

## Relationship between mathematical anxiety and academic performance in mathematics in high school students

### Relación entre ansiedad matemática y rendimiento académico en matemáticas en estudiantes de secundaria

### Relação entre ansiedade matemática e rendimento acadêmico em matemática em estudante de ensino médio

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**Abstract:** The objective of this correlational research is to identify the relation between mathematical anxiety and academic performance in the area of mathematics by analyzing the answers to the Fennema – Sherman mathematical anxiety scale (.88 confidence level) given by 127 secondary school students (68 girls and 59 boys) with an average age of 14.34 years old. The GPA of students was 4.1, a high GPA according to the criteria of the Colombian Ministry of National Education. Furthermore, girls obtained a higher GPA than boys although their level of anxiety was higher too. Regarding the relation between mathematical anxiety and academic performance in the area of mathematics, this study shows that they are inversely related, that is, the greater the anxiety, the lower the academic performance. As a result of this study, the staff of school directors were suggested to design a program to modify the emotional responses of students, considering the fact that girls are influenced by affection – related factors with regard to the mathematical learning process.

**Keywords:** Mathematical anxiety, secondary education students, mathematics, relation, academic performance

**Resumen:** Esta investigación correlacional buscó identificar la relación entre ansiedad matemática y rendimiento académico en matemáticas. Se trabajó con 127 estudiantes de un colegio de secundaria de Colombia, 68 niñas y 59 niños, con edad promedio de 14.34 años, quienes respondieron la Escala de ansiedad matemática de Fennema-Sherman, la cual tiene un nivel de confiabilidad de .88. Los resultados mostraron que el promedio académico es 4.1, alto según los criterios establecidos por el Ministerio de Educación Nacional de Colombia, que las niñas tienen un promedio más alto y que su nivel de ansiedad es mayor que los niños. En la relación ansiedad matemática vs. rendimiento académico en matemáticas, se halló una relación inversa, es decir a mayor ansiedad menor rendimiento académico. Como conclusión se propuso a las directivas del colegio diseñar un programa en pro de la modificación de respuestas emocionales, debido a que se evidenció en las niñas, la influencia de factores afectivos en el aprendizaje de las matemáticas.

**Palabras clave:** ansiedad matemática, estudiante de secundaria, matemáticas, relación, rendimiento académico



**Resumo:** Esta pesquisa correlacional buscou identificar a relação entre ansiedade matemática e rendimento acadêmico em matemática. Trabalhou-se com 127 estudantes de um colégio de ensino médio da Colômbia, 68 meninas e 59 meninos, com idade média de 13.34 anos, que responderam à Escala de ansiedade matemática de Fennema-Sherman, cujo nível de confiabilidade é de .88. Os resultados demonstraram que a média acadêmica é 4.1, considerada alta de acordo com os critérios estabelecidos pelo Ministério de Educação Nacional da Colômbia; que as meninas têm uma média mais alta; e que seu nível de ansiedade é maior que o dos meninos. Em relação à ansiedade matemática vs. rendimento acadêmico em matemática, foi encontrada uma relação inversa, ou seja, quanto maior a ansiedade, menor o rendimento acadêmico. Como conclusão, se propõe à direção do colégio projetar um programa a favor da modificação das respostas emocionais, devido ao fato de a influência de fatores afetivos no aprendizado da matemática ser evidente nas meninas.

**Palavras-chave:** ansiedade matemática, estudante de ensino médio, matemática, relação, rendimento acadêmico

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## Introduction

The term Mathematical Anxiety resulted after the conduction of a comprehensive research process worldwide showing that emotional difficulties affect mathematical learning at all ages and levels of education.

This concept was the result of a study conducted by Dreger and Aiken who demonstrated that many University students show discomfort when they are asked to solve mathematical problems. The authors named this feeling “Anxiety to Numbers” and described it not as a type of generalized anxiety but rather as a sort of specific anxiety associated to calculus rules and other numerical operations (Dos Santos & Morales, 2012).

