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Mathematical Anxiety and Scientific Literacy of Secondary School Students

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Abstract

Mathematical Anxiety refers to a "feeling of tension, apprehension, or fear that interferes with mathematical performance" (Ashcraft, 2002). It can make it hard to concentrate, solve problems, or even try mathematical tasks. It can lead to avoidance of mathematical-related tasks, poor performance, and low self-confidence. Scientific Literacy is the "ability of students to use their Scientific knowledge and skills in different areas and life situations", PISA (2006). It includes understanding scientific concepts, processes, and the ability to think critically, interpret data, and apply scientific reasoning (OECD, 2019). This paper intends to find out the relationship between the Mathematical Anxiety and Scientific Literacy of Secondary School Students. The investigator used the normative survey method for the present study. The population of the present study comprises all the secondary students in Kerala. A sample of 150 secondary students was selected from Thiruvananthapuram district. The investigator used the Mathematical Anxiety Scale, which included components of mathematical test anxiety and numerical anxiety, and the Scientific Literacy Test, which assessed science content, context of science, science processes, and scientific attitudes, to collect the data. Descriptive statistics, t-test and coefficient of correlation were used for interpreting the data. The investigator analyzed a significant and strong negative correlation between Mathematical Anxiety and Scientific Literacy of Secondary School Students. The study found that high Mathematical Anxiety can significantly impact Scientific Literacy, as students may struggle with quantitative scientific tasks, such as interpreting graphs, solving equations, and analyzing data (Ashcraft & Krause, 2007). This outcome of the study is consistent with Khoule, Ayub, and Mahmud's (2020) research, which showed that lower Mathematical Anxiety correlates with more positive attitudes toward science and improved performance in science-related tasks, highlighting a critical emotional link between mathematical comfort and scientific understanding.

1. Introduction

In the context of modern educational reform and the growing focus on Science, Technology, Engineering, and Mathematics (STEM) education, Mathematical Anxiety and Scientific Literacy have become two key factors affecting the academic development and cognitive growth of secondary school students. Mathematical Anxiety, as defined by Ashcraft and Krause (2007), refers to feelings of tension, apprehension, or fear that disrupt mathematical performance and problem-solving. Several factors, including weak foundational skills, negative classroom experiences, high-stakes assessments, and decreased self-efficacy, contribute to this emotional condition. Khasawneh (2021) points out that Mathematical Anxiety hampers numerical reasoning and problem-solving skills, both in academic settings and in real-life situations. This anxiety often results in avoidance behaviors, decreased classroom participation, and lower achievement in STEM fields.

Although Mathematical Anxiety is an emotional condition, it is distinct from cognitive deficits such as dyscalculia; the two, however, can co-exist and compound performance difficulties (Mammarella et al., 2015; Helal et al., 2011). Importantly, research indicates that even students with adequate mathematical aptitude may exhibit elevated anxiety levels due to affective factors, further impairing their academic performance (Olango, 2016). This emotional barrier can significantly hinder students' academic trajectories and career aspirations, particularly in fields that require strong quantitative skills.

Parallel to this, Scientific Literacy, defined as the capacity to comprehend scientific concepts, engage in scientific reasoning, and apply scientific knowledge to everyday life, is a cornerstone of modern education and a key competency for global citizenship (OECD, 2019). Scientific Literacy empowers learners to critically evaluate information, make evidence-based decisions, and participate meaningfully in societal discourse on pressing issues such as climate change, health, and technological advancement. However, the development of Scientific Literacy is often intricately linked with mathematical competence. Students experiencing Mathematical Anxiety frequently struggle with interpreting graphs, analyzing data, and understanding quantitative aspects of scientific phenomena, thereby impeding their scientific understanding and engagement.

