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Mathematics, Technology and Learning: How to Align These Variables in Order to Explain Anxiety Towards Mathematics and Attitude Towards the Use of Technology for Learning Mathematics

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ABSTRACT

The aim of study is determining the set of variables which explain a student anxiety towards mathematics, as well as the student attitude towards the use of technology in PLM. To do this, the RMARS and MTAS scales were used. The instruments were applied to 522 undergraduate students at ITSON. The statistical procedure was EFA. The results obtained for the RMARS scale are: Bartlett's Test of Sphericity with KMO (0.689), χ^2 of 603.529 with 3 *df* and sig. 0.000 p<0.00, MSA Measure of Sampling Adequacy all more than >0.5, with an eigenvalue (2.219) which explains the 73.955 % of the total variance. In the MTAS Scale, Bartlett's Test of Sphericity obtains a KMO value (0.678), χ^2 of 427.405 with 10 *df* and sig. 0.000 with MSA values more than >0.5 in all cases, indicating that the variables of the MTAS Scale allow for establishing students' attitude towards mathematics and towards learning it using technology. The empirical evidence obtained allows us to believe that the use of technology may be a variable influencing students' attitude towards the process of teaching-learning mathematics measured using ICT, and that anxiety over mathematics may be a factor which determines this attitude.

Keywords: anxiety, attitude, mathematics, technology, students

BACKGROUND

The Eurydice network in Europe, made up of 31 countries, analyzes the situation of teaching mathematics at the primary and secondary school levels. Here the results of the international studies of the Program for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS) show that a large percentage of students do not achieve the expected level of mathematical competence. However, fewer than half of the European countries have carried out studies or have reported the causes of these deficiencies in mathematics. Those countries that have researched the low levels of performance report factors which influence

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State of the literature

- According to various investigations, students at all academic levels constantly say that mathematics is their most difficult subject. This causes student's high levels of anxiety and a negative attitude which obstructs acquiring knowledge when studying mathematics.
- Mathematical anxiety has been defined by various authors as a state of uneasiness which is caused by all of the activities which make up the teaching-learning process in the area of mathematics, even in the subject and courses themselves. Students manifest their anxiety by means of frustration, stress, fear, apprehension, aversion and concern. Besides these, other factors which influence student anxiety have been found, such as the student's personality, intellectual aspects and even environmental factors.

Contribution of this paper to the literature

- Richardson and Suinn (1972) carried out their seminal studies, and Pierce, Stacey and Barkatsas (2007) developed scales for measuring the level of anxiety towards mathematics and the attitude towards the use of technology in the teaching-learning process of mathematics. Since then, several empirical studies have been developed: García-Santillán, Escalera-Chávez and Córdova-Rangel (2012), García-Santillán, Escalera-Chávez, Camarena-Gallardo, García-Díaz Mirón (2012), García-Santillán, Flores-Serrano, López-Morales and Ríos-Álvarez, (2014), García-Santillán, Escalera-Chávez, Moreno-García, Santana-Villegas, (2015) and García-Santillán, Ortega-Ridaura and Moreno-García (2016). The results of these studies have indicated that university undergraduates, both men and women, experience anxiety over mathematics.
- Anxiety is based on the feelings of frustration that arise when the students try to solve a mathematical problem. The mere fact that they do not feel self-confident leads to their not being able to visualize the problem clearly and thus they feel stress during the process.
- Another point which must be mentioned is gender-based differences of anxiety towards mathematics. It has been determined that females have higher levels of anxiety than their male counterparts.

this, such as the years of schooling of parents, the lack of educational resources and help at home, the intrinsic lack of motivation of the student and under-qualified teachers (Eurydice, 2011).

In Latin America and the Caribbean, Valverde and Näslund-Hadley (2010) carried out studies on the state of education of mathematics and natural science for preschool, primary and secondary levels using data from standardized international tests including the Second Regional Comparative and Explanatory Study (SRCES), TIMSS and PISA as well as the results of the Caribbean Examination Council (CSEC). The research shows that the average levels of knowledge and skill in mathematics and in important areas of natural science are below the goals established by local educational policies and notably below the performance of students in eastern Asia and the industrialized countries which make up the Organization for Economic Co-operation and Development (OECD). According to this study, there are multiple causes: weak programs, deficient learning materials, lack of ability of teachers, memorization of routine computational operations and mechanical reproduction of concepts (Cabrol & Székely, 2012).