Once this problem was detected and the term Mathematical Anxiety was accepted, several definitions were designed to describe it (Perez – Tyteca, Monje & Castro, 2013; Reali, Maldonado & Jimenez, 2015; Richardson & Suinn, 1972). Mathematical Anxiety is currently considered as an intensely negative emotional reaction (characterized by tension, nervousness, fear, concern, doubt, irritability, impatience, confusion, and mental blockage) preventing students from finding solutions to mathematical problems present in our daily life or at academic level. This feeling contributes to the increase of a self-perception of incompetence to complete this kind of tasks.

The definition above states that mathematical anxiety is a special condition resulting when personality factors (low self-esteem and fear of asking questions) are combined with

environmental (negative math learning experiences and negative attitudes of parents and teachers) and intellectual situations (feeling of incompetence to learn mathematics, lack of understanding about the use of mathematical knowledge and deficiency in the coordination between teaching styles of teachers and the learning strategies of students) (Jaggermauth & Jameson- Charles, 2010).

The following are the consequences of this phenomenon: avoidance, because students choose careers and areas of knowledge that are not related to mathematics; consolidation of negative feelings toward anything that could be associated with Calculus and arithmetic, and negative impact on the mathematical motivation and self-confidence (Palacios, Hidalgo, Maroto & Ortega, 2013) as well as academic performance deficiency.

Regarding the mathematical anxiety - academic performance relation, Reyes (1984) states that research on this relation has demonstrated the existence of a significant negative correlation between these two factors, that is, the greater mathematical anxiety there is, the lower the academic performance.

According to Ashcraft and Kirk (2001), students showing high levels of mathematical anxiety have to confront other issues when doing a math assignment such as feeling concerns, anguish, and fear of this topic. The situation has an impact on his own perception of skills to approach the course content successfully.

Hidalgo, Maroto and Palacios (2004, p. 93) identify a series of events where anxiety plays the role of being the triggering factor regarding the difficulty experienced by students to attain their academic expectations in the area of mathematics. This chain of events is described as follows:

The Intrinsic and cumulative difficulty of students in the area of mathematics could leave important gaps in their education that, sooner or later, could result in non-satisfactory school performance. This, in turn, determines a progressive decrease of their mathematical self- concepts and the adoption of negative causality attributions (fatalism) and rejection and feelings of boredom that worsen the situation. With time, students shall perceive mathematics as a torment that they have to endure year after year.

This situation has led some scholars to do some research on both University and middle education students. In the first study on this topic, the authors Dreger and Aiken predicted the existence of an inverse relation between mathematical anxiety and academic performance (Ashcraft & Moore, 2009). Several research works conducted in Colombia, Mexico, and Peru by Reali et al. (2015), Serrano and Sanchez (2017) and Castro (2017) confirmed this finding. Furthermore, Aguero, Meza, Suarez and Schmidt (2017) noticed that 78% of middle school students of Costa Rica show mathematical anxiety and found that women are more anxious than men, and that as the education level increases, the mathematical anxiety also increases.

One explanation for the relation between low academic performance in mathematics and undesirable levels of anxiety is the fact that this anxiety is the product of student actions who diminish the importance of attaining good academic performance in this area to focus on their personal difficulties and previous failures (Rivas, 1997).

However, not all scholars believe that mathematical anxiety is the origin of low results in this area. Guerrero and Blanco (2004) stated that optimum levels of anxiety result in an optimum performance level, funding their theory on the “Inverted-U” hypothesis also known as the Optimum Performance Theory.

Regarding the academic performance of Colombian students in the area of mathematics, the results attained by them both in the standardized OECD PISA testing system and in the Colombian State examinations (*SABER*) are deficient. Regarding the OECD PISA test, the lowest scores were obtained by the students in the area of mathematics since only 1% of the students attained the level 5 or Superior in this subject (OECD, 2019). On the other hand, the

results of the Colombian State examination show that the average score in the area of mathematics was below the average score of the test (Mesa, 2016).