In light of India's recent policy initiatives, such as the National Education Policy (NEP) 2020, which emphasizes interdisciplinary, inquiry-based, and experiential learning, the intersection of Mathematical Anxiety and Scientific Literacy warrants serious pedagogical and policy attention. Empirical evidence suggests that heightened Mathematical Anxiety negatively correlates with students' interest in science, scientific reasoning abilities, and overall STEM performance (Khale, Ayub, & Mahmud, 2020). This not only hinders individual academic achievement but also poses challenges to national educational goals focused on fostering innovation, critical thinking, and lifelong learning.

Addressing the dual challenge of mitigating Mathematical Anxiety while fostering Scientific Literacy necessitates a comprehensive and integrated pedagogical strategy. Such an approach should encompass affective support, conceptual scaffolding, and active learning environments that reduce anxiety, build confidence, and enhance cognitive engagement. Only through such inclusive and responsive educational practices can students be truly empowered to navigate the complexities of the 21st-century world.

2. Need and Significance of The Study

In the modern educational framework, the dual concerns of Mathematical Anxiety and Scientific Literacy have become crucial factors in student success, especially at the secondary school level. Mathematical Anxiety is described as a persistent feeling of tension or apprehension that hinders mathematical performance, creating a significant obstacle to students' academic achievement and ongoing interest in STEM fields. This emotional response often develops during adolescence, a key developmental stage for shaping academic self-concept and career choices. Evidence shows that students experiencing high levels of Mathematical Anxiety display reduced working memory capacity and tend to avoid complex math tasks, which can negatively affect their academic progress (Morsanyi et al., 2014). In India, Khatoon and Mahmood (2010) found that around 50% of secondary school students show moderate to high math anxiety, which is closely linked to poorer math performance. This ongoing anxiety not only limits academic involvement but also leads to a notable underrepresentation of students in math-intensive careers.

Concurrently, Scientific Literacy, defined as the ability to apply scientific knowledge and reasoning in real-world contexts, has become a fundamental competency in the 21st century. It equips learners with the capacity to make evidence-based decisions on issues related to public health, environmental sustainability, and technological progress (Schneegans & Nair-Bedouelle, 2021). The National Education Policy (NEP) 2020 in India emphasizes the importance of integrating scientific inquiry and critical thinking into the school curriculum to promote innovation, problem-solving, and informed citizenship. However, a significant body of research highlights that students who experience Mathematical Anxiety often struggle with the quantitative aspects of scientific reasoning, as numeracy skills are essential for interpreting data, understanding graphs, conducting experiments, and conceptualizing abstract scientific phenomena.

Moreover, Scientific Literacy acts as a vital shield against misinformation, pseudoscientific beliefs, and science denialism. Improving scientific understanding is essential not only for individual decision-making but also for reaching broader societal goals, including those related to sustainable development, environmental

responsibility, and public engagement with science (Paz & Vasconcelos, 2025). In this context, low levels of mathematical confidence may indirectly hinder efforts to develop a scientifically literate population capable of contributing to a knowledge-based, innovation-driven economy.

Addressing Mathematical Anxiety and fostering Scientific Literacy are not mutually exclusive educational goals; rather, they are interdependent and synergistic constructs. A reduction in Mathematical Anxiety can enhance students' capacity to engage with scientific content, while strengthened Scientific Literacy can reinforce confidence in applying quantitative reasoning in diverse contexts. Therefore, integrated pedagogical strategies that support emotional well-being in mathematics while encouraging inquiry-based learning in science are imperative. Such approaches have the potential to significantly improve academic outcomes, promote sustained interest in STEM fields, and prepare students for informed participation in both national and global contexts.

Although Mathematical Anxiety and Scientific Literacy are important issues in education, there are very few detailed studies that explore how they are connected, especially among secondary school students. This lack of research highlights the importance of the present study. It aims to understand how these two factors affect student learning and influence each other. By filling this gap, the study hopes to provide useful information that can help improve teaching methods and support the creation of better and fairer learning environments.

