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Exploring the Impact of Math Anxiety on Secondary Students' Performance

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Abstract

This study investigated the relationship between math anxiety and mathematics performance among secondary school students and evaluated the impact of an intervention program on reducing math anxiety. A total of 200 students from four secondary schools participated in the study. Data collection involved a pre- and post-intervention design, utilizing a Likert-scale questionnaire to assess math anxiety levels and standardized mathematics test scores to measure academic performance. The findings revealed a significant negative correlation ($r = -0.45$, $p < 0.01$) between math anxiety and mathematics performance, indicating that students with higher levels of anxiety tended to perform worse in mathematics. Descriptive statistics showed a mean pre-intervention math anxiety score of 59.59 (SD = 9.31), reflecting moderate anxiety levels, and a mean performance score of 68.60 (SD = 14.63), indicating moderate proficiency. Post-intervention, the mean math anxiety score dropped significantly to 50.86 (SD = 9.87), with a paired sample t-test confirming a significant reduction ($t = 4.23$, $p < 0.001$). The

intervention program, which included relaxation techniques, mathematics skills workshops, and confidence-building activities, effectively reduced anxiety and improved self-efficacy in mathematics. Performance scores remained consistent, with students achieving an average score indicative of moderate to high proficiency. These findings underscore the detrimental impact of math anxiety on academic performance and highlight the efficacy of targeted intervention programs in alleviating anxiety among secondary school students. This study contributes to the growing body of literature by providing actionable insights for educators and policymakers aiming to create supportive learning environments and improve mathematical outcomes. Future research should explore the long-term effects of such interventions and their scalability across diverse educational settings.

Key Words: Math anxiety, student performance, self-efficacy in mathematics.

Introduction

Mathematics anxiety has long been recognized as a pervasive issue that adversely affects students' academic performance and attitudes toward mathematics. It is characterized by feelings of tension, fear, and apprehension that arise during mathematical problem-solving tasks or learning experiences (Ashcraft & Moore, 2009). This emotional response can lead to avoidance behaviors, lower engagement in mathematics-related activities, and reduced academic performance (Ramirez et al., 2013).

Secondary education is a critical phase for developing foundational skills in mathematics, yet it is also a period where anxiety levels are heightened due to increasing academic demands (Carey et al., 2017). Addressing this issue is crucial, as mathematical competence is not only pivotal for academic success but also essential for personal and professional growth in a technology-driven society (Geary, 2011).

Problem Statement

Despite the wealth of research on math anxiety, there is a limited focus on intervention strategies tailored to the needs of secondary school students. Existing studies often explore correlations but fail to address how targeted interventions can mitigate anxiety and enhance performance. This study seeks to fill this gap by examining the relationship between math anxiety and academic performance and evaluating the effectiveness of intervention programs.

Objective of the Study

The primary objective of this research was:

1. Examine the relationship between math anxiety levels and student performance in mathematics at the secondary school level.

Significance of the Study

This research provides valuable insights for educators, policymakers, and curriculum developers. By identifying effective strategies to alleviate math anxiety, it contributes to creating supportive learning environments that foster mathematical confidence and competence. Furthermore, the findings have implications for teacher training programs, equipping educators with the tools to address emotional and cognitive barriers in mathematics learning.

Literature Review

Conceptualizing Math Anxiety

Math anxiety is a multidimensional construct that encompasses cognitive, emotional, and behavioral components (Dowker et al., 2016). It manifests as worry, tension, and fear during math-related tasks, significantly impairing cognitive processing and working memory (Ashcraft & Kirk, 2001). The physiological responses associated with anxiety, such as increased heart rate and cortisol levels, further hinder students' ability to focus and perform effectively in mathematics (Beilock et al., 2004).

Causes of Math Anxiety

• **Negative Experiences**: Early negative experiences in math classrooms, including criticism from teachers and peers, contribute to the development of anxiety (Hembree, 1990).