Several reasons have been proposed to explain low results in this area: Linares (2013) associates this result to an alleged “hatred” for mathematics and to the common belief that this subject is difficult. The OECD (2019) links this result to the social and economic level of the students; according to this agency, these socioeconomic factor explains the 13 % variation in performance in the mathematical area; also this agency links the results to the gender of students (boys obtained 20 score points more than girls in mathematics). Finally, Fernandez, Hernandez, Prada and Ramirez (2018) include other elements such as the instruction techniques applied in schools, affection, beliefs about mathematics, and the behavior of teachers. Regarding the affection - related factors, the authors link anxiety to some content that the students find difficult to understand.

That situation described above brings about the raises the following question: Is there a relation between academic performance in the area of mathematics, mathematical anxiety, and the gender of students in a secondary education institution in Colombia?

This question captures our interest to conduct a research project in order to identify the relation between mathematical anxiety and academic performance. As a result, this study focuses on the analysis of the impact of mathematical anxiety on academic performance according to the gender in a private secondary school in Colombia, considering that the results of the Saber State examination for this school the year 2017 classified the institution in the category B because approximately 55% of the students were allocated in the lower 33% regarding their results in the mathematical section of the test.

## **Methodology**

This is an empirical and analytical correlational-type study whose objective is to find the existence or absence of relation between two continuous variables: The score in a mathematical anxiety test and the academic performance of participant students in the area of mathematics.

### ***Population***

The population for this study was 135 secondary school students enrolled in a private school in the year 2018.

### ***Sample***

The sample for this study consists of 127 students, corresponding to 94.07% of the student population registered in the school for the year 2018. 68 students (54%) were girls while the remaining 59 students (46%) were males. Therefore, there is a slightly higher number of female students and this datum concurs to the Colombian national and regional information reporting that the proportion of female students in basic secondary and middle education is higher than men. The average age of participating students was 14.34 years old, with a deviation of 0.164.

### ***Inclusion criteria***

Several criteria were considered before approving the participation of students in this study: First, students had to be registered in the school and show no learning difficulties. Another requirement was that the mathematical teacher had to be the same for all students; also, in order to be included in this study, students had to manifest that they did not receive extra math

classes outside the school. Finally, their parents or legal Guardians needed to accept the participation of the students in this research by signing a written consent and the students as well had to sign a document manifesting their willingness to participate.

### ***Instruments***

Two instruments were used: On one hand, the Fennema – Sherman mathematical anxiety scale, a Likert-type test with a confidence level of .87 was used to evaluate anxiety; on the other hand, a matrix was used for the assessment of the academic performance in the area mathematics.

The Fennema - Sherman mathematical anxiety scale analyzes three dimensions: Mathematical global anxiety, anxiety to math problem - solving situations only, and anxiety to math exams. The scale evaluates 12 items through the answering of multiple choice questions whose options ranged from completely disagree (1) to completely agree (5).

The Dimension 1 analyzed the answers to statements like “I am scared of math”. Regarding the Dimension 2, it included statements like “When I try to solve math problems my mind, goes blank and I cannot think clearly”. The Dimension 3 includes statements like “I usually get nervous when sitting a mathematical exam (Sanchez, Segovia, & Miñan 2011).

The Table 1 shows the scale designed by Perez-Tyteca (2012) used in this research.

Table 1

*Range of the Fennema – Sherman Mathematical Anxiety Scale according to Perez – Tyteca*

Average score	Anxiety level
Less than 2	Very low
Between 2 and 2.9	Low
Between 3 and 3.9	High
Greater than 4	Very high

Source: Perez – Tyteca, P. (2012)

Regarding the aspect of academic performance, a matrix was designed with the grades received by each student in the course of mathematics during the four academic terms. The grading scale ranges from 0.1 to 5.0 being 3.5 the minimum passing grade. These passing parameters has been accepted by the school. This research has determined the performance of each student in the course of mathematics by adding the four grades received by the students in each academic term and the total is divided by four. The grading scale set out by the Colombian Ministry of Education for all the schools in Colombia is stated in the Colombian degree 1290 of 2009. The official grading scale in Colombia is the following:

- Superior performance: Grades between 4.6 and 5.0 (excellent academic performance)
- High performance: Grades between 4.0 + 4.5 (good academic performance)
- Basic performance: Grades between 3.5 and 3.9 (the student passes the course with the minimum passing grade)
- Low performance: Grades between 0.1 and 3.4 (the student fails the course).

