Pedagogical Exemplars for Mathematics Across Learning Styles

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Article History:
Received: Feb 27, 2023
Revised: Mar 16, 2023
Accepted: Mar 28, 2023
Online First: Apr 01, 2023

Keywords:
Interactive Media Approach, Learning Styles, Mathematics, Multimedia Instruction, Pedagogical Exemplars.

Kata Kunci:
Contoh Pedagogik, Gaya Belajar, Instruksi Multimedia, Matematika, Pendekatan Media Interaktif.

How to cite:
Ocampo, E.N., Siahaan, K.W.A., Sinaga, S.J., & Cutillas, A.L. (2023). Pedagogical Exemplars for Mathematics Across Learning Styles. *Edunesia: Jurnal Ilmiah Pendidikan, 4*(2), 644-658.

Abstract: This study investigated the effectiveness of different pedagogical exemplars for teaching mathematics across various learning styles using multimedia technology. The study utilized a quasi-experimental design. The experimental group received the intervention through an interactive computer presentation program, while the control group used the standard dialogue and discussion techniques. The study used survey questionnaires adapted from BARSCH's Learning Style Inventory and self-made pre-and post-tests to measure students' learning and engagement. The research findings revealed that students with different learning styles benefited differently from multimedia-assisted instruction, suggesting the importance of considering individual differences in instructional design. The use of multimedia technology in teaching mathematics facilitates the learning process of students with different learning styles. The results of this study also support the importance of using statistical analysis to evaluate the effectiveness of educational interventions and to inform evidence-based decision-making in education. This study identified the most effective pedagogical exemplars for each learning style and highlighted the benefits of interactive media teaching mathematics. These findings suggest that teaching methods that align with students' learning styles can improve academic performance.

Abstrak: Penelitian ini bertujuan untuk menyelidiki keefektifan contoh pedagogis yang berbeda untuk mengajar matematika di berbagai gaya belajar dengan bantuan teknologi multimedia. Penelitian ini menggunakan desain kuasi-eksperimental. Kelompok eksperimen menerima intervensi melalui program presentasi komputer interaktif, sedangkan kelompok kontrol menggunakan teknik dialog dan diskusi tradisional. Studi ini menggunakan kuesioner survei yang diadaptasi dari Learning Style Inventory BARSCH dan tes pra dan pasca yang dibuat sendiri untuk mengukur pembelajaran dan keterlibatan siswa. Temuan penelitian mengungkapkan bahwa siswa dengan gaya belajar yang berbeda mendapat manfaat yang berbeda dari instruksi berbantuan multimedia, menunjukkan pentingnya mempertimbangkan perbedaan individu dalam desain instruksional. Penggunaan teknologi multimedia dalam pembelajaran matematika memudahkan proses belajar siswa dengan gaya belajar yang berbeda. Hasil penelitian ini juga mendukung pentingnya menggunakan analisis statistik untuk mengevaluasi efektivitas intervensi pendidikan dan untuk menginformasikan pengambilan keputusan berbasis bukti dalam pendidikan. Studi ini mengidentifikasi contoh pedagogis yang paling efektif untuk setiap gaya belajar dan menyoroti manfaat menggunakan pendekatan media interaktif dalam mengajar matematika. Temuan ini menunjukkan bahwa metode pengajaran yang selaras dengan gaya belajar siswa dapat meningkatkan prestasi akademik.

https://doi.org/10.51276/edu.v4i2.415

A. Introduction

In today's diverse classrooms, teachers are challenged to provide effective and inclusive instruction to students with various learning styles (Ary et al., 2018). As Mobo et al (2022) argued, the academic world is full of scientific surprises because education is changing rapidly because of its alignment with various sectoral fields. This challenge is particularly acute in mathematics, where the subject matter can be abstract and challenging for many students (Veeck et al., 2020; Burbules et al., 2020). Educators have explored different pedagogical exemplars for mathematics tailored to different learning styles to address this challenge. These pedagogical exemplars aim to create an inclusive and engaging learning environment that enables all students to succeed in mathematics (Comarú et al., 2021; Hasumi & Chiu, 2022).

