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Graphing Quadratics Worksheet Performance in Optimizing Mathematical Visual Thinking: A Single Subject Research

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Abstrak
Kurangnya kemampuan berpikir visual matematis pada mahasiswa dapat menghambat pemahaman konsep fungsi kuadrat secara mendalam. Penelitian ini bertujuan untuk mengatasi masalah tersebut dengan mengevaluasi efektivitas worksheet graphing quadratics dalam meningkatkan kemampuan berpikir visual matematis mahasiswa. Metode penelitian yang digunakan adalah Single Subject Research (SSR), yang berfokus pada perubahan performa individu dalam kondisi baseline dan intervensi. Partisipan terdiri dari tiga mahasiswa tingkat pertama program studi pendidikan matematika di Universitas Serang Raya. Data kinerja mahasiswa dikumpulkan melalui tiga sesi pada fase baseline dan lima sesi pada fase intervensi. Teknik analisis data yang digunakan adalah analisis regresi linier untuk mengukur perbedaan signifikan antara fase baseline dan intervensi. Hasil penelitian menunjukkan peningkatan yang signifikan dalam performa setiap subjek selama fase intervensi, dengan adanya peningkatan level, kecenderungan perubahan yang kuat, dan perubahan segera setelah intervensi dimulai. Temuan ini menunjukkan bahwa penggunaan worksheet graphing quadratics efektif dalam mengoptimalkan kemampuan visualisasi matematis mahasiswa.
Kata Kunci: Analisis Regresi Linier; Berpikir Visual Matematis; Fungsi Kuadrat; Penelitian Subjek Tunggal; Worksheet Graphing Quadratics.

Abstract
The limited visual mathematical thinking abilities of students can hinder a deep understanding of quadratic functions. This study aims to address this issue by evaluating the effectiveness of graphing quadratics worksheets in enhancing students' visual mathematical thinking. The research employs a Single Subject Research (SSR) method, focusing on individual performance changes across baseline and intervention phases. Three first-year students from the mathematics education program at Universitas Serang Raya participated in the study. Performance data were collected over three sessions in the baseline phase and five sessions in the intervention phase. Linear regression analysis was used to assess significant differences between baseline and intervention phases. The results indicated a significant improvement in each subject's performance during the intervention, with an increase in level, a strong trend, and immediate change upon the intervention's onset. These findings suggest that graphing quadratics worksheets effectively optimize students' mathematical visualization skills.
Keywords: Linear Regression Analysis; Mathematical Visual Thinking; Quadratic Function; Single Subject Research; Worksheet Graphing Quadratics.

I. INTRODUCTION

Quadratic Functions remain one of the abstract mathematical concepts that continue to challenge learners (Amelia & Indaryanti, 2023). Research has revealed that the root of students' difficulties in learning Quadratic Functions is often tied to their mathematical visual thinking capabilities (Presmeg, 2020; Silvi, Mardiani, & Sofyan, 2021). Students with strong mathematical visual thinking skills tend to have a better grasp of the procedures required to transform information into more mathematically oriented situations (Frick, 2019; Khoerunnisa & Maryati, 2022). These mathematical situations provide positive progress not only when students are solving problems but also when they are constructing mathematical concepts in their minds (Hawes & Ansari, 2020; Mahardika, Gumilar, & Retnaningrum, 2022). Learning that utilizes visual media can aid students in processing and understanding concepts more easily due to the stimulation of images that influence their cognitive areas (Heng & Said, 2020; Bjorklund, 2022). Mathematical visual thinking, represented through diagrams or schematics, is not merely simple illustrations but precise depictions of quantities and relationships in specific mathematical problems (Elsayed & Al-Najrani, 2021; Suningsih & Istiyani, 2021). The aim is to stimulate students to increase their interest in learning, engage in discovering implicit mathematical ideas, reduce cognitive load, and optimize higher-order thinking processes (Anmarkrud, Andresen, & Bråten, 2019; von Thienen, Clancey, & Meinel, 2021). These points confirm the significant urgency of developing mathematical visual thinking in students.