### ***Procedure***

6 steps were followed in order to attain the attainment of the research objectives:

*Step 1.* Delivery of the authorization letter to the principal of the school

*Step 2.* The math teacher delivers each student a written consent in order for the parents or legal guardians to authorize the participation of the underage child in the research process and the disclosure of the corresponding grade.

*Step 3.* Delivery of written consent to each student in order for them to express their willingness to participate in this research

*Step 4.* Explanation of the research instruments and instructions to initiate the process.

*Step 5.* Design of a database based on the results of the test and on the results received by the students in each sub-test. This database also contains the GPA received by the student in the area of mathematics. The Sigmastat 3 software is used for the conduction of the statistical procedures. The distribution of data is one of the factors to be considered in order to decide on the statistical test used. The Spearman correlation coefficient or Rho is the variable correlation measure used in this research because of the absence of a normal distribution. In order to identify differences based on anxiety level or gender, this study first considers the data behavior in the test as a whole and then the result received in each one of the dimensions described above. Considering that a normal distribution is not observed in the Dimensions names “Total Test” and “Solution to Math Problems”, in order to find out whether there are differences or not, the Mann – Whitney U Test is used. Regarding the dimension “Fear to Exams” the T student distribution is used based on the fact that the homoscedasticity test shows that it is a normal distribution.

*Step 6.* Description and Analysis of results.

## Results

### *Academic Performance*

That GPA of the sample population for the subject of mathematics in the year 2018 is 4.1, with a deviation of 0.05. The minimum grade obtained in this group is 2.8 while the maximum grade is 5.0. Therefore, the GPA is allocated within the high performance category.

Regarding the result by gender, the GPA received by males is 3.9 (deviation 0.08) while the GPA of females is 4.25 (deviation 0.07).

### *Mathematical anxiety*

The average value for the mathematical anxiety is 2.53. This value, according to the scale described above correspond to the Low category that ranges from 2.0 to 2.9 (deviation 0.80). Regarding the population distribution according to their level of anxiety, the results shown in the Table 2 indicate that that highest percentage is allocated in the low the level of anxiety, followed by the low and high levels.

Table 2

*Distribution of the sample population according to their anxiety level*

Anxiety Level	Very high		High		Low		Very low		Total
	N	%	N	%	N	%	N	%	
Persons	5	3.93	32	25.19	58	45.66	32	25.19	127

That result of each Dimension is analyzed considering that the anxiety scale utilized for this research considers three dimensions. The overall mean for each dimension is shown in the Table 3 indicating that the highest anxiety corresponds to the “Sitting an Exam” category.

Table 3

*Distribution of the sample population according to the mathematical anxiety dimension*

Anxiety	N	Minimum	Maximum	Mean	Deviation
Total exam	127	1.0	4.8	2.146	0.817
Problem-solving	127	1.0	4.7	2.607	0.893
Exams	127	1.0	5.0	2.811	1.073

***Mathematics Anxiety and Gender***

The Table 4 shows that both genders experience the highest level of anxiety when sitting an exam.

Table 4.

*Distribution of the sample population according to the gender for each Mathematical anxiety dimension*

Anxiety	GENDER									
	FEMALE					MALE				
	N	Min	Max	Mean	Dev	N	Min	Max	Mean	Dev
Total	68	1.0	4.8	2.27	.9006	59	1.0	3.5	2.022	.6963
Problem solving		1.0	4.7	2.804	.9190		1.0	4.3	2.410	.8199
Exams		1.0	5.0	3.051	1.1004		1.0	4.7	2.571	.9905

The anxiety level according to the gender show that female students experience greater feelings of mathematical anxiety in the three dimensions. The next step, then, is to determine if these differences are statistically significant by analyzing the data distribution information. The results that no normal distribution is identified for the first two categories, that is, the total exam and problem-solving (Table 5). Therefore, the Mann-Whitney U test is used to determine the differences in the mean values.