3. Objectives of the Study

1. To find out the level of Mathematical Anxiety of Secondary School Students
2. To find out the level of Scientific Literacy of Secondary School Students
3. To find out the relationship between Mathematical Anxiety and Scientific Literacy of Secondary School Students
4. To find out whether there is significant difference in Mathematical Anxiety for sub-sample based on gender.
5. To find out whether there is significant difference in Scientific Literacy for sub-sample based on gender.

4. Methodology

The present study employed a normative survey research design to investigate the relationship between Mathematical Anxiety and Scientific Literacy among secondary school students. The target population comprised secondary school students across the state of Kerala, India. A representative sample of 150 students was drawn from the Thiruvananthapuram district using a simple random sampling technique, ensuring equal probability of selection and minimizing sampling bias.

Two standardized tools were used for data collection. First, a Mathematical Anxiety Scale, constructed with a five-point Likert-type rating format. The scale focused on two key dimensions of Mathematical Anxiety: mathematical test anxiety and numerical anxiety. Second, a Scientific Literacy Test, this test covered four major components of Scientific Literacy: science content knowledge, context of science, scientific processes, and scientific attitudes. To analyses the collected data, both descriptive and inferential statistical techniques were used. Descriptive Statistics, Karl Pearson's Product-Moment Coefficient Correlation, and t-test were used for this study.

5. Analysis and Interpretation of Data Collected

5.1 Descriptive Statistics of Mathematical Anxiety and Scientific Literacy of Secondary School Students

The descriptive statistics for Mathematical Anxiety and Scientific Literacy of Secondary School Students are presented in the following table:

Table 1: Descriptive Statistics of Mathematical Anxiety and Scientific Literacy of Secondary School Students

Variables	Mean	Standard Deviation	Skewness	Kurtosis
Mathematical Anxiety	82.41	16.1	0.72	-0.39
Scientific Literacy	18.98	6.58	-0.25	-0.68

From table 1 presented above, the mean score for Mathematical Anxiety, the mean is 82.41, and the standard deviation is 16.1, reflecting a wider variability in students' abilities. The skewness of 0.72 indicates a positive skewness, implying that most students have average or lower anxiety levels, while only some students experience very high anxiety. The kurtosis value is -0.39, indicating that the distribution is slightly flatter than a normal distribution (platykurtic).

For Scientific Literacy, the mean is 18.98 with a standard deviation of 6.58, indicating a moderate level of performance with a fairly consistent spread of scores. The skewness value of -0.25 indicated that the distribution is fairly symmetrical, but with a small tail on the left. This means a few students have lower-than-average

Scientific Literacy scores. The kurtosis value (-0.68) is close to zero, indicating a platykurtic distribution, which is flatter than a normal distribution with fewer extreme values.

5.2 Level of Mathematical Anxiety of Secondary School Students

Table 2: Data and results of the Mathematical Anxiety of secondary school students

Level	Number of Students	Percentage
High	31	20.67
Moderate	89	59.33
Low	30	20

From table 2 given above, it is clear that the majority of secondary school students (59.33%) experience a moderate level of Mathematical Anxiety. This suggests that more than half of the students encounter Mathematics Anxiety, which could affect their learning experience and performance negatively. Additionally, 20.67% of students report a high level of Mathematical Anxiety, which is a cause for concern as it may significantly hinder their engagement and Achievement in Mathematics. Meanwhile, 20% of the students exhibit low Mathematical Anxiety, indicating a relatively small group who feel confident and at ease with mathematical tasks. The overall trend highlights the need for strategies to support students in managing math-related stress, particularly those with moderate to high anxiety levels.

5.2.1 Graphical Representation of the Level of Mathematical Anxiety of Secondary School Students

The graphical representation given below presents a visual summary of the distribution of secondary school students across high, moderate, and low levels of Mathematical Anxiety.