The Organization for Economic Co-operation and Development (OECD) presented an analysis of the results of PISA in the evaluation of mathematics in Mexico where 15-year-old students obtained 408 points in 2015, an increase of 23 points over PISA 2003, which was the largest increase among OECD countries. Additionally, the majority coincide with the decrease in the percentage of students at the basic level of achievement in mathematics established in the study of 66% in 2003 to 57% in 2015. However, the scores of Mexican students are 82 points below the average of 490 for countries in the OECD, which is the equivalent of approximately two years of teaching. Moreover, less than 1% of 15-year-old Mexican students achieved the best performance in mathematics compared to 10.7% of the students of the countries which make up the OECD (Organization for Economic Co-operation and Development, 2016).

The Mexican Ministry of Public Education (2014) carries out a standardized test for upper secondary education called Evaluación Nacional del Logro Académico en Centros Escolares (National Evaluation of Academic Achievement in Schools) (ENLACE) which evaluates basic competence in the fields of communication (reading comprehension) and mathematics. This is an annual exam first given in 2008 in which student's achievements are classified as insufficient, elementary, good and excellent. In 2008 46.54% of the students were placed in the category of insufficient while in 2014 only 26.60% were in this lowest level, an improvement of 19.94%. The category of elementary achievement decreased 3.76% and the students with results which were considered good increased by 7.76% over the same period. The increase in the percentage of students who received an excellent grade from 3.43% in 2008 to 19.38% in 2014 was noteworthy.

While the results of ENLACE are promising, Santiago, McGregor, Nusche, Ravela and Toledo (2012) suggest an in-depth study be made of the impact of the test on schools and classes. With sciences such as Mathematics, besides the difficulty arising due to the differences between the ways it is taught and learned, this knowledge for many students represents knowledge which does not appeal to them; they reject it: they fear it and even have doubts about their ability to learn it as expressed by Rouquette and Suárez (2013).

The results of the various standardized tests (TIMSS, PISA, ENLACE) expose students' deficiencies in the area of Mathematics. This situation reflects the academic deficiencies of students when entering the university. It is for this reason that the Technological Institute of Sonora included in its academic agenda the development of this study.

In the OCDE report of 2009 in which the theme is "21st Century Skills and Competences for New Millennium Learners in OECD Countries" it is pointed out that nowadays young people use new forms of socialization and acquisition of social capital to a large extent using ICT (Information and Communication Technology).

To this respect Coll (2009) has suggested as an alternative solution for learning Mathematics, changing the traditional focus of teaching for methods using ICT as instruments which transform the cognitive processes, taking advantage of the potential of technology to create new forms of teaching and learning. While today the importance of using ICT in upper secondary education is acknowledged, there are factors which have prevented integrating it into the system.

However, Rouquette and Suárez's (2013) statements in relation to the student's feeling of rejection and fear of mathematics, as well Coll (2009) who points out as a solution to counteract the low performance in mathematics the use of ICT, allow us justify the following questions, objectives and hypotheses for this study.

Question 1: What is the set of latent variables that explain the student's level of anxiety towards mathematics?

Question 2: What is the set of variables that allow knowing the student's perception towards the use of technology in the teaching-learning process of mathematics?

Objective 1: To determine the set of variables that explain the student's level of anxiety towards mathematics.

Objective 2: To determine the set of variables that explain the attitude of the student to the use of technology in the process of teaching mathematics.

H_1: There is a set of variables that explain the student's level of anxiety towards mathematics.

H_2: There is a set of variables that explain the student's attitude towards the use of technology in the process of learning mathematics.

As a part of the initial approach, the variables involved in the problem were identified and placed within theoretical and empirical reality. Said variables are: Anxiety towards mathematics, attitude towards technology as a measure of the process of teaching-learning mathematics, from which the following theoretical-conceptual model has been established.