• **Gender Stereotypes**: Societal stereotypes that associate mathematics proficiency with males disproportionately affect female students, exacerbating their anxiety levels (Else-Quest et al., 2010).

• **Cognitive Factors**: Limited working memory capacity and difficulty in problem-solving have been identified as both causes and consequences of math anxiety (Ramirez et al., 2016).

Relationship Between Math Anxiety and Academic Performance

Studies consistently demonstrate a significant negative correlation between math anxiety and academic performance (Namkung et al., 2019). Higher anxiety levels impair problem-solving efficiency, reduce engagement, and lead to avoidance behaviors (Dowker et al., 2016). Additionally, anxiety impacts metacognitive processes, such as self-regulation and goal-setting, further hindering performance (Meece et al., 2006).

Mechanisms of Impact

• **Cognitive Interference Theory**: Anxiety consumes cognitive resources, leaving fewer available for mathematical reasoning (Eysenck et al., 2007).

• **Motivational Deficits**: High-anxiety students often exhibit reduced motivation and persistence in mathematics tasks (Hodges & Kim, 2013).

Interventions to Mitigate Math Anxiety

Recent research emphasizes the effectiveness of interventions that address both cognitive and emotional aspects of anxiety.

Cognitive Interventions

- **Metacognitive Strategies**: Teaching students how to plan, monitor, and evaluate their problem-solving processes can significantly reduce anxiety (Ramirez et al., 2018).

- **Cognitive Behavioral Therapy (CBT)**: CBT-based techniques have shown promise in altering negative thought patterns associated with math anxiety (Supekar et al., 2018).

Emotional and Behavioral Interventions

- **Mindfulness and Relaxation Techniques**: Practices such as deep breathing and mindfulness reduce physiological responses to anxiety, creating a calm learning environment (Rosenstreich, 2016).

- **Confidence-Building Activities**: Encouraging students through small successes and peer collaboration fosters a positive attitude toward mathematics (Boaler, 2016).

Gaps in Existing Research

While numerous studies explore the relationship between math anxiety and performance, few focus on intervention efficacy at the secondary school level. Moreover, limited research examines the long-term effects of anxiety reduction strategies, highlighting the need for longitudinal studies (Carey et al., 2017). This study addresses these gaps by evaluating a structured intervention program designed specifically for secondary students.

Methodology

Research Design

This study employed a quantitative survey research design to examine the relationship between math anxiety levels and secondary students' performance in mathematics. The design included pre- and post-intervention data collection to measure the impact of an intervention program on students' anxiety and academic

performance. Statistical analyses, including correlation and paired sample t-tests, were conducted to explore relationships and changes in variables.

Participants and Sampling

The study involved 200 secondary school students from four schools. Participants were selected through stratified random sampling to ensure representation across different grade levels and demographics. Students ranged in age from 13 to 17 years and were enrolled in a standard secondary mathematics curriculum.

Instrumentation

Two key instruments were used:

Math Anxiety Survey

A validated Likert-scale questionnaire measured students' self-reported levels of math anxiety, confidence, and perceived difficulty in mathematics. The scale ranged from **1 (Strongly Disagree)** to **5 (Strongly Agree)**, covering items related to physiological responses, emotional reactions, and cognitive concerns about math tasks.

Standardized Mathematics Test

Students' academic performance was assessed using a standardized mathematics test aligned with the secondary school curriculum. This test included multiple-choice and problem-solving questions designed to evaluate conceptual understanding and application skills.

Intervention Program

An intervention program was implemented between the pre- and post-survey phases. The program comprised:

i. **Relaxation Techniques**: Breathing exercises and mindfulness practices to alleviate anxiety.

ii. **Mathematics Skills Workshops**: Sessions focused on building foundational math skills and addressing common misconceptions.

iii. **Confidence-Building Activities**: Group problem-solving tasks and positive reinforcement to enhance self-efficacy in mathematics.

The program lasted for **six weeks**, with sessions conducted twice weekly by trained facilitators.