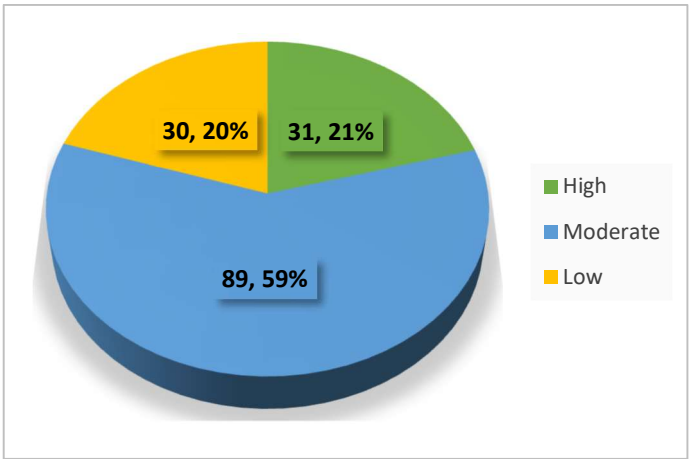

Fig.1 Pie diagram showing the level of Mathematical Anxiety of Secondary School Students.

The graph 1 shows that 59% of secondary school students demonstrate a moderate level of Mathematical Anxiety.

5.3 Level of Scientific Literacy of Secondary School Students

Table 3: Data and results of the Scientific Literacy of secondary school students

Level	Number of Students	Percentage
High	27	18
Moderate	97	64.67
Low	26	17.33

From table 3 given above, 64.67% of secondary school students demonstrate a moderate level of Scientific Literacy. This majority reflects that there is an urgent need to further enhance the Scientific Literacy of Secondary School Students. A smaller proportion, 18%, shows a high level of Scientific Literacy, indicating that only a few students have a strong understanding of scientific concepts and the ability to apply them effectively. On the other hand, 17.33% of students fall in the low category, suggesting limited understanding and potential difficulty in comprehending scientific ideas. These findings suggest that although most students are moderately scientifically literate, efforts should be made to increase the proportion of students achieving high literacy while providing support to those who are currently struggling.

5.3.1 Graphical Representation of the Level of Scientific Literacy of Secondary School Students.

The graphical representation given below presents a visual summary of the distribution of secondary school students across high, moderate, and low levels of Scientific Literacy.

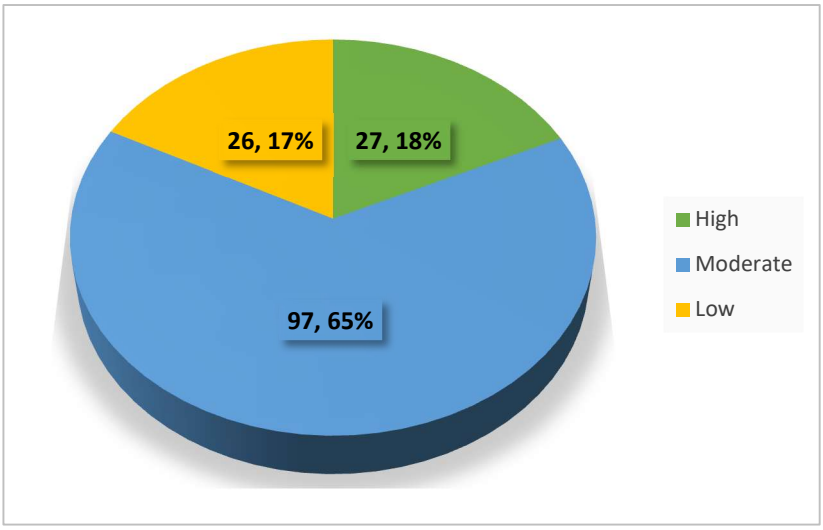

Fig.2 Pie diagram showing the level of Scientific Literacy of Secondary School Students.

The graph 2 shows that 65% of secondary school students demonstrate a moderate level of Scientific Literacy.

5.4 Relationship between Mathematical Anxiety and Scientific Literacy of Secondary School students

In order to find out the nature of relationship between Mathematical Anxiety and Scientific Literacy of Secondary School Students, the investigator used Karl Pearson's Product Moment Correlation and the details of r, t, SE and level of significance for the total sample are given in the table.