Learning styles are the preferred ways individuals process and retain information (Jurado de los Santos et al., 2020; Kärchner et al., 2022). Some students may be visual learners who learn best through visual aids and diagrams, while others may be kinesthetic learners who learn best through hands-on activities and movement (Kubilinskiene, 2020; Mandinach & Schildkamp, 2021). Understanding and catering to different learning styles can improve students' engagement and academic performance in mathematics. However, some educators have criticized the notion of learning styles, arguing that little scientific evidence supports the effectiveness of tailoring instruction to individual learning styles (Partovi & Razavi, 2019; Rahman et al., 2021).

Moreover, learning styles play an essential role in mathematics education. According to Cardino & Cruz (2020), students' learning styles can impact their academic achievement in mathematics. Mathematics involves various cognitive processes, including problem-solving, reasoning, and logical thinking (Yu et al., 2022). Catering to students' different learning styles can make mathematics more accessible and engaging for all learners.

For instance, visual learners prefer to process information through visual aids and diagrams. They may need help understanding mathematics concepts if presented purely verbally. To cater to visual learners, educators can use visual aids such as graphs, charts, and diagrams to represent mathematical concepts (Gates, 2018). Additionally, educators can use videos and animations to present complex mathematical concepts in a more accessible manner (Sheridan et al., 2020). Research suggests that visual aids in mathematics instruction can improve students' understanding and retention of mathematical concepts (Dahal et al., 2022). According to Philominraj et al (2017), using visual aids such as diagrams, charts, and graphs has been proven to be an effective pedagogical approach for visual learners. Visual aids are particularly useful in teaching mathematical concepts that involve spatial reasoning, such as geometry and trigonometry. Teachers can use visual aids to represent mathematical ideas and concepts more concretely and tangibly, making it easier for visual learners to understand (Quigley, 2021). Some other studies have also shown that visual aids in mathematics instruction can significantly improve student achievement and engagement (Milligan et al., 2018).

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On the other hand, auditory learners prefer to process information through sound and spoken language. They may need help understanding mathematics concepts if presented purely visually. To cater to auditory learners, educators can use oral explanations and lectures to present mathematical concepts (Capinding, 2021). Additionally, educators can use podcasts and audio recordings to provide students additional resources for understanding mathematical concepts (Donevska-Todorova, 2021). Research suggests that using auditory aids in mathematics instruction can improve students' understanding and retention of mathematical concepts (Soares et al., 2018). Auditory learners learn best through hearing and listening. Teachers can incorporate auditory elements such as music, podcasts, and audio recordings into their mathematics instruction. These auditory elements can introduce mathematical concepts, reinforce learning, and provide feedback to students (Pires et al., 2022). One study found that incorporating music in mathematics instruction can improve student motivation and engagement (Lim et al., 2018).

Meanwhile, kinesthetic learners prefer to learn through hands-on activities and movement. They may need help understanding mathematical concepts if presented visually or through auditory. To cater to kinesthetic learners, educators can use manipulatives and games to present mathematical concepts (Willingham, 2017). Kinesthetic learners, also known as tactile learners, learn best through hands-on activities and movement. Teachers can incorporate manipulatives and interactive activities into their mathematics instruction. Manipulatives such as blocks, cubes, and counters can help kinesthetic learners understand mathematical concepts through physical manipulation and exploration (Furner & Worrell, 2017). Interactive activities such as games, puzzles, and simulations can also engage kinesthetic learners and promote their understanding of mathematical concepts (Iqbal et al., 2019).

In addition to these pedagogical approaches, technology can cater to different learning styles in mathematics instruction. For instance, interactive whiteboards and digital manipulatives can engage visual and kinesthetic learners (Cockett & Kilgour, 2015). Online learning platforms and educational software can also cater to auditory and visual learners by incorporating audio and video elements into instruction (WASİK et al., 2019).

Despite the benefits of catering to different learning styles in mathematics instruction, some educators have criticized the notion of learning styles, arguing that there is little scientific evidence to support tailoring instruction to individual learning styles (Pashler et al., 2008; Willingham, 2018). Some researchers argue that learning styles are not fixed and can change over time, depending on factors such as motivation, attention, and interest (Popovska Nalevska & Kuzmanovska, 2020).