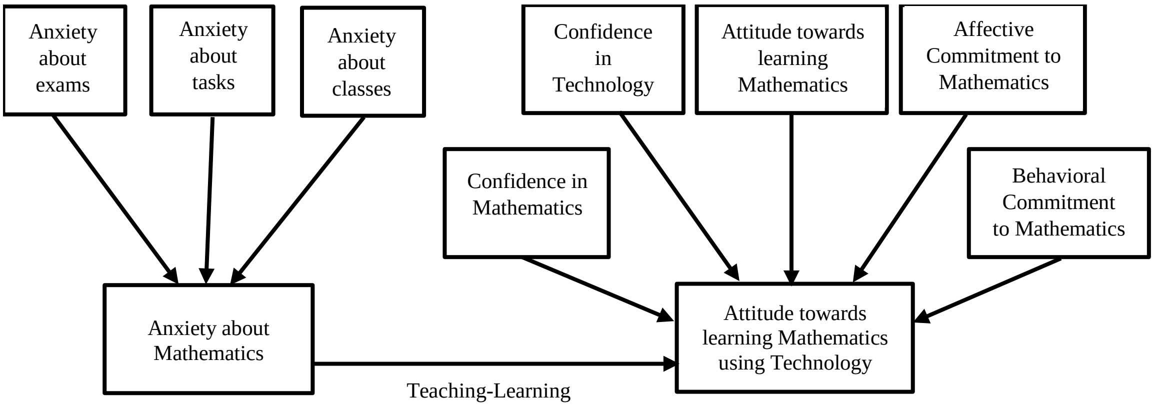

Figure 1. Preliminary Model of ATM* and attitude towards the use of technology in PEAM**
*ATM: Anxiety towards Mathematics
**PEAM: Process of teaching-learning Mathematics
Source: own

REVIEW OF LITERATURE

First, anxiety towards mathematics was measured in order to make a diagnosis and offer treatment for countering it. The instrument called MARS (Mathematics Anxiety Rating Scale) was developed by Richardson and Suinn (1972) and consisted of 98 items which made up one general factor. Various versions based on this instrument have arisen in which the number of items has been reduced and two or three factors have been established. One of the original authors even presented a version consisting of 30 items which he called MARS30-brief (Suinn and Winston, 2003). This abbreviated version is considered comparable to the original scale, reporting a Cronbach's Alpha score of 0.96 and a level of reliability of a test-retest of 0.90.

A 25-item version was developed by Alexander and Martray (1989). The name of this instrument is RMARS (Revised Mathematics Anxiety Rating Scale) and consists of three dimensions for measuring students' anxiety towards mathematics. A sub-scale measures anxiety due to exams in mathematics by means of items which describe students' reactions to situations which involve evaluations of math. Another sub-scale measures anxiety towards math tasks and this is measured by the anxiety towards basic activities such as multiplication and division. A third sub-scale measures the anxiety towards math class and is developed to measure students' reactions to being in math class. The internal reliability score is 0.96 and reliability on test-retest is 0.90 in a study carried out with 517 students.

There are various other scales developed to measure students' attitudes towards mathematics, such as those made by Fennema and Sherman (1976) and more recently the scale of Muñoz and Mato (2007, 2008). Various empirical studies have been made using these scales (García-Santillán, Flores-Serrano, López-Morales and Ríos-Álvarez, 2014; García-Santillán, Escalera-Chávez, Moreno-García, Santana-Villegas, 2015).

In turn, scales have been developed which not only measure students' attitude towards mathematics, but also towards the use of technology for learning mathematics. One of these instruments is Galbraith and Haines' scale (1998) which consists of 48 items and six subscales. Another is Pierce, Stacey and Barkatsas' scale (2007) with 20 items and five sub-scales, aimed at measuring students' attitudes towards learning mathematics using technology. Studies have been made based on these scales such as Gómez-Chacón (2010) which explores these constructs with additional techniques such as observations and interviews.

Similarly, there is other empirical evidence from research which seeks to determine the variables which intervene in students' attitudes towards mathematics and learning mathematics using technology such as studies made by García-Santillán, Escalera-Chávez and Córdova-Rangel (2012), García-Santillán, Escalera-Chávez, Camarena-Gallardo, García-Díaz Mirón (2012), García-Santillán, Ortega-Ridaura and Moreno-García (2016).

Based on the analysis and discussion in literature which explains the phenomenon of this study, the construct of the causal theoretical model, which is shown in **Figure 2**, is justified.

