Latent Variables to Understand Anxiety Perceived by the Undergraduate Student when Faced with Mathematics Courses

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Abstract

There could be several causes by which a student may show a symptom of anxiety associated with mathematics courses. Hence, in this paper the findings obtained from a study in southeastern Mexico, specifically in the state of Oaxaca, are shown. Tests were applied to 302 students in different undergraduate programs. The results of the followed statistical procedure allow to state that factors ANSIEVAL, ANSITEM, ANSICOM, ANSINUM, and ANSISIMA are a set of latent variables explaining the feeling of anxiety in students toward math courses (the Bartlett test of sphericity, KMO=0.85, X2=1214.505 with 10 df, Sig.=0.00, p<0.01).

Keywords: *Anxiety toward Mathematics, mathematics abilities, temporality toward mathematics, evaluation toward mathematics.*

1. Introduction

Regarding mathematics learning in Mexico, Universidad Cristóbal Colón has recognized the need to delve into analysis related to mathematics anxiety in students of higher education. Of particular interest is what occurs in the southeast region of the country. Hence, the object of this study is the population of university students in Tuxtepec city, located in Oaxaca State.

The topic of education has always been a reason of concern and attention. It now acquires greater importance, as the report on the results of the Programme for International Student Assessment (PISA) 2012 of the Organization for Economic Cooperation and Development (OECD) reveals clearly how Mexico is performing in this regard: 55% of the students do not reach the level of basic competency in mathematics, with an average score of 413, below Portugal (487), Spain (484) and Chile (423). The average OECD score is 494, closely equivalent to two years of schooling. Though the study shows some improvement in Mexico with regards to 2003, it has been said that, with the results obtained in 2012, the country would require another 25 years to reach the current OECD averages in the field of mathematics.

At the same time, it has been stated that less than 1% of students at the age of 15 reaches the highest levels of competency in mathematics; the OECD average is 13%. The document highlights the important gap performance of students at the highest and the lowest social-economic levels. At 78 points, this is the lowest among OECD countries.

The report also presents information regarding anxiety toward mathematics. It points out that over 75% of the students express concern over the difficulty of the subject, and that females experience it at higher levels. It is important to point out that the document states that Mexico presents the highest level of mathematics anxiety in the OECD; this corroborates the relevance of research on the subject (OECD, 2013).

It must also be said that though the information refers to 15-year-old students, it allows us to see the level reached by students who will soon be entering university. Special attention must be given to this, in order to avoid the problems derived from mathematics anxiety. Thus, the main question is: what are the latent variables which allow us to understand mathematics anxiety in undergraduate students in southeast Mexico?

2. Literature Review

In a first theoretical approximation, it can be seen that mathematics anxiety is a topic which has been studied in different environments and at different levels: in primary education (Nuñez, et.al, 1998), in secondary education (Muñoz & Mato, 2007; Pérez Tyteca et.al, 2009), at the tertiary level, and by genders (Fennema & Sherman, 1976), according to its causes (Geist, s/a), and its consequences (Haciomeroglu Guney, 2013), and in relation to in-service faculty training (Haciomeroglu Guney 2013), among others.

Pérez-Tyteca and others (2011) follow Hembree (1990) who considers anxiety as "a state of emotion underpinned by qualities of fear and dread. This emotion is unpleasant, and its special characteristics are the feelings of uncertainty and helplessness in the face of danger"; as well as Fennema & Sherman (1976) who affirm that Math anxiety is a set of anxiety feelings, fear, nervousness and associated physical symptoms that arise from doing math.

McLeod (1992, 1993) makes reference to affective issues as being central in mathematics teaching, stating that the term refers to "a wide range of beliefs, feelings which are usually considered beyond the domain of cognition: in the context of education in mathematics are frequently described with words such as anxiety, confidence, frustration and satisfaction." He also points out that affective aspects should be included in research into the teaching and learning of math; this would not be difficult.