Despite these criticisms, many educators continue developing pedagogical exemplars for mathematics designed to cater to different learning styles (Serdyukov, 2017). This research paper explores different pedagogical exemplars for mathematics across learning styles and analyses their effectiveness in promoting student learning and engagement. Specifically, this paper will review the existing literature on pedagogical

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exemplars for mathematics across different learning styles and identify the most effective exemplars for each learning style (Truong, 2016).

The paper will begin by providing a brief overview of learning styles and their importance in mathematics education (El-Emadi et al., 2019; Zhong & Xia, 2020). It will then discuss the pedagogical exemplars developed for different learning styles, including visual, auditory, kinesthetic, and tactile learners (Batubara, 2019; Nind, 2020). The paper will review the existing literature on these pedagogical exemplars and analyze their effectiveness in promoting student learning and engagement (Troussas et al., 2020).

B. Method

This research uses a quasi-experimental design whereby the pre-test result from both groups (experimental and controlled) was utilized as the basis if there is a mean gain after an intervention is administered to both the experimental and the control groups. The formula is presented below:

Table 1. Research Design

Exp.	O_1	X_1	O_3
Cont	O_2	X_2	X4

Where:
O1 and O2 – Observations 1 and 2 were the pre-tests
X1 – interactive media
X2 – traditional method
O3 and O4 – observations 3 and 4, were the post-test

This study utilized multimedia learning material, referred to as the pedagogical exemplars developed for Senior High School (SHS) students, particularly in their Mathematical lessons. This study consisted of three sections of Grade 11 learners, having 54 respondents that represent each group, who were universally placed into the learning groups based on their dominant learning style.

https://doi.org/10.51276/edu.v4i2.415

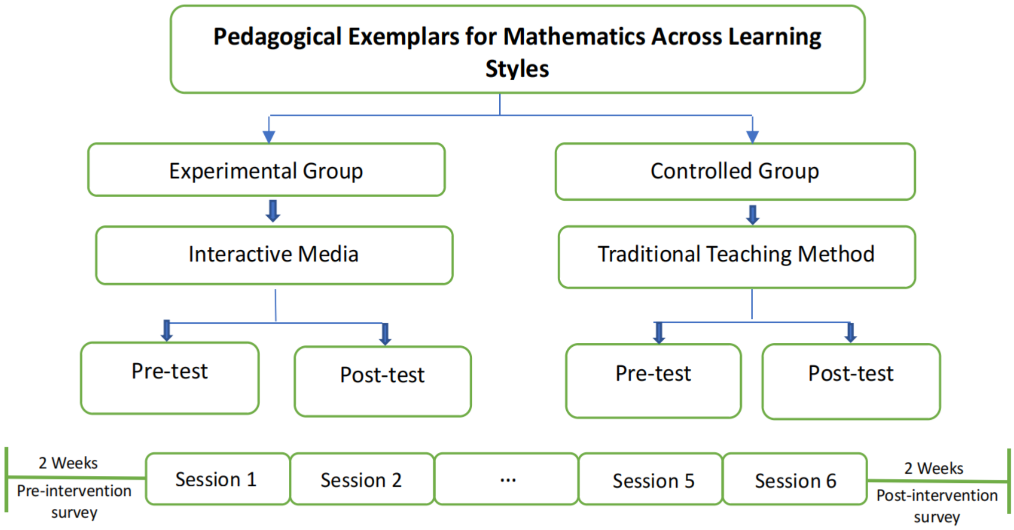

Figure 1. Research Flow of the Study

BARSCH's learning style inventory was developed by Neil D. Fleming (in Delgado-Rebolledo & Zakaryan, 2020). was used to classify the respondents as Visual, Auditory, or Kinesthetic (VAK). Then, each learning group was divided evenly by drawing their names alternately one by one, one as the experimental group and the other as the controlled group, until all names were put to either of the groups. After doing this, there were six (6) different groups, two groups (experimental and controlled) for Visual learning style, another two groups for Auditory learners, and two groups for Kinesthetic learners.