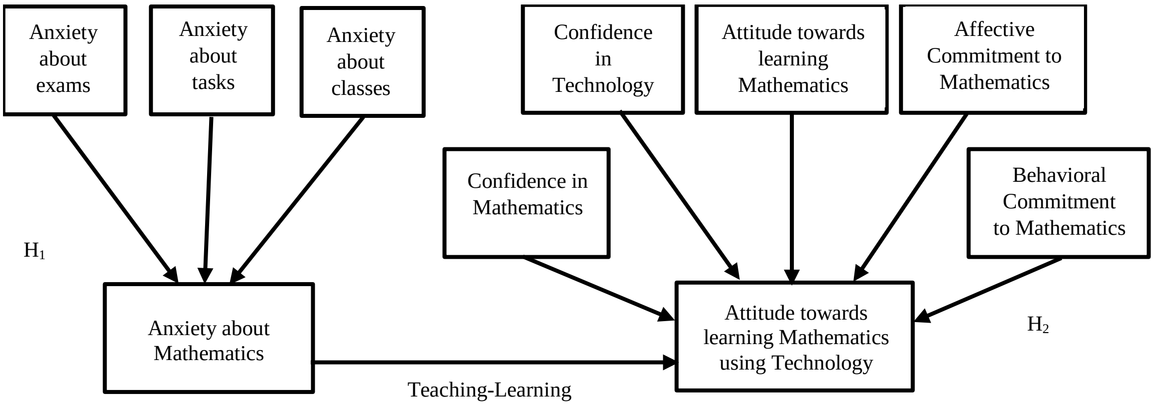

Figure 2. Definitive theoretical model of Anxiety towards Mathematics* and Attitude towards Technology in PEAM** of mathematics
*ATM: Anxiety towards Mathematics
**PEAM: Process of teaching-learning Mathematics
Source: own

DESIGN AND METHOD

This is a non-experimental study since the independent variables are not manipulated and therefore the effects (dependent variables) will not be conditioned towards a predetermined result. It is a cross-sectional study since the data collection in the application of the instrument and the analysis and interpretation are not carried out over time. It is an explicative study because it is our desire to learn the level of anxiety of students towards mathematics and their attitude towards the use of technology in the teaching-learning process of mathematics.

Instruments

Our study used two instruments, the first developed by Alexander and Martray (1989) with the acronym RMARS meaning a "Revised Mathematics Anxiety Rating Scale," and whose seminal source is the 98-factor scale of Richardson and Suinn (1972). The second survey is the one built by Pierce, Stacey and Barkatsas (2007), the "Mathematics and Technology Attitudes Scale" with the acronym MTAS.

Based on the MARS scale of Richardson and Suinn (1972), other versions were designed where the number of questions is reduced and the number of factors is increased. A revision of the scale was done by Alexander and Martray (1989), where the instrument was reduced to 25 affirmations that integrate, in turn, three dimensions. This version of the scale is called "Revised Mathematics Rating Scale" (RMARS) and was applied in 517 students where it obtained an internal reliability of 0.96 and a test-retest reliability of 0.90.

One of the dimensions of the RMARS scale is to measure anxiety about math exams by exposing situations that describe students' reactions to an assessment activity. The second dimension is about numerical tasks, where statements about reactions to basic multiplication and division activities are described. The third dimension is to measure anxiety towards the subject of mathematics and poses situations about the student's reaction when he is in a mathematics class. **Table 1** presents the items that make up the scale dimensions.

Table 1. Factors of the RMARS scale of anxiety towards mathematics

Indicators	Definition	Code/Items
1-15	Anxiety towards math tests	RMARS 1 through RMARS 15
16-20	Anxiety towards numerical tasks	RMARS 16 through RMARS20
21-25	Anxiety towards math course	RMARS 21 through RMARS25

Source: taken from Alexander and Martray (1989)

The scale used is a Likert type scale which presents values ranging from 1 to 5, in which 1 is not at all and 5 is very much: N= not at all; P=a little; R=Normal; M=a lot; D=very much.

Just as there are scales to measure anxiety towards mathematics, instruments have also been developed to measure student attitudes toward learning mathematics with technology. One of these instruments is the scale of Pierce, Stacey and Barkatsas (2007) with 20 items and five subscales, aimed at measuring students' attitude toward learning mathematics with technology. The dimensions that comprise this scale are confidence in mathematics, confidence with technology, attitude toward learning math with technology, affective commitment and behavioral commitment. **Table 2** shows the items that make up each dimension of the scale.

Table 2. Factors of the MTAS scale of attitude towards mathematics and technology

Indicators	Definition	Codes/Items
1-4	Commitment to behavior	MTAS1 al MTAS4
5-8	Confidence in technology	MTAS5 al MTAS8
9-12	Confidence in mathematics	MTAS9 al MTAS12
13-16	Affective commitment	MTAS13 al MTAS16
17-20	Attitude towards learning mathematics using technology	MTAS17 al MTAS20

Source: taken from Pierce, Stacey and Barkatsas (2007)

The scale used was a Likert type scale. For the first four items, the options for answers are: CN=Almost never, AV=At times, MV= half of the time, U=Usually and CS=Almost never. For items 5 through 20, the options for answers are: MDS=Strongly disagree, ED=Disagree greatly, NS=Disagree, DE=Agree and MD=Strongly agree.