Table 4: Relationship between Mathematical Anxiety and Scientific Literacy of Secondary School Students

Group	N	r	t	SE_r	99%Confidence Interval	
					Upper Level	Lower level
Total	150	-0.784	-15.36	0.02	-0.853	-0.688

From table 4 above, coefficient of correlation for the total sample is -0.784. The 'r' lies between the confidence interval -0.853 and -0.688 at the 0.01 level. Hence, it is significant at the 0.01 level. The significant 'r' indicates that there exists a true relationship between the Mathematical Anxiety and Scientific Literacy of Secondary School Students. The magnitude of 'r' reveals that the relationship between Mathematical Anxiety and Scientific Literacy is high and negative. This indicates that the students who have high Mathematical Anxiety possess low Scientific Literacy.

The obtained Fischer's t-value is -15.36, which is greater than the table value at the 0.01 level. Hence, it can be considered that there is a significant relationship between the two variables. Therefore, it can be concluded that the relationship between the variables is a high negative relationship.

5.5 Scatterplot showing Relationship between Mathematical Anxiety and Scientific Literacy of Secondary School Students

A Scatter Diagram showing the relationship between Mathematical Anxiety and Scientific Literacy for the total sample is given below.

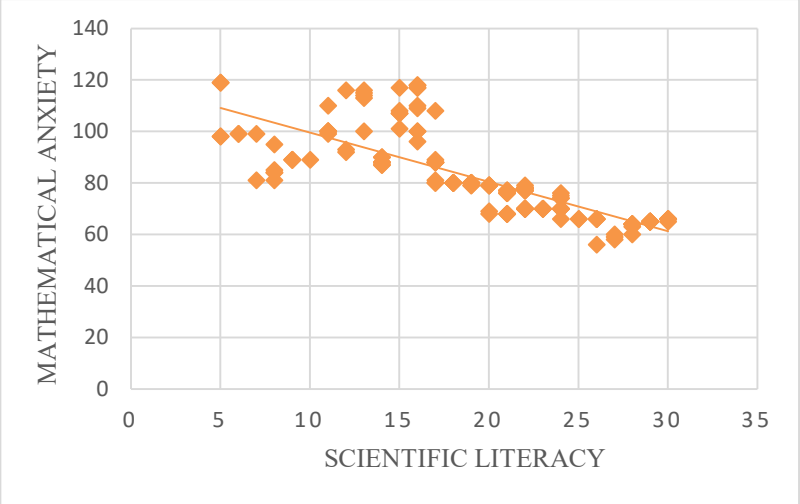

Fig.3 Scatterplot showing between Mathematical Anxiety and Scientific Literacy of Secondary School Students.

In figure 3, the points are clustered around a line, and also the increase in one variable is associated with a decrease in the other variable, which shows that there is a direct, negative and high relationship exists between Mathematical Anxiety and Scientific Literacy of Secondary School Students.

5.6 Comparison of Mathematical Anxiety of Secondary School Students based on Gender

The Mathematical Anxiety scores of the male and female secondary school students of the selected sample were compared using the test of significance difference between means. The difference between their mean scores was computed by using the critical ratio. Details regarding the results obtained are given in Table 5

Table 5: Data and results of the test of significance of the difference between the mean Mathematical Anxiety scores of male and female secondary school students

Gender	N	Mean	SD	df	t-value	p-value
Boys	70	85.59	16.97	145	2.27	0.02
Girls	80	79.63	14.85			

From table 5, it is clear that the obtained t-value is 2.27 with a p-value of 0.02, which is less than the critical value at the 0.05 level. Hence, there is no significant difference between the mean scores of Secondary school students based on Gender. This indicates that gender does not have a significant influence on the Mathematical Anxiety of Secondary School Students.