It would seem that mathematics anxiety is monolithic; however, Perry (2004), quoted by Pérez-Tyteca and others (2009) mentions different types among undergraduate students: "a) moderate and variant math anxiety, b) long-term math anxiety which began as the result of teacher action, and c) anxiety caused by the mechanical mode of teaching and the lack of understanding for learning mathematical concepts."

Muñoz & Mato (2007) analyze anxiety in regards to mathematics in secondary level students, considering factorial structure and reliability coefficient. Their testing instrument is divided into five factors: test anxiety, temporal anxiety, understanding of math problems, anxiety for numbers and mathematical operations, and anxiety in the face of real life math situations.

A relevant aspect in regards to mathematics anxiety has not to do with the student, but rather with the teacher, who also experiences the feeling when he or she is in training, as shown a study carry out by Haciomeroglu Guney (2013). This study analyzes the constructs of math anxiety and confidence in regards to mathematics in teacher in training in Turkey. It finds that teachers with lower anxiety levels carry out their teaching activities more effectively than those with higher levels of anxiety. It also shows that teachers with greater confidence who felt comfortable teaching mathematics devoted more time to the subject than those in the opposite case. It is important to note that teachers can easily transmit their mathematics anxiety to their students.

This same research shows that mathematics anxiety has consequences such as blocking logical reasoning, avoiding courses or careers which include mathematics, feelings of shame and guilt, among others.

On the other hand Nuñez and colleagues (2005a) state, based on Watt (2000) that at higher educational levels it is possible to observe more negative attitudes toward mathematics learning, and a tendency toward male dominance. They agree with Utsumi and Mendes (2000) that, as the student advances from primary to secondary education, his or her attitude toward mathematics becomes increasingly negative, whereas, those who had not repeated any courses showed more positive attitudes.

Table 1 shows and inventory of some scales which measure attitudes toward statistics and mathematics in the international context.

Table 1. Scales attitude toward statistics and toward mathematics

Author and scale	Items	Population	Sample	α	Validity type
Fennema & Sherman (1976) SATM	108 9 categories	Were designed to measure the attitudes and beliefs of secondary students. They consist of a group of nine instruments:	--	0.89	(1) Attitude Toward Success in Mathematics Scale, (2) Mathematics as a Male Domain Scale, (3) and (4) Mother/Father Scale, (5) Teacher Scale, (6) Confidence in Learning Mathematics Scale, (7) Mathematics Anxiety Scale, (8) Affectance Motivation Scale in Mathematics, and (9) Mathematics Usefulness Scale.
Robert and Bilderbak (1980) SAS	33 5 categories	Students from Pennsylvania University USA	N = 92, N = 81, N = 65	0.93 to 0.95	Predictive Correlations > 0.33 to 0.54
Wise (1985) ATS	29 5 categories	Students from University Center and West USA	N = 92	0.92 to 0.90	Predictive Correlations > 0,27 Factorial: 2 factors explain 49% of total variance

McCall et al. (1990) SASc	20 5 categories	Students University of Transkei South Africa	*N* = 43	0.95	Factorial: Three factors, 1 factor explain 64,4% of total variance
Auzmendi (1992) EAE	25 5 categories	Middle School students	N = 2,052	0.91	SASb Sub-scale: Usefulness, Anxiety, Confidence, Likeness and Motivation
Schau et al. (1995) SATS	28 7 categories	Students of 33 courses, from University of Nuevo México and South Dakota USA	*N* = 1,403	Affective: 0.81 to 0.85 Cognitive: 0.77 to 0.83 Value: 0.80 to 0.85 Difficult: 0.64 to 0.77	Predictive Correlation with a scale ATS: 0.34 to 0.79 Factorial: Coefficient of adjustment = 0.97
Mato & Muñoz (2007) Anxiety toward Mathematics ATM	24 5 categories	Students in middle school from Coruña.	N = 1,220	0.95	Determinant close to 1, high correlations Factorial: 5 factors: 1º explains 37,209% of total variance and the other one 16,064%.

Source: adapted from Cazorla, Borim-Silva, Vendramini and Ferreira (1999).

2.1 Objective and hypothesis

O_1: To identify the structure of latent variables which allow us to understand anxiety felt by the undergraduate student when faced by mathematics.