Table 5

*Data normality test for the mathematical anxiety scale*

Test and Sub-tests	Kolmogorov-Smirnov			Shapiro - Wilk		
	Statistical	gl	Sig.	Statistical	gl	Sig.
Total test	0.075	127	0.073	0.983	127	0.106
Anxiety to problem solution	0.118	127	0.000	0.969	127	0.005
Total anxiety	0.114	127	0.000	0.947	127	0.000
Anxiety due to exams	0.082	127	0.036	0.967	127	0.004

The results for the category of anxiety to the total test show that there is not a gender significant difference. The category of anxiety level related to the solution to math problems, the data in the Table 6 show that the anxiety in this type of situation is greater in girls than in boys with a significant difference of .05. The anxiety level when sitting an exam, the homoscedasticity test reveals a normal distribution. The results in the Table 5 reveal the existence of significant differences according to the gender and indicate that females experience more anxiety during problem-solving and exam situations than boys.

Table 6  
*Differences according to the gender in each dimension*

Subtest	Gender	Data distribution	Test used	t	Sig.
Anxiety – Total test	Male Female	Non-normal distribution	Mann-Whitney	3483	.156
Anxiety – Problem solving	Male Female	Non-normal distribution	Mann-Whitney	3271	.014
Anxiety - Exams	Male Female	normal distribution	t Student	-2.569	.011

Sig. .05

### ***Correlation between Mathematical Anxiety and Academic Performance***

The data of the test correlation between the grades received in the math course and the total test in the Table 7 show a significantly negative correlation of .05 both in the Total test category and in each one of the dimensions studied. This leads to the assumption that as mathematical anxiety increases, academic performance in mathematics decreases

Table 7  
*Correlation between GPA vs Total Scale and dimensions*

CORRELATION	N	Spearman's Rho	Significance
Course grades vs. Total scale		-.337*	.000
Course grades vs. Exam anxiety	127	-.247*	.005
Course grades vs. Total test		-.321*	.000
Course grades vs. Problem-solving		-.317*	.000

Sig. .05

## **Discussion**

This study shows that the academic performance of students in the subject of mathematics based on the results attained by them in the evaluations designed by the teacher are not consonant with the scores received by the students in the exams organized by national and International agencies such as the Colombian Institute for the Evaluation of Education (ICFES) and the Program for International Student Assessment (PISA).

This lack of concordance can be explained by analyzing the structure and the objective of each assessment Instrument. Massive tests are designed based on psychometric parameters and consider the that there is a unique and single knowledge that is independent from the context or culture (Sanchez, 2017). Besides, these evaluations are taken at the end of a cycle and have a cumulative character. By contrast, the classroom tests (internal) are designed by teachers and have an educational character. The final grade received by the student results from the combination of several activities such as exams, workshops, oral presentations, and assignments, among other.

This situation described above shows fundamental differences between the massive tests and the internal school tests to such an extent that they are not compatible. Massive evaluations, for instance, are taken once; they are cumulative, terminal and decontextualized examinations. Other important difference is that the objective of massive tests is to evaluate the educational



system and not the students. By contrast, classroom tests are mainly educational in their purpose, are applied on a continuous manner, come in many modalities, and are focused on the students.

Regarding the analysis of the variables results and gender of the population, it is clear that mathematical performance is better in girls than in boys and this difference is statistically significant. This result contradicts the findings reported by other research studies such as Alvarez (2012), and Barrera, Gutierrez, Lara and Villalpando (2011). Other authors like Capriles, Valles, Potron, Creixamsv and Arasanz (2008) have mentioned that there are many factors that explain why men obtain higher scores than women. Cacia, Reyes, Rosales and Marroquin (2012) and Radovic (2018) believe that this difference is due to social aspects while Gamboa (2012) and Mendick (2005) think that this is due to the prevalence of stereotypes. The reasons for our results are unknown but we infer that this is due to the influence of motivational factors, the personal expectations of the participant girls, and because of the classroom environment.