5.6.1 Graphical Representation showing the comparison of the Mathematical Anxiety of Secondary School Students based on Gender

The graphical representation given below presents a visual summary of the comparison of the Mathematical Anxiety of Secondary School Students based on Gender.

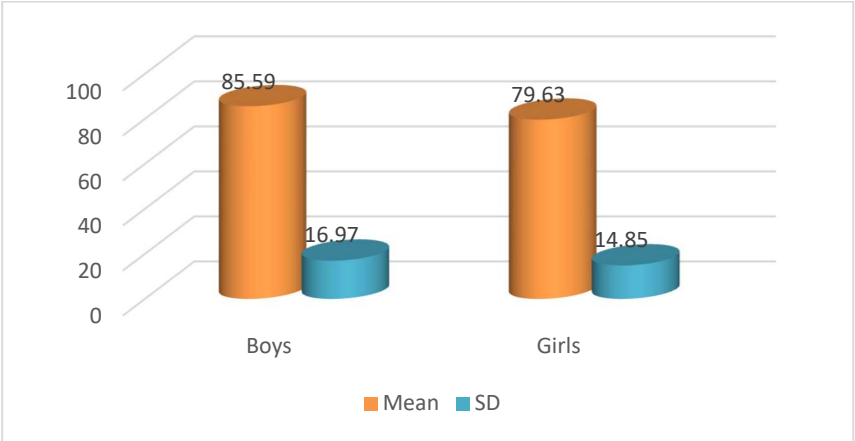

Fig.4 Comparison of Mathematical Anxiety of Secondary School Students based on Gender.

The graph 4 shows that gender does not have a significant influence on the Mathematical Anxiety of Secondary School Students.

5.7 Comparison of Scientific Literacy of Secondary School Students based on Gender

The Scientific Literacy scores of the male and female secondary school students of the selected sample were compared using the test of significance difference between means. The difference between their mean scores was computed by using the critical ratio. Details regarding the results obtained are given in Table 6

Table 6: Data and results of the test of significance of the difference between the mean Scientific Literacy scores of male and female secondary school students

Gender	N	Mean	SD	df	t-value	p-value
Boys	70	19.3	8.98	145	-0.71	0.48
Girls	80	20.09	9.37			

From the table, it is clear that the obtained t-value is 0.71 with a p-value of 0.48, which is less than the critical value at the 0.05 level. Hence, there is no significant difference between the mean scores of Secondary school students based on Gender. This indicates that gender does not have a significant influence on the Scientific Literacy of secondary school students.

5.7.1 Graphical Representation showing the comparison of Scientific Literacy of Secondary School Students based on Gender

The graphical representation given below presents a visual summary of the comparison of the Scientific Literacy of Secondary School Students based on Gender.

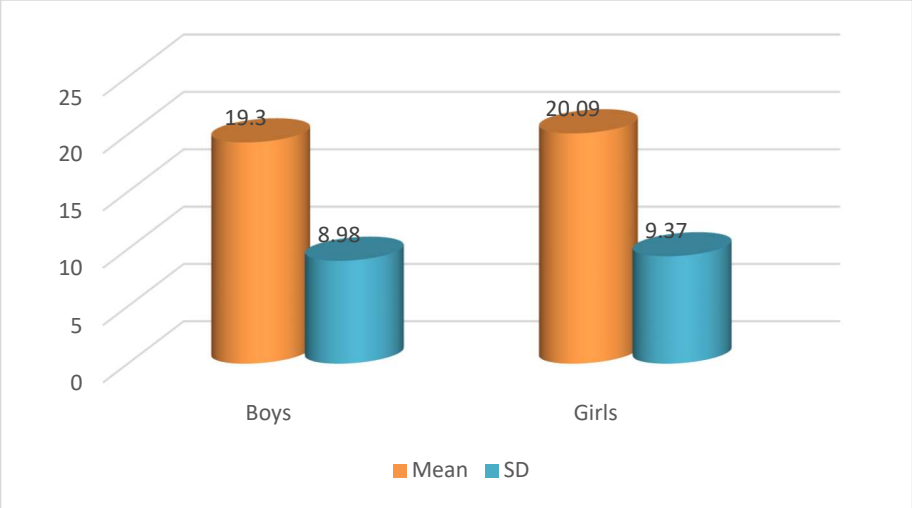

Figure 5: Comparison of Scientific Literacy of Secondary School Students based on Gender.