H_1: There are a number of latent variables which explain the phenomenon of mathematics anxiety among undergraduate students.

H_2: Mathematics anxiety in students can be explained by at least one factor.

3. Study

The sample comprised 302 undergraduate students from Tuxtepec, Oaxaca, enrolled in a variety of fields. The application of the instrument was carried out face-to-face, with the authorization of the academic authorities of each educational center.

The questionnaire designed by Muñoz & Mato (2007) was applied. This questionnaire consists of 24 items divided into 5 factors or dimension. The factor "anxiety toward evaluation" comprises 11 items, the factor "anxiety toward temporality" includes 4 items, the factor "anxiety toward the understanding of mathematical problems" with 3 items, the factor "anxiety toward numbers and math operations" which includes 3 items and the factor "math anxiety situations of real life" which includes 3 items." The items of each of the dimensions in the scale proposed by Muñoz & Mato are shown in Table 2, together with the codes used to identify each of the dimensions during the statistical procedure with factor analysis.

Table 2. Scales anxiety toward mathematics

Code	Dimensions	Items
ANSIEVAL	Anxiety toward evaluation	1,2,8,10,11,14,15,18,20, 22,23
ANSITEM	Anxiety toward temporality	4,6,7,12
ANSICOM	Anxiety toward understanding mathematical problems	5,17,19
ANSINUM	Anxiety toward numbers and operations	3,13,16
ANSISIMA	Anxiety toward real life situations	9,21,24

Source: own

3.1 Statistical Procedure

For evaluation of the collected data, we followed the statistical procedure proposed by García-Santillán, Escalera-Chávez and Venegas Martínez (2013). We established the following criterion: Statistical hypothesis: Ho: $\rho=0$ there is no correlation, Hi: $\rho\neq0$ there is a correlation. The statistical test is χ^2 and the Barlett´s test of sphericity KMO (Kaiser-Meyer-Olkin), and additionally the value of MSA (Measure Sampling Adequacy) for each variable of the model.

This statistic is asymptotically distributed with p(p-1)/2 freedom degrees, a significance level: $\alpha = 0.01$, *$p<0.01$ or*

<*0.05* load factorial of 0.70 ; and loads increased to 0.55 If Ho is true, values worth 1 and its logarithm would be zero, therefore the statistical tests worth zero, otherwise with high values of χ^2 and a low determinant, it would suggest that there is a high correlation, then if the critical value: χ^2 calc > χ^2 tables, there is evidence to reject of *Ho. S*o, the decision rule is; Criterion: KMO > 0.5 ; MSA >0.5 ; p<0.01 Thus: decision is reject: Ho if χ^2 calc > χ^2 tables.

4. Data Analysis

Following, the results are presented. Firstly, the main characteristics of the population of study, such as gender and field of studies. Later, the results of the factorial analysis with extracted components rotated are presented.

Gender on the sample were 48% female and 52% male, and they were distributed as shown on Table 3.

Table 3. Distribution of sample by field / specialty

Field (degree/specialty)	No. Obs.	% Obs.
Business Management Engineering	28	9
Civil Engineering	17	6
Public Accounting	31	10
Electromechanical Engineering	12	4
Biochemistry	5	2
Informatics Engineering	13	4
Electronics Engineering	8	3
Management	62	21
Nursing	5	2
Computer Systems Engineering	21	7
Logistics	44	15
Communications	1	0
Humanities	5	2
Architectural Drawing	17	6
Industrial Mechanics	5	2
Clinical Lab	19	6
Programming	4	1
IEBO	4	1
Computer Science	1	0

Source: own

Data analysis began with an assessment of instrument reliability, based on Cronbach's Alpha. A value of 0.812 was obtained, meaning that measures are consistent, as shown in Table 4.

Table 4. Reliability statistics

Cronbach's Alpha	No. of cases	%	Alpha
Valid cases	302	100	0.812
Excluded	0	0	
Total	302	100	5

Source: own

Next, descriptive analysis was performed. As shown in Table 5, descriptive data reflect that the variable ANSIEVAL presented the least dispersion (34.46%), whereas ANSISIMA presented the greatest (45.51%).