All groups took the pre-test in SHS Mathematical Lessons as one of the bases of the mean gain from the competencies of the selected topics in Senior High School Mathematical lessons before they were conducted with an intervention. In this research, two types of data were collected, primary and secondary data. The preliminary data was taken from the respondents' responses as to what particular gadget they thought was the best tool for them to learn Mathematics independently; then, the classification of the degrees of the common problems encountered in learning Mathematical lessons; and the dominant learning styles upon using the adapted BARSCH's learning style inventory developed by Neil D. Fleming. This Learning Style Inventory checked the exact learning style of the respondents and the consideration of their Mathematics Achievement through interactive media and conventional/ traditional methods in teaching the mathematics lesson (Sáez-López et al., 2019).

The secondary data was determined from the pre-test and post-test results in SHS Mathematics. The pre-test was administered before the intervention, while the post-test was administered right after the last day of the intervention to both groups (experimental and controlled). After conducting the research, data were tabulated, analyzed, and interpreted using appropriate statistical tools.

https://doi.org/10.51276/edu.v4i2.415

C. Result and Discussion

Result

Dominant Perceptual Learning Styles

The data in the table show the pre-test and post-test scores for students in three different learning style groups (visual, auditory, and kinesthetic) in four different mathematical tasks. The results indicate that all groups significantly improved from pre-test to post-test scores in all tasks. Specifically, the auditory group showed the greatest improvement in performing mathematical operations of functions and illustrating, classifying, and finding random variables. The visual group showed the greatest improvement in understanding, defining, and formulating statistical hypotheses. In contrast, the kinesthetic group showed the highest gain in illustrating and symbolizing propositions and distinguishing between simple and compound propositions.

Table 2. Dominant Perceptual Learning Styles of the Respondents

Study Groups	Learning Styles						Total	
	Visual		Auditory		Kinesthetic			
	f	%	*f*	%	*f*	%	*f*	%
Experimental	22	20.4	20	18.52	12	11.11	54	50.00
Controlled	22	20.37	20	18.52	12	11.11	54	50.00
Total	44	40.74	40	37.04	24	22.22	108	100.00

The implications of this study suggest that teachers should consider students' learning styles when designing instructional materials and activities. Teachers could use various methods to present information, including visual aids, auditory explanations, and hands-on activities. The results of this study also suggest that students may have different strengths in different areas, depending on their learning style, which could be considered when assigning tasks or forming groups (Moreno-Guerrero et al., 2020).

The article investigates the effects of multimedia-assisted instruction on the mathematical problem-solving skills of students with different learning styles. The study involved 108 ninth-grade students and found that multimedia-assisted instruction positively impacted the students' problem-solving skills. Additionally, the study found that students with different learning styles benefited differently from multimedia-assisted instruction, suggesting the importance of considering individual differences in instructional design. As Kärchner et al (2021) affirmed, cell phones, tablets, and other handheld technological gadgets increasingly support student learning. Hence, this finding provides insights into how multimedia technology can be utilized in education to cater to students with different learning styles.

https://doi.org/10.51276/edu.v4i2.415

Mathematics Performance of the Experimental Group

The table presents the pre-test and post-test scores for three learning styles - visual, auditory, and kinesthetic - on four mathematical tasks. The scores represent the mean score for each learning style group, with the pre-test scores on the left and the post-test scores on the right.

Table 3. Mathematics Performance of the Experimental Group

Competencies \ Learning Styles	Visual		Auditory		Kinesthetic	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Perform the Mathematical Operations of Functions	6.36	13.45	6.55	14.20	6.33	10.75
Illustrate, Classify, and Find the Random Variables	6.45	13.00	6.95	15.25	5.92	10.58
Illustrate and Symbolize Propositions and Distinguish between Simple and Compound Propositions	10.36	12.14	10.40	14.15	9.42	11.17
Formulate Statistical Hypothesis; Distinguish between Null and Alternative Hypotheses, Non-directional and Directional, Left-tailed and Right-tailed	2.23	9.59	3.95	9.60	4.42	9.08

In the first row, the visual group had a mean score of 6.36 on the pre-test for performing mathematical operations of functions and a mean score of 13.45 on the post-test. Similarly, the auditory group had a mean score of 6.55 on the pre-test and a mean score of 14.20 on the post-test, while the kinesthetic group had a mean score of 6.33 on the pre-test and a mean score of 10.75 on the post-test.