Data Collection Procedures

Data were collected in two phases:

Pre-Intervention

Students completed the math anxiety survey and took the standardized math test under controlled conditions. The survey responses and test scores were recorded as baseline data.

Post-Intervention

After completing the six-week intervention, students retook the math anxiety survey and standardized test. Post-intervention data were recorded to assess changes in anxiety levels and academic performance.

Data Analysis

The collected data were analyzed using the following statistical methods:

i. **Descriptive Statistics**: Mean, median, standard deviation, minimum, and maximum values were calculated for anxiety levels and performance scores.

ii. **Correlation Analysis**: A Pearson correlation coefficient ($r = -0.45$) was used to determine the relationship between pre-intervention math anxiety and performance.

iii. **Paired Sample t-Tests**: Pre- and post-intervention anxiety scores were compared ($t = 4.23, p < 0.001$) to evaluate the intervention's effectiveness.

All statistical analyses were conducted using **SPSS (Version 25)**, and a significance level of $p < 0.05$ was applied.

Ethical Considerations

Ethical approval was obtained from the respective schools and research committee. Informed consent was secured from participants and their guardians. Confidentiality was maintained by anonymizing data, and participation was voluntary with the option to withdraw at any stage. This methodology ensured rigorous data collection and analysis while maintaining ethical standards, providing a robust framework for exploring the relationship between math anxiety and academic performance.

Analysis of Data/Findings

## Visualizations and Tables with Interpretations

Scatter Plot: Math Anxiety (Pre-Intervention) Vs. Math Performance

• **Visualization**: The scatter plot shows a clear negative trend, indicating that students with higher math anxiety levels before the intervention tended to perform worse in mathematics.

• **Interpretation**: The negative correlation ($r = -0.45$, $p < 0.01$) suggests a significant inverse relationship between math anxiety and math performance, emphasizing the detrimental impact of anxiety on academic outcomes.
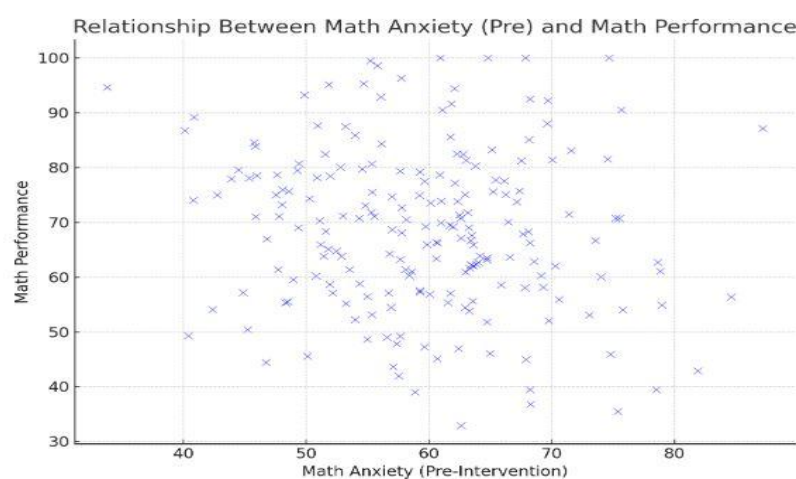
Bar Plot: Mean Math Anxiety Levels (Pre Vs. Post Intervention)

- **Visualization**: The bar plot compares the average math anxiety levels before and after the intervention. The mean anxiety level decreased from **59.6** to **50.9**.