The assigned values for the answers are from one to five, where one is for *almost never* or *very much in disagreement*, up to five in the option *almost always* or *very much in agreement*.

This instrument was applied by Pierce et al. (2007) to 350 students from six schools. Principal component analysis indicated that the five factors each with an eigenvalue greater than one explained 65% of the variance, where almost 26% was attributed to the first factor. The reliability analysis with Cronbach's alpha gave values between 0.65 to 0.89 which indicates the strength in the internal consistency of each subscale.

Participants

The study was carried out at the Technological Institute of Sonora, which is a university located in the south of the State of Sonora. This program offers undergraduate and postgraduate programs with a student population of 16,442 students in the 2015-2016 school years (Instituto Tecnológico de Sonora, 2016).

The research included 522 undergraduate students enrolled in a mathematics subject during the August-December 2016 semester. This sample is representative of students taking math courses at the university.

The sample was a convenience sample, as the scale was applied to students in a mathematics class where the teacher yielded class time for this purpose. Student participation was anonymous and voluntary. The instruments were responded on paper in the presence of the interviewer and within university facilities.

The composition of the population which was the object of the study is as follows: 33% women, 67% men; 22% in bachelor's degree programs in economic administrative science and 78% in engineering. 58% of the students were in their first semester, 23% in the third semester, 8% in the fifth semester and 11% were distributed among the second and eleventh semesters. Average age of the women was 18 years old. 17% work at least 10 hours per week. Among the male students, the average age was 18, and 27% work at least 10 hours per week. 75% of the students mentioned having sufficient economic funds for their studies, 13% mentioned they were insufficient, and 12% indicated they were excellent.

Procedure

The theoretical criteria established that the hypotheses are the invariant type: Null Hypothesis: Ho: $\rho = 0$ indicating that there is no correlation and Hi: $\rho \neq 0$ which indicates that there is a correlation.

Therefore, for measuring the data obtained in the field and the contrast of hypotheses H_1 and H_2, the multivariate technique of exploratory factor analysis was used with extraction of components, based on the following criteria: validation of the test using Cronbach´s alpha score, belonging to the model to Bartlett´s test of Sphericity with Kaiser KMO, the χ^2 with gl and 0.01 significance, the measure of sampling adequacy by variable (MSA), factor loading of 0.70. The criteria of decision for rejecting HO in all cases is: Reject Ho if χ^2 calc > χ^2 tables. To this end, we follow the procedure which García-Santillán *et al* (2012, 2013, 2014 and 2017) recently carried out in some studies and which is presented in the following data matrix in **Table 3**.

Table 3. Matrix of students' data

Students	Variables
1	$X_{11}, X_{12}, \dots, X_{1p}$
2	$X_{21}, X_{22}, \dots, X_{2p}$
…	…
522	$X_{n1}, X_{n2}, \dots, X_{np}$

where $X_{11}, X_{12}, \dots, X_{n1}$ is given by the following equations: $X_1 = a_{11}F_1 + a_{12}F_2 + \cdots + a_{1k}F_k + u_1$; $X_2 = a_{21}F_1 + a_{22}F_2 + \cdots + a_{2k}F_k + u_2$; …; $X_p = a_{p1}F_1 + a_{p2}F_2 + \cdots + a_{pk}F_k + u_p$.
Source: own

Therefore, the expression is the following:

$$X = Af + u\widehat{U}X = FA' + U \tag{1}$$

where

Data matrix	Factorial loading matrix	Factorial matrix
$X = \begin{pmatrix} x_1 \\ x_2 \\ \vdots \\ x_p \end{pmatrix}, f = \begin{pmatrix} F_1 \\ F_2 \\ \vdots \\ F_3 \end{pmatrix}, u = \begin{pmatrix} u_1 \\ u_2 \\ \vdots \\ u_3 \end{pmatrix}$	$A = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1k} \\ a_{21} & a_{22} & \cdots & a_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ a_{p1} & a_{p2} & \cdots & a_{pk} \end{pmatrix}$	$F = \begin{pmatrix} f_{11} & f_{12} & \cdots & f_{1k} \\ f_{21} & f_{22} & \cdots & f_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ f_{p1} & f_{p2} & \cdots & f_{pk} \end{pmatrix}$

with a variance equal to:

$$\mathrm{Var}(X_i) = \sum_{j=1}^{k} a_{ij}^2 + \Psi_i = h_i^2 + \Psi_i; i = 1,2,\dots,p \tag{2}$$

$$h_i^2 = \mathrm{Var}\left(\sum_{j=1}^{k} a_{ij}F_j\right) \dots y \dots \Psi_i = \mathrm{Var}(u_i) \tag{3}$$