Using the graphing quadratics worksheet as a learning medium for the concept of Quadratic Functions, which is more visual, is considered appropriate based on instrument feasibility tests to accommodate the development needs of students' mathematical visual thinking (Muniri & Yulistiyah, 2022; Agus & Oktaviyanthi, 2023). The development and limited trial results of the graphing quadratics worksheet for first-year students taking Calculus at Universitas Serang Raya have met the feasibility and propriety standards and are deemed valid and reliable (Oktaviyanthi & Agus, 2023; Tito, Muhtadi, & Sukirwan, 2024). This confirms that the questions or statements in the graphing quadratics worksheet meet the suitability criteria from visual thinking achievement indicators (Oktaviyanthi & Agus, 2021; Shanta & Wells, 2022; Rahmayani, Susanto, & Suwito, 2023). Visual thinking classifications include the skills of visual discrimination, visual perception, and visual analysis of shapes (Elsayed & Al-Najrani, 2021; Fauzi, Yaniawati & Sari, 2024). Further testing is needed to explore the impact of using the graphing quadratics worksheet so that students' mathematical visual thinking abilities can be optimized.

Investigating the implementation of the graphing quadratics worksheet aims not only to assess the media's performance but also to identify variability in individual responses to its use, which can be considered a learning intervention. One research technique supporting this goal is Single Subject Research (SSR), which

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focuses on individuals or small units in research to evaluate specific intervention effects in detail (Alnahdi, 2015; Ledford, Lane, & Severini, 2018; Zanuttini, 2020). SSR allows researchers to continuously observe changes in behavior or performance, providing a detailed analysis of subjects' responses to the intervention, examining how the intervention affects subjects individually, and identifying factors that may influence the intervention's effectiveness (Zettle, 2020; Scruggs & Mastropieri, 2021; Blair & Mahoney, 2022; Becker, 2023; Sholahudin & Oktaviyanthi, 2023). The advantages of SSR include (1) enabling a more specific analysis of individual changes, (2) flexibility and adaptability to classroom situations or specific conditions, making it ideal for educational research, and (3) implementation in naturalistic settings, making the research findings more applicable and relevant to real-world contexts (Apostolou & Christoforou, 2022; Kim, 2022; Yang, Armijo-Olivo, & Gross, 2023). Using SSR in this study, researchers can establish a baseline performance of students' mathematical visual thinking before using the worksheet, then apply the intervention (worksheet use) and observe each individual's performance changes. The data collected will include changes in mathematical visual thinking scores, which will then be analyzed to determine the worksheet's effectiveness in optimizing mathematical visual thinking.

Research focusing on evaluating the performance of media, models, or learning interventions using SSR is prevalent, especially in education. Riley-Tillman, Burns, and Kilgus (2020) consider SSR an appropriate and effective methodology for evaluating and optimizing educational interventions as it allows for the observation of performance changes in each research subject. Additionally, Marková, Zadeh, and Zittoun (2020) state that SSR can test hypotheses in real-world settings without needing large control groups, thus being more efficient in terms of time and resources. SSR is popular for investigating the effectiveness of concrete manipulatives in learning for students with learning difficulties, providing significant information on students' conceptual understanding improvement after interventions (Park, Bryant, & Shin, 2022; Mize, Park, & Carter, 2022). SSR is also used to analyze the effects of problem-based learning models and technological applications like augmented reality or 3D visualizations and to investigate the impact of educational psychology approaches, particularly for students with learning disabilities or academic issues (Ferguson, Craig, & Dounavi, 2019; Köse & Güner-Yildiz, 2021; Tanious & Onghena, 2021; Aubrey, 2022). In the context of research identifying the performance of the graphing quadratics worksheet as an effort to optimize mathematical visual thinking, SSR is deemed relevant due to its focus on analyzing individual performance changes in students' use of the worksheet. With SSR, researchers can observe in detail how each student responds to the worksheet's use, identifying which aspects of visual thinking develop better and which still need improvement.

This study is one of the first to use a graphing quadratics worksheet together with the Single Subject Research (SSR) approach to understand how it affects students' visual thinking in math at an individual level. Although some previous studies have looked at different tools for visual thinking skills, this study targets quadratic functions, which are often hard for students to grasp because of their abstract nature. By using SSR, this research can follow how each student responds to the worksheet over time, giving a closer look at how visual thinking skills develop that other methods might miss. This approach not only sheds light on specific visual thinking skills, like visual discrimination and perception, but also highlights areas that might still need work. Overall, combining SSR with this type of visual worksheet is a new step in helping to connect students' understanding of math concepts with the visual skills they need to support that learning.