The table shows that all three learning styles improved their scores on all four mathematical tasks from the pre-test to the post-test, indicating that the intervention effectively improved mathematical performance. However, the degree of improvement varied across tasks and learning styles. The data in the table show the pre-test and post-test scores for students in three different learning style groups (visual, auditory, and kinesthetic) in four different mathematical tasks. The results indicate that all groups significantly improved from pre-test to post-test scores in all tasks. Specifically, the auditory group showed the greatest improvement in performing mathematical operations of functions and illustrating, classifying, and finding random variables. The visual group showed the highest gain in understanding, defining, and formulating statistical hypotheses. In contrast, the kinesthetic group showed the greatest improvement in illustrating and symbolizing propositions and distinguishing between simple and compound propositions.

Pre-Post Mean Gain on the Mathematics Performance of Two Groups

The results show that the experimental group had a higher mean score on the pre-test (26.46) than the control group (25.09), indicating that the two groups were not equivalent

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at the start of the study. However, after the intervention, the experimental group had a significantly higher mean score on the post-test (48.57) than the control group (42.74), indicating that the intervention effectively improved academic performance. Additionally, the experimental group had a larger mean gain (22.11) than the control (17.65), indicating that the intervention had a greater impact on academic performance.

Table 4. Pre-Post Mean Gain on the Mathematics Performance of Two Groups

Study Groups	Mean		Mean Gain
	Pre-test	Post-test	
Experimental	26.46	48.57	22.11
Controlled	25.09	42.74	17.65

These data imply that the intervention improved academic performance and impacted academic performance more than the control group. These findings suggest that the intervention could benefit individuals or groups with similar academic needs. The data also suggest that it is important to establish a control group to ensure that any observed improvements can be attributed to the intervention and not to other factors. Overall, the study highlights the importance of evidence-based interventions and the need to evaluate their effectiveness through rigorous research designs.

Significant Difference of the Mean Gain between the Experimental and Controlled Groups

Many studies have proven that multimedia in delivering lessons to learners can increase students' performance. Table 4 shows the significant difference in the mean gain between the experimental and controlled groups.

Table 5. Significant Difference of the Mean Gain between the Experimental and Controlled Groups

Groups	Mean Gain	Computed T-Value	Critical t-value	Decision	Interpretation
Experimental	22.11	9.68	2.01	Reject Ho	Significant
Control	17.65				

The table presented displays the mean gain, computed t-value, critical value, decision, and interpretation of a study comparing two experimental and control groups' learning outcomes. The mean gain for the experimental group is 22.11, while for the control group, it is 17.65. The computed t-value is 9.68, greater than the critical value of 2.01 for a two-tailed test with a 99% confidence level. Therefore, the null hypothesis is rejected, and the alternative hypothesis is accepted. The decision is to reject Ho, and the interpretation is that there is a significant difference in the mean gain between the experimental and control groups.

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These data imply that the experimental group showed a significantly higher mean gain than the control group, indicating that the intervention or treatment used in the experimental group was effective in improving learning outcomes.

Significant Difference in Mathematics Performance

Table 5 presents the results of a study examining the effectiveness of different learning styles on academic performance. The study involved experimental and controlled groups for the three learning styles: visual, auditory, and kinesthetic. The mean gain score represents the difference between each group's post-test and pre-test scores. The computed t-value indicates how different the experimental and control groups were. The critical t-value is the value at which the difference is considered significant.

Table 6. Significant Difference in Mathematics Performance

Learning Styles	n	Learning Groups	Mean Gain	Computed t-value	df	Tabled - value	Decision	Inter pretation
Visual	44	Experimental	22.77	23.25	43	2.02	Reject Ho	Significant
		Controlled	20.78					
Auditory	40	Experimental	25.35	16.46	39	2.02	Reject Ho	Significant
		Controlled	17.35					
Kinesthetic	24	Experimental	15.50	11.31	23	2.07	Reject Ho	Significant
		Controlled	12.42					

The results show that the experimental groups had significantly higher mean gain scores than the controlled groups for each of the three learning styles, as indicated by the computed t-values and the rejection of the null hypothesis. For example, the experimental group for visual learners had a mean gain score of 22.77 compared to the control group's mean gain score of 20.78, with a computed t-value of 2.02 and a significant p-value. These findings suggest that teaching methods that align with students' learning styles can improve academic performance.