This equation corresponds to the communalities and the specificity of the X_i variable. So, the variance of each variable is made up of two parts:

a) Its h_i^2 communalities representing the variance explained by common factors and
b) The specificity Ψ_i which corresponds to the specific variance of each variable.

Thus calculating:

$$\mathrm{Cov}(X_i, X_l) = \mathrm{Cov}\left(\sum_{j=1}^{k} a_{ij}F_j, \sum_{j=1}^{k} a_{lj}F_j\right) = \sum_{j=1}^{k} a_{ij}a_{lj}, \forall i \neq l \tag{4}$$

Bartlett's test of sphericity is obtained with the transformation of the correlation of the matrix of determinants and is calculated with the following equation:

$$d_R = -\left[n - 1 - \frac{1}{6}(2p+5)\ln|R|\right] = -\left[n - \frac{2p+11}{6}\right]\sum_{j=1}^{p} \log(\lambda_j) \tag{5}$$

where n = size of the sample, ln = natural logarithm, λ_j $(j = 1,2,\dots,p)$ values which belong to R, R= Correlation matrix.

In order to compare the magnitude of the correlation of the coefficients observed with the magnitude of the partial correlation of the coefficients, a measure of the sampling adequacy (KMO) developed by Kaiser, Meyer and Olkin was carried out, as well as calculating the measure of sampling adequacy of each variable (MSA), where only the coefficients of the variable to be evaluated were included. The two measurements are given for the expressions:

$$\mathrm{KMO} = \frac{\sum_{j\neq i}\sum_{i\neq j} r_{ij}^2}{\sum_{j\neq i}\sum_{i\neq j} r_{ij}^2 + \sum_{j\neq i}\sum_{i\neq j} r_{ij(p)}^2}, \mathrm{MSA} = \frac{\sum_{i^1 j} r_{ij}^2}{\sum_{i^1 j} r_{ij}^2 + \sum_{i^1 j} r_{ij(p)}^2}; i = 1,2,\dots,p \tag{6}$$

where $r_{ij}(p)$ is the reason of the partial correlation of the $X_i y X_j$ variables in all cases. Next, we present the empirical results obtained.

DATA ANALYSIS

First, it is necessary to evaluate the internal consistency of the instruments used in the study, which are the Alexander and Martray test (1989) and the Piercy, Stacey and Barkatsas test (2007). To this end, Cronbach's alpha score (α) was used. This coefficient of Cronbach's alpha score represents the square of the coefficient of the correlation which measures the consistency of the items using the average of all of the correlations among all of the questions. The closer it is to 1, the better the reliability. Cronbach's alpha scores of 0.80 or more are considered acceptable. For this reason, Cronbach's alpha score may be defined in function of the number of items and the average of the correlations among these items.

$$\partial = \frac{N\bar{r}}{1 + (N-1)\bar{r}}$$

where N=the number of items or latent variables; r = the average of correlations among items.

RESULTS

The empirical results are presented for each scale by individual constructs of Anxiety towards Mathematics and Attitude towards the process of teaching-learning mathematics using technology.

Table 4 describes the results of the reliability analysis for the survey "Revised Mathematics Anxiety Rating Scale" for the construct of Anxiety towards Mathematics.

Table 4. Reliability test

Concept	Cases	%	α
Valid cases	522	100.0	$\alpha = 0.941$ 25 factors
Excluded (a)	0	0.0	
Total	**522**	**100.0**	
Dimensions	ANXTASKM		$\alpha = 0.640$ with 3 dimensions
	ANXCOURM		
	ANXTESTM		

(a) Elimination based on all variables of the procedure

The results show an α of 0.941 for all items and grouped into three dimension the Alfa value is 0.640, which are acceptable, according to the theoretical statement exposed by Hair, Anderson, Tatham and Black (1999) with α> 0.6. Based on this, we can say that the scale has the characteristics of internal consistency and reliability which are prerequisites for the validity of the instrument. Therefore, we now present the empirical evidence for the first construct as shown in **Figure 3**.