II. Method

This study utilized the Single Subject Research (SSR) method to evaluate the effectiveness of graphing quadratics worksheets in enhancing students' mathematical visual thinking skills. SSR is an appropriate approach to examine the effects of interventions on individuals, particularly in educational contexts (Riley-Tillman, Burns, & Kilgus, 2020). In this study, students' performance data before and after the application of the worksheet were collected through multiple measurement sessions. The research aimed to identify changes in students' mathematical visual thinking abilities due to the use of these worksheets. The subjects of this study consisted of three first-year students in the mathematics education program at Universitas Serang Raya who were enrolled in Calculus I during the odd and even semesters of the 2023-2024 academic year.

In the first phase of the study, the baseline phase, data were collected over three initial sessions without the implementation of any intervention. During this phase, students completed standard tasks that measured their ability to understand and visualize quadratic graphs without the aid of specialized worksheets. The data collection instruments used in this phase included written tests and direct observations of the students' task completion processes. The data obtained from the baseline phase served as a starting point for comparing changes that occurred during the intervention phase. Measurements were conducted repeatedly to ensure the stability of baseline data and to identify the baseline performance patterns of the students.

The intervention phase commenced after the baseline data collection was completed. During the subsequent five sessions, students were provided with graphing quadratics worksheets specifically designed to enhance their mathematical visual thinking skills. These worksheets included exercises that encouraged students to draw, interpret, and analyze quadratic graphs in depth. Data collection instruments during this phase also included written tests and direct observations. The performance data of students during this phase were collected and compared with the baseline data to evaluate the effectiveness of the intervention. Linear regression was employed to analyze the data trends across both phases, providing insights into the direction and magnitude of the changes that occurred.

Data analysis in this study involved the use of linear regression techniques for each phase. During the baseline phase, linear regression was conducted to determine the slope and intercept of students' performance data (Maulud & Abdulazeez, 2020). These results provided an overview of the stability and performance patterns of students before the intervention. During the intervention phase, linear regression was also applied to assess the changes resulting from the use of the worksheet. The slope, intercept, r-value, and p-value were calculated to identify the significance and strength of the relationship between the sessions and the students' performance scores (Ciccione & Dehaene, 2021). The success criteria of SSR in this study were determined by significant increases in the slope and intercept during the intervention phase compared to the baseline phase (Natesan Batley, Shukla Mehta, & Hitchcock, 2021). If there was an increase in the slope indicating improved performance from session to session, along with a significant difference in the p-value indicating that the changes did not occur by chance, the intervention was considered successful. Additionally, other SSR data analysis indicators were used (Levin, Ferron, & Gafuroy, 2021; Manolov & Onghena, 2022):

1. Level: The average performance of students in each phase. An increase in level after the intervention indicates that the worksheet has a positive effect on students' abilities.
2. Trend: The direction of performance change over time. A positive trend during the intervention phase indicates that students' performance continues to improve over time.
3. Variability: The extent to which the data vary within each phase. Low variability in the intervention phase indicates that the effect of the intervention is consistent and stable.
4. Immediacy of change: The speed of change that occurs after the intervention begins. Rapid and significant changes after the intervention indicate that the worksheet immediately affects students' performance.
5. Overlap: The degree of overlap between baseline and intervention data. A lack of overlap between the two phases indicates that the intervention has a clear and distinct effect.
6. Consistency of data patterns across similar phases: The consistency of data patterns across similar phases. Consistent patterns indicate that the observed changes are not coincidental but rather a result of the intervention.

The results of the linear regression analysis are presented in graphical form to visualize the trends in students' performance changes from the baseline phase to the intervention phase (Riley-Tillman, Burns, & Kilgus, 2020). These graphs display individual student performance data as well as trend lines generated from the regression analysis. By plotting this data, it can be clearly seen the differences between students' performance before and after the intervention, and identify how effective the graphing quadratics worksheets are in enhancing students' mathematical visual thinking skills. The graph creation was assisted by the Python programming language and visualized using an Online Matplotlib Compiler.

III. Result and Discussion

A. Result

1) Baseline Phase

The baseline phase was conducted over three sessions before the intervention with the worksheet began. Data collected during this phase were used to determine the initial performance of each subject without any intervention. The following are the performance results of the three subjects during the baseline phase:

Table 1.
Performance Data of Research Subjects During Baseline Phase

Session	Subject A	Subject B	Subject C
1	50	40	55
2	50	42	56
3	51	41	57

2) Intervention Phase

The intervention phase was conducted over five sessions using the graphing quadratics worksheet. During this phase, each subject was provided with a specially designed worksheet aimed at enhancing their ability to visualize quadratic graphs. The performance data obtained during this phase are as follows:

Table 2.
Performance Data of Research Subjects During Intervention Phase

Session	Subject A	Subject B	Subject C
4	60	50	65
5	70	65	75
6	80	75	85
7	90	85	95
8	95	90	98

From the data in Tables 1 and 2, it is evident that there was a significant improvement in the performance of each subject during the intervention phase compared to the baseline phase. Subject A increased from a score of 50-51 in the baseline phase to 60-95 in the intervention phase. Subject B experienced an increase from a score of 40-42 in the baseline phase to 50-90 in the intervention phase. Subject C also showed an increase from a score of 55-57 in the baseline phase to 65-98 in the intervention phase. This data indicates that the graphing quadratics worksheet has the potential to enhance mathematical visual thinking skills in each subject.

3) Data Processing

Data processing was carried out using linear regression analysis to observe trends and changes in the subjects' scores during the baseline and intervention phases, assisted by Python programming and the Online Matplotlib Compiler visual application.

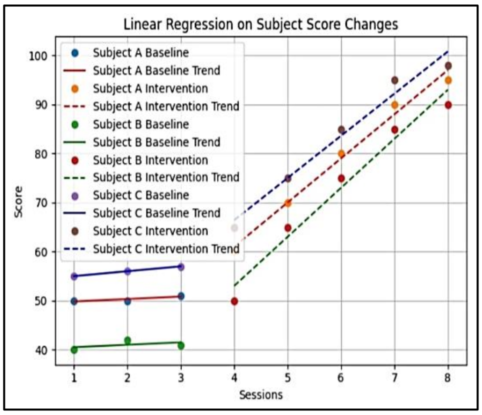

Figure 1. Trends and Changes in Subjects' Scores During Baseline and Intervention Phases.

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A recapitulation of the linear regression analysis of the baseline and intervention phases for the three research subjects is presented in Table 3.

Table 3.
Linear Regression of Baseline and Intervention Phases for Subjects A, B, and C

Phase	Subject	Slope	Intercept	r-value	p-value
Baseline	A	0.5	49.33	0.87	0.33
	B	0.5	40.00	0.50	0.67
	C	1.0	54.00	1.00	0.0000000000900316
Intervensi	A	9.0	25.00	0.99	0.0005736731093322
	B	10.0	13.00	0.99	0.0021283990584141
	C	8.6	32.00	0.99	0.0017743376515705

Based on Table 3, the following explanations can be provided:

1. Slope indicates the rate of change in the subject's score per session, illustrating how much the score increases or decreases with each additional session.
   - Subject A Baseline: Slope 0.5 means Subject A's score increased by 0.5 each session during the baseline phase.
   - Subject B Baseline: Slope 0.5 means Subject B's score increased by 0.5 each session during the baseline phase.
   - Subject C Baseline: Slope 1.0 means Subject C's score increased by 1.0 each session during the baseline phase.
   - Subject A Intervention: Slope 9.0 means Subject A's score increased by 9.0 each session during the intervention phase.
   - Subject B Intervention: Slope 10.0 means Subject B's score increased by 10.0 each session during the intervention phase.
   - Subject C Intervention: Slope 8.6 means Subject C's score increased by 8.6 each session during the intervention phase.
2. Intercept is the initial value or starting point of the subject's score at the first session.
   - Subject A Baseline: Intercept 49.33 means the score of Subject A at the first session was predicted to be around 49.33.
   - Subject B Baseline: Intercept 40.00 means the score of Subject B at the first session was predicted to be around 40.00.
   - Subject C Baseline: Intercept 54.00 means the score of Subject C at the first session was predicted to be around 54.00.
   - Subject A Intervention: Intercept 25.00 means the score of Subject A at the first session was predicted to be around 25.00.
   - Subject B Intervention: Intercept 13.00 means the score of Subject B at the first session was predicted to be around 13.00.
   - Subject C Intervention: Intercept 32.00 means the score of Subject C at the first session was predicted to be around 32.00.