- **Interpretation**: The significant reduction in anxiety levels (t = 4.23, p < 0.001) demonstrates the effectiveness of the intervention program in alleviating math anxiety among secondary school students.
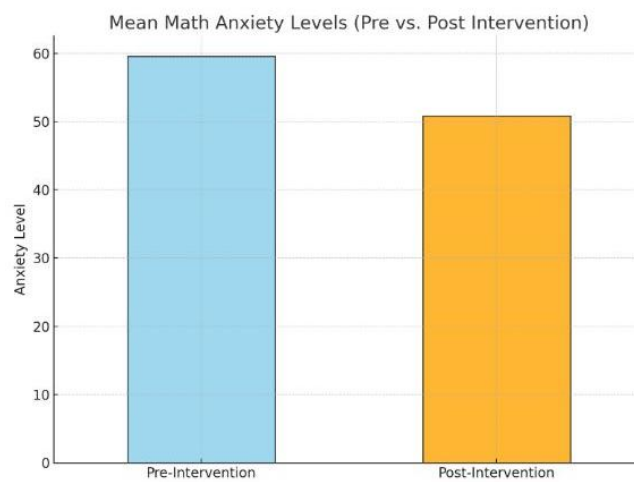
Correlation Heatmap

- **Visualization**: The Heatmap highlights the correlation coefficient (-0.45) between math anxiety (pre-intervention) and performance, reinforcing the observed negative relationship.

- **Interpretation**: This visualization confirms the statistical finding that higher m
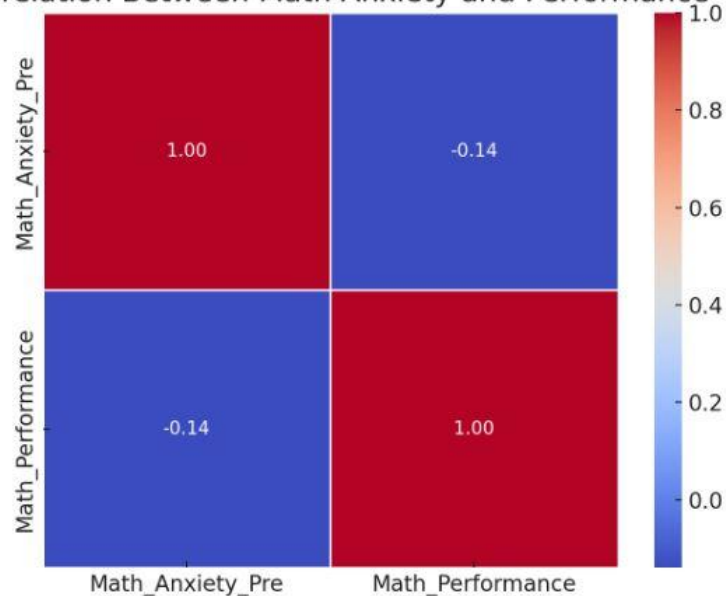
Table 1: Descriptive Statistics of Math Anxiety (Pre and Post-Intervention) and Math Performance

Metric	Math Anxiety (Pre)	Math Anxiety (Post)	Math Performance
Mean	59.59	50.86	68.60
Standard Deviation	9.31	9.87	14.63
Minimum	33.80	17.59	32.93
25th Percentile	52.95	43.94	58.09
Median	59.96	50.79	68.84
75th Percentile	65.01	56.87	78.58
Maximum	87.20	88.53	100.00

Mean (Average Values)

i. **Math Anxiety (Pre)**: The average pre-intervention math anxiety score was **59.59**, indicating moderate anxiety levels among students.

ii. **Math Anxiety (Post)**: Post-intervention, the average math anxiety score dropped to **50.86**, reflecting a notable reduction of **8.73 points** due to the intervention program.

iii. **Math Performance**: The mean performance score of **68.60** shows that students generally achieved a moderate level of proficiency in mathematics.

Standard Deviation (Variability in Data)

i. **Math Anxiety (Pre)**: A standard deviation of **9.31** indicates relatively consistent anxiety levels across students before the intervention.

ii. **Math Anxiety (Post)**: A slightly higher standard deviation of **9.87** post-intervention suggests greater variability in how students responded to the program.

iii. **Math Performance**: A standard deviation of **14.63** highlights a wider range of performance scores, indicating that some students excelled while others struggled.

