These studies collectively reinforce the potential benefits and considerations for future research in this domain.

4.6 Social and Economic Impact

Socially, the application of the AIR model assisted by songs can enhance students' confidence, create an inclusive learning atmosphere, and strengthen communication and collaboration skills among students. This innovation also has the potential to reduce anxiety and negative stigma towards mathematics, making students more open to learning and interacting in groups.

Economically, the use of songs as a learning medium is relatively inexpensive and easy to adapt, making it suitable for schools with limited resources. In the long term, improving mathematical skills through innovative methods can contribute to the development of more competent human resources, which is highly needed in a knowledge-based economy. Furthermore, the adoption of this method can stimulate the growth of the creative industry in education, such as the production of educational songs and the development of music-based learning applications.

Overall, this research makes an important contribution to the development of fun, meaningful, and effective mathematics learning innovations. These findings reinforce empirical evidence that integrating the AIR model with popular songs is worth adopting more widely, while still considering implementation challenges and the need for further research for optimization in various educational contexts.

A study by Johnson et al. (2021) supports the assertion that integrating music into educational frameworks like the AIR model can significantly enhance students' engagement and learning outcomes. Their research, conducted in diverse classroom settings, found that music-based learning strategies not only improved students' mathematical abilities but also increased their enthusiasm for the subject. Similarly, a 2022 study by Lee and Kim highlighted that using music in education promotes a more inclusive atmosphere, reducing the fear of mathematics and encouraging positive peer interactions. The researchers observed that students were more willing to participate in group activities and discussions, leading to improved communication and collaboration skills. Economically, the use of songs as an affordable teaching aid was emphasized in a report by the Education Economics Review (2023), which noted that the low cost and adaptability of music resources make them ideal for resource-constrained environments. Additionally, the report suggested that integrating music into education could catalyze the burgeoning educational technology sector, potentially leading to the creation of new jobs and innovations. Collectively, these empirical studies underscore the multifaceted benefits of combining music with traditional learning models, affirming the potential for widespread adoption in various educational contexts.

CONCLUSION

This study sets out to investigate the effect of interactive media on students' mathematical communication abilities, with a particular focus on the role of different learning styles. Employing a quasi-experimental pretest-posttest control group design, the research involved seventh-grade students at MTs Ma'arif Roudlotut Tholibin Metro, representing a diverse mix of learning preferences and gender. The experimental group received mathematics instruction through interactive media tailored to their individual learning styles—visual, auditory, kinesthetic, and read/write—while the control group was taught using traditional methods.

The findings of this study provide clear and compelling evidence that the integration of interactive media into mathematics instruction significantly enhances students' mathematical communication abilities. Students in the experimental group consistently outperformed their peers in the control group on posttest measures of mathematical communication, demonstrating not only improved understanding but also greater confidence in expressing mathematical ideas both orally and in writing. This result is in line with recent literature, which highlights the potential of interactive and multimedia tools to make abstract mathematical concepts more accessible, engaging, and meaningful for learners.

A key insight from the research is the differential impact of interactive media across learning styles. Visual learners, in particular, showed the greatest improvement, benefiting from the rich visualizations, animations, and graphical representations provided by the interactive media. This supports theoretical frameworks such as Mayer's Multimedia Learning Theory, which posits that learning is most effective when information is presented through both visual and auditory channels . However, the study also found that students with auditory, kinesthetic, and read/write preferences experienced gains, albeit to a lesser extent, suggesting that interactive media—when designed to be multimodal—can support a broad spectrum of learners.

Beyond cognitive gains, the use of interactive media fostered greater student engagement, motivation, and collaboration in the classroom. Observational data indicated that students were more enthusiastic, participated more actively in discussions, and demonstrated improved digital literacy and soft skills. These outcomes are particularly relevant in the context of 21st-century education, where communication, collaboration, and technological fluency are essential competencies.

Despite these positive outcomes, the study acknowledges several limitations. The sample size was relatively small and drawn from a single educational context, which may affect the generalizability of the findings. Additionally, while the study tailored media to students' self-reported learning styles, the ongoing debate regarding the efficacy of learning styles theory suggests that future research should further explore the benefits of multimodal and universally designed instructional strategies .

In light of these findings, the study offers several recommendations for practice and future research. Educators are encouraged to integrate interactive media into mathematics instruction, ensuring that materials are varied and adaptable to different learning preferences. Professional development for teachers in the effective use of technology is also essential. Future research should consider larger and more diverse samples, investigate the long-term effects of interactive media on mathematical communication, and explore how these tools can be optimized for all learners, regardless of their preferred learning style.

In conclusion, this study demonstrates that interactive media, especially when adapted to students' learning styles, can play a pivotal role in enhancing mathematical communication abilities. The integration of such media not only supports academic achievement but also prepares students with the skills necessary for success in a rapidly evolving, technology-driven world. The findings underscore the importance of continued innovation and research in mathematics education to ensure that teaching practices remain responsive to the diverse needs of learners and the demands of the 21st century.

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