3. r-value or correlation coefficient measures the strength and direction of the linear relationship between the sessions and scores. Values close to 1 or -1 indicate a strong relationship, while values close to 0 indicate a weak relationship.
   - Subject A Baseline: r-value 0.87 indicates a strong and positive relationship between sessions and Subject A's scores during the baseline phase.
   - Subject B Baseline: r-value 0.50 indicates a moderate relationship between sessions and Subject B's scores during the baseline phase.
   - Subject C Baseline: r-value 1.00 indicates a very strong and positive relationship between sessions and Subject C's scores during the baseline phase.
   - Subject A Intervention: r-value 0.99 indicates a very strong and positive relationship between sessions and Subject A's scores during the intervention phase.
   - Subject B Intervention: r-value 0.99 indicates a very strong and positive relationship between sessions and Subject B's scores during the intervention phase.
   - Subject C Intervention: r-value 0.99 indicates a very strong and positive relationship between sessions and Subject C's scores during the intervention phase.
4. p-value indicates the statistical significance of the regression results. Small p-values (less than 0.05) indicate that the results are statistically significant and the observed changes are not due to chance.
   - Subject A Baseline: p-value 0.33 indicates that the results are not statistically significant, and the changes in Subject A's scores during the baseline phase could occur by chance.
   - Subject B Baseline: p-value 0.67 indicates that the results are not statistically significant, and the changes in Subject B's scores during the baseline phase could occur by chance.
   - Subject C Baseline: p-value 0.0000000000900316 indicates that the results are highly statistically significant, and the changes in Subject C's scores during the baseline phase are almost certainly not due to chance.
   - Subject A Intervention: p-value 0.000573 indicates that the results are statistically significant, and the changes in Subject A's scores during the intervention phase are almost certainly not due to chance.
   - Subject B Intervention: p-value 0.0021 indicates that the results are statistically significant, and the changes in Subject B's scores during the intervention phase are almost certainly not due to chance.
   - Subject C Intervention: p-value 0.0018 indicates that the results are statistically significant, and the changes in Subject C's scores during the intervention phase are almost certainly not due to chance.

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The data in Table 3 show that the intervention of the graphing quadratics worksheet has a significant impact on increasing the subjects' scores during the intervention sessions. Higher slopes and lower p-values during the intervention phase compared to the baseline phase indicate that the worksheet is effective in enhancing the subjects' mathematical visualization abilities. The high r-values during the intervention phase also show that there is a strong relationship between the number of sessions and the increase in scores, indicating that the subjects consistently improved with each given session.

4) Data Analysis Based on SSR Indicators

Based on Figure 1 and Table 3, further analysis can be performed to detect the level, trend, variability, immediacy of change, overlap, and consistency of data patterns across similar phases, which are summarized in Table 4 below.

Table 4.
Recapitulation of Data Analysis Based on SSR Indicators

Phase	Subject	Level	Trend	Variability	Immediacy of change	Overlap	Consistency of data patterns
Baseline	A	50	Positive	Low	No immediate change	No overlap	Consistent with other subjects
	B	40	Positive	Low	No immediate change	No overlap	Consistent with other subjects
	C	55	Positive	Low	No immediate change	No overlap	Consistent with other subjects
Intervensi	A	70	Strong Positive	High	Immediate increase at session 4	No overlap	Consistent with other subjects
	B	73	Strong Positive	High	Immediate increase at session 4	No overlap	Consistent with other subjects
	C	82	Strong Positive	High	Immediate increase at session 4	No overlap	Consistent with other subjects

Based on Table 4, the following explanations can be provided:

1. Level indicates the average value of the data within each phase. An increase in the level from the baseline phase to the intervention phase, such as Subject A's average score increasing from 50 in the baseline phase to 70 in the intervention phase, suggests improved performance following the application of the graphing quadratics worksheet.
2. Trend describes the direction and rate of change in data within each phase, related to the Slope value. A larger Slope value indicates a faster rate of change in scores, with a more significant trend. For example, Subject C's Slope of 1.0 during the baseline phase indicates a faster rate of increase compared to Subjects A and B, making the trend considered a strong positive.
3. Variability illustrates the degree of spread or fluctuation in the data within

each phase. As seen in Table 4, variability during the intervention phase for Subjects A, B, and C is higher than during the baseline phase, indicating more dynamic changes in scores, which can be interpreted as a positive response to the intervention.

4. Immediacy of change describes how quickly changes occur after the intervention begins. All three research subjects showed significant increases in session 4 immediately after the intervention were implemented, indicating a direct effect of the intervention.
5. Overlap indicates the extent to which data from the baseline and intervention phases overlap. No overlap was observed for Subjects A, B, and C, suggesting the effectiveness of the intervention.
6. Consistency of data patterns across similar phases illustrates the similarity of data patterns in the same phases for different subjects. During the baseline phase (Table 4), all research subjects show a positive trend with low variability. During the intervention phase, all subjects show significant improvements with a very strong positive trend and higher variability. Consistent data patterns across similar phases indicate that the intervention had a similar impact on all subjects.