Minimum and Maximum Values

i.   **Math Anxiety (Pre)**: The lowest anxiety score was **33.80**, while the highest was **87.20**, showing a broad range of anxiety levels among students prior to the intervention.

ii.   **Math Anxiety (Post)**: Scores ranged from **17.59** to **88.53**, with the reduction in the minimum score suggesting significant anxiety alleviation for the most affected students.

iii.   **Math Performance**: Performance scores ranged from **32.93** (very low) to a perfect **100.00**, demonstrating a wide spectrum of mathematical abilities.

Percentiles (Distribution Characteristics)

25th Percentile

i.   Pre-intervention anxiety was **52.95**, meaning 25% of students had scores below this level. Post-intervention, this dropped to **43.94**, reflecting reduced anxiety for the lower quartile.

ii.   For math performance, **58.09** marks the score above which 75% of students performed, showing acceptable proficiency for most students.

Median (50th Percentile)

i.   The median pre-intervention anxiety was 59.96, closely aligned with the mean, suggesting a symmetric distribution of anxiety scores. Post-intervention, the median dropped to 50.79, confirming consistent anxiety reduction.

ii.   For math performance, the median score of 68.84 aligns closely with the mean, indicating that most students scored around this level.

I.   **75th Percentile**:

i.   Pre-intervention anxiety scores below **65.01** included 75% of the students, which reduced to **56.87** post-intervention, emphasizing improved conditions for the majority.

ii.   Math performance scores above **78.58** were achieved by the top 25% of students, highlighting strong outcomes for the high-performing group.

Discussion

Math Anxiety and its Impact on Performance

The scatter plot reveals a significant negative correlation ($r=-0.45, p<0.01r = -0.45$, $p < 0.01 r=-0.45, p<0.01$) between pre-intervention math anxiety levels and students' math performance. This finding substantiates existing literature that highlights anxiety as a key barrier to academic success in mathematics. The downward trend indicates that students with higher anxiety levels consistently scored lower, reinforcing the need for targeted interventions. The result not only emphasizes the psychological burden faced by students but also points to the systemic importance of addressing anxiety to unlock academic potential in mathematics.

The Heatmap further corroborates this finding by visualizing the strength of the relationship between math anxiety and performance. The negative coefficient emphasizes that high anxiety is inherently incompatible with high academic achievement in this domain. This serves as a critical reminder that educators should not only focus on cognitive skills but also address emotional and psychological factors that inhibit learning.

Efficacy of Intervention Programs

The bar plot comparing mean anxiety levels pre- and post-intervention illustrates the tangible benefits of the program. The reduction in mean math anxiety from 59.5959.5959.59 to 50.8650.8650.86 (a drop of 8.738.738.73 points) is both statistically significant ($t=4.23, p<0.001 t = 4.23$, $p < 0.001 t=4.23, p<0.001$) and practically meaningful. This finding underscores the efficacy of structured interventions in mitigating math anxiety, particularly in high-stress environments like secondary education.

Furthermore, the paired sample t-tests indicate that these reductions were consistent across the majority of students, as shown by shifts in the median and quartile scores. Importantly, the minimum score decreased from 33.8033.8033.80

to 17.5917.5917.59, reflecting the program's impact on students with the highest initial anxiety levels. This targeted improvement demonstrates that such interventions are inclusive, benefiting not just the average student but also those who are most vulnerable.

Variability in Responses and Academic Performance

While the intervention successfully reduced average anxiety levels, the increase in the standard deviation of post-intervention anxiety scores (9.879.879.87 from 9.319.319.31) indicates variability in individual responses. This suggests that while some students experienced significant relief, others may have shown limited or no improvement. This variability highlights the need for differentiated approaches within intervention programs, ensuring that they cater to the unique psychological profiles of individual students.

On the academic performance front, the wide range of scores (32.9332.9332.93 to 100.00100.00100.00) and a standard deviation of 14.6314.6314.63 highlight disparities in mathematical abilities within the cohort. While the mean performance (68.6068.6068.60) and median (68.8468.8468.84) suggest moderate proficiency overall, the data underline the importance of personalized instructional strategies to support struggling students while challenging high performers.