Table 5. Descriptive statistics

Factor	Mean	Standard deviation	No. of analysis	Coefficient of variation CV = DT/MED
ANSIEVAL	30.0364	10.35108	302	34.46 %
ANSITEM	10.6556	4.26069	302	39.99 %

ANSICOM	7.5993	2.90750	302	38.26 %
ANSINUM	7.8974	3.08346	302	39.04 %
ANSISIMA	6.2550	2.84679	302	45.51 %

Source: own

Later, Bartlett's Sphericity Test with KMO and Sampling Adequacy Measure for each variable was carried out for each variable, from the value of a determinant. This allowed us to prove that the use of Factorial Analysis is appropriate for this study. Statistical KMO shows a value close to one (0.85), meaning that the selected variables explain the studied phenomenon. Table 6 shows the KMO values obtained, X^2, and their significance.

Table 6. KMO correlation matrix

KMO, Bartlett's Sphericity Test, $X^2(df)$		
Kaiser-Meyer-Olkin Sampling Adequacy		0.85
	Approximate Chi-squared	1214.505
Bartlett's Sphericity Test	Df	10
	Sig.	0.000

Source: own

Table 7 shows the anti-image matrices. The anti-image correlation matrix shows results in a range between 0.817 and 0.892. These values are close to one, corroborating the pertinence of factorial analysis for this study.

Table 7. Anti-image Matrices

		ANSIEVAL	ANSITEM	ANSICOM	ANSINUM	ANSISIMA
Anti-image covariance	ANSIEVAL	0.188	-0.12	-0.06	-0.058	0.007
	ANSITEM	-0.12	0.216	-0.01	-0.068	0.018
	ANSICOM	-0.06	-0.01	0.315	-0.086	-0.17
	ANSINUM	-0.058	-0.068	-0.086	0.254	-0.043
	ANSISIMA	0.007	0.018	-0.17	-0.043	0.649
Anti-image correlation	ANSIEVAL	**0.817**[a]	-0.597	-0.248	-0.267	0.02
	ANSITEM	-0.597	**0.822**[a]	-0.037	-0.29	0.047
	ANSICOM	-0.248	-0.037	**0.870**[a]	-0.303	-0.377
	ANSINUM	-0.267	-0.29	-0.303	**0.892**[a]	-0.107
	ANSISIMA	0.02	0.047	-0.377	-0.107	**0.857**[a]

a. Sampling adequacy measure

Source: own

With regards to commonalities, the totality of the factors approximates one. The factor with the highest value is ANSINUM (0.892[a]). On the other extreme, the factor with the smallest value is variable ANSIEVAL (0.817[a]). Thus we can state that results show a high correlation and the pertinence of applying factorial analysis. Better yet, by obtaining factorial weights and high commonalities, we can obtain a higher percentage of explanation of the variance of the complete data set, leading to rejection of the null hypothesis.

Once it has been determined that Factorial Analysis is an appropriate technique for analyzing the data, we proceed to examine the factors and components. Hence, Table 8 shows the component matrix and commonalities as well as eigenvalues, which will explain the total variance.

Table 8. Components Matrix, Commonalities , Eigenvalue and total Variance

Factors	Component 1 Factorial weights	Commonalities
ANSIEVAL	0.920	0.847
ANSIETEM	0.897	0.805

ANSICOM	0.890	0.792
ANSINUM	0.915	0.838
ANSISIMA	0.643	0.413
Eigenvalue	3.695	
Total Variance	0.7390 = 73.90%	

Source: own

Based on the criterion of eigenvalue greater than 1 (3.695), it suggests the presence of 1 factor (see Table 9 and Graph 1), which may explain the total variance in 73.90% of total variation on the data.