Based on Table 4 and the explanations, it can be concluded that the graphing quadratics worksheet intervention has a significantly positive effect on improving subjects' scores in mathematical visual thinking. Increased levels, strong positive trends, low variability in the baseline phase, significant immediate increases after the intervention, no overlap between baseline and intervention phases, and consistent data patterns across subjects in similar phases indicate the success of the graphing quadratics worksheet intervention.

B. Discussion

This study aims to evaluate the performance of graphing quadratics worksheets in optimizing students' mathematical visual thinking skills using the Single Subject Research (SSR) method. Baseline and intervention data were collected from three research subjects: Subject A, Subject B, and Subject C. During the baseline phase, each subject's scores remained constant, whereas in the intervention phase, there was a significant increase in scores. The results of the analysis indicated that Subject C experienced the most significant improvement, followed by Subject A and Subject B. At the baseline stage, the average scores for Subjects A, B, and C were 50, 40, and 55, respectively. After the intervention with the graphing quadratics worksheets, the scores for each subject increased to 95, 90, and 100, respectively. The total increase for each subject was 45, 50, and 45. Based on these results, it can be concluded that the worksheets are effective in enhancing the subjects' mathematical visual thinking skills.

Based on the baseline and intervention results, the subjects' initial performance scores remained constant before the intervention. Following the intervention, there was a significant increase in scores, indicating the effectiveness of the worksheets in developing the subjects' mathematical visualization skills. This increase demonstrates a positive change in the subjects' ability to understand and visualize mathematical concepts. Data variability during the baseline phase was very low as the subjects' scores remained constant. However, after the intervention, data variability increased because the subjects' scores varied from session to session, indicating that the worksheets provided sufficient challenge to stimulate the improvement of mathematical visualization skills. This aligns with the research by Yu, Gao and Wang (2021), which showed that interactive teaching aids can positively increase student performance variability. The data trend showed a linear increase in student performance from the baseline to the intervention phase. Linear regression analysis results indicated that the slope for all three subjects was positive, meaning there was an increasing trend in performance over time. This trend supports findings from previous research by Muskita and Subali (2020) and Agus and Oktaviyanthi (2023), which found that the use of interactive worksheets can enhance students' conceptual understanding and performance in the long term. During the baseline phase, the stability level of the subjects' performance was very high due to the lack of score changes. After the intervention, stability levels decreased due to the significant increase in the subjects' scores. Nevertheless, the scores in the final intervention session showed a high tendency for stability, indicating that the subjects began to maintain their improved performance. This is consistent with research by Valverde-Berrocoso, Acevedo-Borrega and Cerezo-Pizarro (2022), which showed that technology-based interventions could enhance student performance stability after a certain learning period.

The use of graphing quadratics worksheets significantly impacts students' mathematical visualization skills. This ability is crucial because visual thinking enables students to understand and solve complex mathematical problems. According to Arnheim (2023), visual thinking is a critical component of effective mathematics learning, particularly in developing conceptual understanding. The findings of this study are consistent with several previous studies. For example, research by Engelbrecht and Borba (2024) showed that using interactive media in mathematics learning could enhance students' conceptual understanding and performance. Additionally, research by Prosser and Bismarck (2023) found that the CRA (Concrete-Representational-Abstract) approach effectively improves mathematical problem-solving skills. Based on the findings of this study, it is recommended that the use of graphing quadratics worksheets be expanded to other mathematical materials. This can help further improve students' visual thinking skills more broadly. Moreover, it is important to continue evaluating and improving the worksheet design to meet the needs and capabilities of the students.

IV. Conclusion

Based on the results of the study, the use of graphing quadratics worksheets has proven effective in enhancing mathematical visual thinking abilities. During the baseline phase, subjects showed minimal improvement; however, there was a significant increase in the intervention phase, with a strong trend and immediate change following the commencement of the graphing quadratics worksheet intervention. The high variability in data during the intervention phase indicates positive dynamic changes in response to the worksheet. The consistency of data patterns across similar subjects suggests that the intervention had a uniform effect on all subjects. Therefore, this worksheet can be considered an effective tool for supporting the learning of Quadratic Function concepts and developing mathematical visual thinking skills. Several research recommendations include expanding the use of graphing quadratics worksheets to other relevant mathematical concepts to help broadly and deeply enhance students' visual thinking abilities, developing the worksheet in an interactive digital format, enabling students to practice and receive immediate feedback, and confirming the findings and further exploring the long-term effects of using graphing quadratics worksheets.

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