The graph 5 shows that gender does not have a significant influence on the Scientific Literacy of Secondary School Students.

6. Findings of The Study

- The findings show that most secondary school students experience a moderate level of Mathematical Anxiety (59.33%) and Scientific Literacy (64.67%). Overall, both Mathematical Anxiety and Scientific Literacy among secondary school students are at a moderate level.
- The results of the study revealed that a significant and strong negative correlation between Mathematical Anxiety and Scientific Literacy of secondary school students, with a Pearson correlation coefficient of ($r = -0.784$). This statistically significant relationship indicates that as Mathematical Anxiety increases, students' Scientific Literacy tend to decrease correspondingly.
- The results of the comparison of Mathematical Anxiety scores between male and female secondary school students statistical t-test, showed a significant result ($t = 2.27$, $p = 0.02$), the practical difference between male and female students was minimal. This suggests that, despite statistical significance, gender does not have a meaningful impact on Mathematical Anxiety among the participants

- Similarly, the comparison of Scientific Literacy scores between male and female secondary school students showed no statistically significant difference ($t = 0.71$, $p = 0.48$), as the p-value was greater than the 0.05 threshold. This indicates that gender does not significantly influence students' Scientific Literacy.

7. Educational Implications of the Study

- As many students experience moderate levels of Mathematical Anxiety, and this negatively affects their Scientific Literacy, schools should use teaching methods that reduce stress in mathematics. Approaches like peer tutoring, group learning, using games, and linking math to real-life situations can help students feel more confident and engaged.
- Since Scientific Literacy is also at a moderate level and closely linked to math skills, teachers should use interdisciplinary methods that connect math with science. Teaching that focuses on understanding concepts, rather than memorizing facts, can improve both scientific thinking and math confidence.
- The study highlights the need to address students' emotional as well as academic challenges. Schools should introduce programs that build students' emotional strength and teach them how to manage academic stress, especially in subjects like mathematics that often cause anxiety.
- Although gender differences in Mathematical Anxiety were statistically significant, they were small in practical terms. There was no significant difference in Scientific Literacy between boys and girls. Therefore, teaching should be inclusive, focusing on the individual needs of students rather than making assumptions based on gender.
- Teachers need training to recognize signs of anxiety in students and use classroom strategies that reduce pressure and encourage participation. Professional development should also help teachers design lessons that connect math and science and make learning more interactive and exploratory.
- Current educational practices often focus on memorization and timed tests, which can increase student anxiety. Curriculum designers and policymakers should promote deeper learning, critical thinking, and application-based assessments. Such reforms can help students build lasting skills in both mathematics and science.
- The results of the study suggest several important steps that educators, school leaders, and policymakers can take to improve learning outcomes in mathematics and science.

8. Conclusion

This study examined the relationship between Mathematical Anxiety and Scientific Literacy among secondary school students. In conclusion, reducing Mathematical Anxiety could be an effective way to enhance students' Scientific Literacy. The study emphasizes the importance of educational interventions aimed at lowering Mathematical Anxiety as a pathway to improve Scientific Literacy. Creating low-stress, student-centered learning environments that meaningfully integrate mathematics and science could support both academic achievement and emotional well-being. These findings underscore the value of a holistic approach to curriculum design and teaching practices, where both cognitive skills and emotional preparedness are addressed together to promote student success. Teachers, schools, and education planners should focus on cultivating supportive, low-stress learning environments that help students build confidence in both mathematics and science.

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Conflict of Interest

There is no conflict of interest to declare for this paper.

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