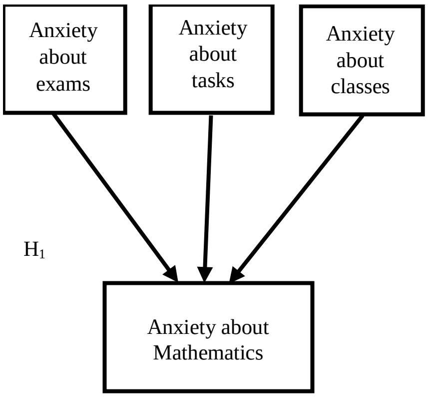

Figure 3. Construct of mathematical anxiety

Table 5 describes the results of the analysis of reliability of the survey, "Mathematics and Technology Attitudes Scale" for the construct of attitude towards mathematics and learning it using technology.

Table 5. Test of reliability

Concept	Cases	%	α
Valid cases	512	98.1	$\alpha = 0.839$ 20 factors
Excluded (a)	10	1.9	
Total	**522**	**100.0**	
Dimensions	BEHENGAM		$\alpha = 0.607$ with 5 dimensions
	AFFENGM		
	CONFTEC		
	ATTMATTE		
	CONFMAT		

(a) Elimination based on all variable of the procedure

The results show an α of 0.839 for all items and for groups of five dimensions the alpha is 0.607, which are acceptable, according to the theoretical statement exposed by Hair, Anderson, Tatham and Black (1999) with α>0.6. Based on this we can say that the scale has the characteristics of internal consistency and reliability which are prerequisites for the validity of the instrument. Therefore, we now present the empirical evidence for the second construct, as shown in **Figure 4**.

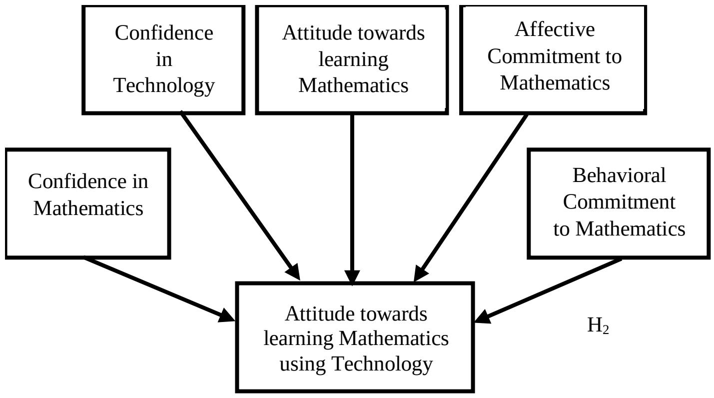

Figure 4. Construct of Attitude towards technology in teaching-learning mathematics
Source: own

RMARS Instruments

Regarding the question: what is the set of latent variables that allow explaining the level of anxiety of the student towards mathematics?, whose objective was to determine the set of latent variables that explain the level of anxiety of the student towards mathematics and the hypothesis that indicates, It was determined that there is a set of latent variables that explain the student's level of anxiety towards mathematics, the following evidence was obtained.

a) *Bartlett's test of Sphericity*

Before beginning the factorial analysis, we verified that this procedure was appropriate and that it would provide information which would explain the variables of the study. To this end Bartlett's test of Sphericity with KMO and Measure of Sampling Adequacy (MSA), were carried out in order to identify whether there was any correlation between the variables of the study and thus justify the selection of this technique.

Bartlett's test of Sphericity is a test which is applied in order to prove a null hypothesis which affirms that the matrix of correlations is a matrix of identity with a variation of zero to one. Small values indicate that the factorial analysis is not appropriate because the correlations between pairs of variable cannot be explained by other variables. If the KMO value is <0.5 this means that there is not a strong correlation between the variables and therefore factorial analysis cannot be used with the data shown in the study.

Table 6 shows the results of Bartlett's test of Sphericity, KMO, MSA, χ^2, with significance p<0.01. The value of χ^2 is 603.529 with 3 degrees freedom, which is high. The KMO Measurement is 0.689 and since it is higher than 0.5 a correlation exists between variables.