A study by Pashler et al (in Alshurafat et al., 2020) found that teaching methods tailored to student's learning styles are less effective than those not tailored to their learning styles. However, other studies have found that teaching methods that align with students' learning styles can improve academic performance (Yang et al., 2020). The results of this study support the latter findings, suggesting that it may be beneficial for educators to consider students' learning styles when designing instructional strategies.

Discussion

The findings of the study suggest that teachers should consider students' learning styles when designing instructional materials and activities (Skilling & Stylianides, 2020). Teachers could use various methods to present information, including visual aids, auditory explanations, and hands-on activities. The results of this study also suggest that students

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may have different strengths in different areas, depending on their learning style, which could be considered when assigning tasks or forming groups.

The experimental group is found to be aggressive and attentive enough through interactive media, which is in the form of e-learning. Kay posits that multimedia offers remarkable opportunities and challenges for teaching mathematics. The teacher's task is to improve the pedagogy built into the technology platform (Ferreira et al., 2020).

This study further suggests that the method or approach used in the experimental group may help enhance learning outcomes in other contexts. The results of this study also support the importance of using statistical analysis to evaluate the effectiveness of educational interventions and to inform evidence-based decision-making in education (Bobyliev & Vihrova, 2021). Ary et al (2018), in their book, "Introduction to Research in Education", provide clear and accessible explanations of complex research concepts and techniques, making it an ideal resource for students new to research methods.

As implied, many studies report that the achievement, motivation, and learning attitudes of students with different learning styles are changed positively when teaching designs are supported by technology (Cevikbas & Kaiser, 2020). With this concept, the rapid spread of internet usage, using the internet effectively in learning environments has become necessary. In these descriptions of environments that support deep student learning, technology can play a key role in answering the call from the higher authority in education to improve students learning with utmost fulfilment (Alam, 2020).

Overall, the study investigated the impact of multimedia-assisted instruction on the mathematical problem-solving skills of students with different learning styles. The findings suggest that multimedia-assisted instruction had a positive effect on the problem-solving skills of ninth-grade students. Moreover, the study highlighted the importance of considering individual differences in instructional design, as students with different learning styles benefited differently from multimedia-assisted instruction. This finding provides insights into how multimedia technology can be utilized in education to cater to students with different learning styles.

The study's implications suggest that teachers should consider students' learning styles when designing instructional materials and activities. Various methods, such as visual aids, auditory explanations, and hands-on activities, can present information to cater to students with different learning styles. The results also suggest that students may have different strengths in different areas, depending on their learning style, which could be considered when assigning tasks or forming groups.

The study's approach in the experimental group may help enhance learning outcomes in other contexts. The results also support the importance of using statistical analysis to evaluate educational interventions' effectiveness and inform evidence-based decision-making in education.

According to previous studies, using technology in teaching can positively impact students' achievement, motivation, and learning attitudes, especially for those with different learning styles. With the rapid spread of internet usage, using the internet effectively in learning environments has become necessary. Thus, technology can play a key role in improving students' learning and achieving their utmost fulfilment.

In summary, this study highlights the importance of considering individual differences in instructional design and the positive impact of multimedia-assisted instruction on students' problem-solving skills. These findings provide valuable insights into how technology can be utilized in education to cater to students with different learning styles and enhance their learning outcomes.

D. Conclusion

In conclusion, this study highlights the importance of recognizing and accommodating individual learning styles in multimedia-assisted instruction. The findings suggest that tailored instructional design based on individual learning styles can improve academic performance. The study also emphasizes the need for evidence-based educational decision-making through statistical analysis to evaluate the effectiveness of educational interventions.

The implications of this study urge teachers to consider various teaching methods, including visual aids, auditory explanations, and hands-on activities, to cater to students' diverse learning styles. The study suggests that teachers can use students' learning styles to assign tasks and form groups to maximize their strengths. Importantly, the study identifies the most effective pedagogical exemplars for each learning style and highlights the benefits of interactive media teaching mathematics.

This research underscores the need to investigate realistic pedagogical exemplars in different contexts to address different learning styles, including visual, auditory, and kinesthetic learners. Overall, this study provides valuable insights into developing effective teaching strategies for mathematics educators and underscores the importance of considering different learning styles to enhance student learning and engagement.

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