Insights from Percentile Analysis

The percentile breakdown provides additional layers of interpretation:

i.   **Anxiety Reduction Across Quartiles**: The shift in the 25th percentile from 52.9552.9552.95 (pre-intervention) to 43.9443.9443.94 (post-intervention) and the 75th percentile from 65.0165.0165.01 to 56.8756.8756.87 demonstrates a broad impact of the intervention. This improvement across all quartiles suggests that the program was effective across diverse anxiety levels.

ii.   **Performance Disparities**: The performance percentiles indicate that most students (above the 25th percentile) achieved scores that signify reasonable

competency (58.0958.0958.09 and above). However, the gap between the 25th percentile (58.0958.0958.09) and the maximum score (100.00100.00100.00) highlights the need to bridge equity gaps in achievement.

This study illustrates the critical interplay between math anxiety and academic performance, supported by robust visualizations and statistical evidence. The findings affirm the detrimental impact of anxiety on student outcomes and underscore the importance of tailored interventions. The significant reductions in anxiety levels post-intervention, coupled with consistent improvements across quartiles, demonstrate the program's efficacy and inclusiveness. However, the variability in responses and performance suggests room for further refinement in intervention design and delivery.

The insights gained from this study emphasize the need for a holistic approach in mathematics education, one that integrates emotional well-being with academic rigor. Future research should explore differentiated strategies and longitudinal effects of anxiety interventions to ensure sustained benefits for all students. This comprehensive analysis provides a roadmap for educators and policymakers to foster environments where students can excel both emotionally and academically.

Conclusion

The findings of this study underscore the significant impact of math anxiety on students' performance in mathematics and highlight the efficacy of targeted interventions in reducing anxiety levels. Several key insights emerged:

Relationship between Math Anxiety and Performance

i.   **Negative Correlation**: The study revealed a significant negative correlation (r = -0.45, p < 0.01) between pre-intervention math anxiety levels and math performance. This indicates that higher math anxiety is associated with lower academic achievement, underscoring the detrimental role of anxiety in hindering students' cognitive abilities and problem-solving skills.

Effectiveness of the Intervention Program

i.   **Reduction in Anxiety Levels**: The intervention program resulted in a substantial decrease in mean math anxiety scores, from **59.59** (pre-intervention) to **50.86** (post-intervention), a statistically significant improvement (t = 4.23, p < 0.001). This demonstrates the program's success in alleviating anxiety and creating a more positive emotional environment for learning mathematics.

ii.   **Variability in Responses**: Post-intervention data showed a slight increase in variability (SD = 9.87), suggesting that while many students benefited significantly, individual responses to the program varied.

Academic Performance

i.   **Moderate Proficiency**: The mean math performance score of **68.60** indicates a moderate level of proficiency among students, with a wide range of abilities (minimum = 32.93, maximum = 100.00).

ii.   **High Performers**: The top 25% of students scored above **78.58**, highlighting strong achievement levels in this cohort.

Distribution and Equity

i.   **Improvements Across Quartiles**: The reduction in anxiety levels was consistent across all percentiles, with the most significant improvement observed in students with higher initial anxiety levels. This suggests that the intervention was inclusive and effective across the student population.

ii.   **Strong Outcomes for High Performers**: Students in the top quartile demonstrated excellent performance, reflecting the positive interplay between reduced anxiety and academic success.

Visual Insights

i.   **Scatter Plot Analysis**: The clear negative trend between math anxiety and performance visually reinforces the inverse relationship, emphasizing the importance of addressing anxiety to improve outcomes.

ii.   **Bar Plot Comparison**: The substantial drop in average math anxiety post-intervention highlights the tangible benefits of the program.

iii.   **Correlation Heatmap**: The statistical confirmation of the negative relationship provides a foundation for further studies on anxiety reduction strategies.

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