Regarding mathematical anxiety, results show that most of the sample population show a low level of anxiety and this confirms the finding of Aguero et al (2017) in his study about middle school students of Costa Rica. Nevertheless, the fact that some students believe that learning mathematics is a difficult task for them, and this belief results in a feeling of “hatred” to this subject, as Rius (2015) has stated. This author belief that the concept of the area of Mathematics among students is not good and this brings about the rejection of this course by them. Gonzalez, Nunez, Gonzalez, Gonzalez, and Rocas (2003) found motivational deficit and negative attitudes toward mathematics in students.

One possible explanation for these results can be related to the fact that participating students have had the same math teacher for the last two years and this situation contributes to the feeling of security, that is, the students do not feel threatened by the environment surrounding the test application. This is a hypothesis because according to Martinez (2010) some teachers and students consider that having the same teacher for a given area during the whole learning process represents a positive aspect because, according to them, this facilitates progress and advance in in-depth study. They also mention that because this teacher is the same throughout the learning process, he/she knows the students better thus a detailed and precise follow-up process is facilitated. Other authors, however, think the opposite and argue that a teacher might leave some topics aside because he/she is not familiar with a particular topic. Also, they consider the possibility of some students who cannot adapt to the methodology of this teacher.

We leave this analysis open. While having same teacher on a continuous basis during the whole learning process results in their mutual teacher-student knowledge of each other, this does not guarantee good academic performance and therefore and cannot be considered as a success variable.

Regarding that relation between anxiety and gender, this study finds that girls are more anxious than boys and this result concurs with the work of Reali et al (2015), Castro (2017), and Aguero et al (2017). It also agrees with the result of a study conducted by the University of Cambridge on British secondary school students showing that girls are more anxious than boys (Alvarez, 2012) and also with the research on Spanish students conducted by Lozano (2013). However, these data cannot be taken as axiomatic information because there are many studies that could not show a gender-based difference while others report higher levels of anxiety in boys than in girls.

In this regard, Birgin Baloglu, Cathoglu and Gurbuz (2010) suggest that this difference can be the result of that the use of different tests to measure mathematical anxiety. However, the studies of Nortés and Nortés (2017) and Aguero et al (2017) using the Fennema – Sherman scale to measure mathematical anxiety, show that females are more anxious than males.

In order to find a more plausible explanation for the results of this research, the authors have considered the theory proposed by Perina (2002) who considers that there is not such a

difference but instead women report more episodes of mathematical anxiety than men when answering tests.

The general objective of this research, that is, the relation between mathematical anxiety and academic performance in the area of mathematics, the results show the existence of an inverse correlation where the higher anxiety level, the lower the academic performance. These results concur with findings of Devine et al (2010), and Castro (2017) who reported that the most anxious students receive the lowest grades. These results have also been found by other authors and led Ma and Xu (2004) to pose the following explanations: a) certain levels of anxiety may result in low school performance. b) low academic performance is a determinant factor for the presence of mathematical anxiety. (c) Anxiety and academic performance in the area of mathematics are two mutually related variables.

Considering that the sample population in this research showed low level of anxiety while their academic performance is high, a possible explanation for this states that “certain levels of anxiety could cause low school performance” thus assuming that the anxiety level found is the result of the adaptation of students to it. This allows students not to distract and therefore stay alert without considering mathematics a threatening subject.

### Conclusions

The results show that mathematics produces low anxiety levels in the participant school students. Also, it was found that the level of anxiety is greater in girls than in boys and that there is an inverse correlation between academic performance in the course of mathematics at school and mathematical anxiety because as anxiety increases, the academic performance decreases. This observation concurs with the works of Mato and Muñoz (2010) thus demonstrating the influence of affection – related factors on the math learning process. These results have also led the authors to propose the school the design of an academic program focusing on the strengthening of the motivational and attitudinal behavior of students, particularly girls, so they change their emotional response to the subject of mathematics.

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