Table 9. Total variance explained

Component	Sums of squared loadings extraction		
	Total	% of the variance	% accumulated
1	3.695	73.904	73.904
Extraction method: Analysis of main components			

Source: own

Graph 1. Sedimentation plot

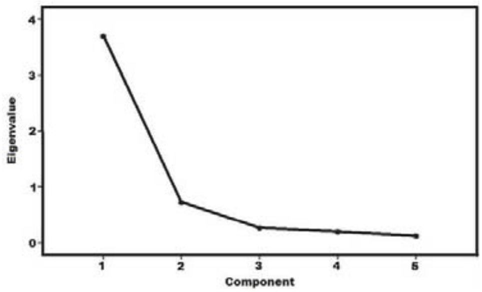

Table 10 shows the values of correlations obtained from the variables studied, where we can see that they are all inter-correlated and the correlation among the variables presents high values (> 0.05) in almost all the cases shown, except three of them (ANSISIMA vs. ANSIEVAL 0.438; ANSISIMA vs. ANSITEM 0.403; ANSISIMA vs. ANSINUM 0.489). This leads us to think that there is a concordance among the set of variables in the model, meaning that factor analysis is appropriate.

Table 10. Correlation Matrix

		ANSIEVAL	ANSITEM	ANSICOM	ANSINUM	ANSISIMA
Correlation	ANSIEVAL	1	0.871	0.751	0.818	0.438
	ANSITEM		1	0.701	0.802	0.403
	ANSICOM			1	0.765	0.586
	ANSINUM				1	0.489
	ANSISIMA					1
Sig.	ANSIEVAL		0	0	0	0
	ANSITEM			0	0	0
	ANSICOM				0	0
	ANSINUM					0
	ANSISIMA	0	0	0	0	

a Determinant = .017

Source: own

5. Findings and Conclusion

This study has a wide range of possibilities for analysis, as it can be approached form different perspectives each including a diversity of problems: related to mathematics content, related to students themselves, their needs, their expectations in regards to their future, their attitudes and emotions when faced with mathematics, and the myths surrounding mathematics (Bodhr and others, n/d), etc.; as well as from the point of view of the teacher, including aspects related to fear and previous learning experiences, enjoyment of teaching or lack of enjoyment, the educational systems, study programs, and the teaching-learning models, among others.

This work focuses specifically on the students and their emotions regarding mathematics, considering the aspect of anxiety as a determining element. This follows McLeod, who highlights the need to incorporate affect into analysis, in order to have a wider view and understand the complexity of the problem.

It was indispensable to follow the footsteps of those who have marked a clear path into inquiry on this subject. Thus, we considered the works of Fennema and Sherman, who pose differences in anxiety among the sexes; and of Muñoz and Mato, who designed the constructs used in this present study.

The study shows that the variable Anxiety toward evaluation (ANSIEVAL) contributes in a greater degree to the problem. Furthermore, in an extreme case, this single variable could explain it. The other factors, Anxiety toward temporality (ANSITEM), Anxiety toward understanding problems (ANSICOM), Anxiety toward numbers and operations (ANSINUM) and Anxiety toward mathematics in real life situations (ANSISIMA) reflect the situation of students facing mathematics within and without the classroom.

In the current globalized world of fierce competition, these are strong challenges. The problem needs to be addressed immediately and deeply. As shown by PISA test results, Mexico is far from reaching international standards. Though it has been said that it will take Mexico 25 years to reach the level of other OECD countries, this is not actually true. During the next 25 years, other countries will continue to advance and it will be harder to reach them.

What can be done? A first step has been taken by implementing new mathematical teaching models with their focus on competencies. These try to shift students from a passive role in order to acquire certain skills or competencies which allow them to use what they have learned in real-life professional situations.

Nevertheless, it is necessary to find new ways of teaching-learning at all levels, seeking to inspire in learners a liking for mathematics, showing how they are applied and, especially, making mathematics learning a pleasure and not a pain.

6. Future Lines of Research

Given the extent of the problem, we foresee four lines for future research:

- Extend the study to other states of southeast Mexico, in order to provide a complete overview of the region.
- With the previous data, carry out a state-by-state comparison-
- Broaden the comparison to include other countries in Latin America and Europe
- Delve into interaction with technology in order to incorporate it into teaching activities, among others.

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