Table 6. KMO, MSA, χ^2 matrix correlation

Variable	MSA	KMO	Bartlett test of Sphericity (χ^2)
ANXTESTM	0.783		603.529
ANXTASKM	0.678	0.689	*df* 3
ANXCOURM	0.641		sig. 0.00

Source: own

The values in **Table 6** confirm that it is appropriate to carry out factorial analysis. Therefore the null hypothesis which expresses that there is no correlation between the variables is rejected. This indicates that the variables which make up the study allow for explaining the phenomenon and factorial analysis may be carried out.

b) *Measure of Sampling Adequacy (MSA)*

Table 7 shows the anti-image correlation matrix in which it may be seen that the MSA values are greater than 0.5, which shows that there is a strong relationship among variables and therefore it is appropriate to carry out factorial analysis.

Table 7. Anti-image correlation matrix

		ANXTESTM	ANXTASKM	ANXCOURM
Anti-image Co-variance	ANXTESTM	0.625	-0.095	-0.196
	ANXTASKM		0.485	-0.264
	ANXCOURM			0.428
Anti-image Correlation	ANXTESM	**0.783[a]**	-0.173	-0.378
	ANXTASKM		**0.678[a]**	-0.579
	ANXCOURM			**0.641[a]**

[a] Measure of sampling adequacy

The diagonal of the anti-image correlation matrix corresponds to the values of the measure of sampling adequacy (MSA) for each variable. The values in the diagonal of the matrix should be greater than 0.5 in order to confirm that the factorial model is appropriate for analyzing the data which was collected. On the diagonal the values are between 0.641[a] and 0.783[a]. This confirms that factorial analysis may be carried out in order to explain the phenomenon of the study.

Table 8 shows the correlations matrix. It may be observed that the values are >0.5 which indicates that the variable are all inter-correlated, establishing that factorial analysis may be carried out.

Table 8. Correlation matrix

		ANXTESM	ANXTASKM	ANXCOURM
Correlations	ANXTESTM	1.000		
	ANXTASKM	0.520	1.000	
	ANXCOURM	0.596	0.707	1.000

(a) Determinant = 0.313

As was described previously, with the transformation of the correlation matrix Bartlett's test of Sphericity is obtained as presented in **Table 6** by means of the equation 5:

$$d_R = -\left[n - 1 - \frac{1}{6}(2p+5)\ln|R|\right] = -\left[n - \frac{2p+11}{6}\right]\sum_{j=1}^{p}\log(\lambda_j)$$

c) *Matrix of components, communalities, eigenvalue and total variance*

Once it has been confirmed that factorial analysis is the correct technique for analyzing this data, evaluation of the factors and components may begin. **Table 9** shows the matrix of components, communalities, eigenvalue and total variance explained.

Table 9. Matrix of components, communalities, eigenvalue and total variance

	Component 1	Communalities
ANXTESTM	0.810	0.656
ANXTASKM	0.868	0.753
ANXCOURM	0.900	0.809
Eigenvalue	2.219	
Total variance	73.955 %	

Source: own

An eigenvalue greater than one (2.219) suggests the existence of a factor with a total explained variance of 73.955% of the total variation of the data. Similarly, in **Table 9** the load of the three factors which were calculated in the main extraction of the components is described. The three factors make up component one with a factorial load >0.5 for all of them. ANXCOURM (0.900) has the largest load; this corresponding to anxiety about Mathematics class, followed by ANXTASKM (0.868) and last ANXTESTM (0.810). With respect to the proportion of variance explained by the communalities, the following values may be observed: ANXCOURM (0.809) with the highest value, followed by ANXTASKM (0.753) and with the lowest value ANXTESTM (0.656).

MTAS Instrument

For the second question: What is the set of latent variables which allows knowing students' attitude towards the use of technology in the teaching-learning process of mathematics?, the following evidence was obtained:

a) *Bartlett's test of Sphericity*

Before beginning factorial analysis, we verified that this procedure was appropriate and that it would provide information which explained the variables of the study. To this end Bartlett's test of Sphericity was carried out with KMO and Measure of Sampling Adecuacy (MSA). This was all done in order to identify whether there was a correlation among the variables of the study, thus justifying the selection of this technique.

Bartlett's test of Sphericity is a test which is made in order to prove the null hypothesis that affirms that the correlations matrix is an identity matrix with a variation of zero to one. Small values indicate that factorial analysis is not appropriate because the correlation between the pairs of variables cannot be explained by other variables. If the KMO value is <0.5 this means that there is not a strong correlation among the variables and therefore factorial analysis cannot be used with the data of the sample of the study.

Table 10 shows the results of Bartlett's test of Sphericity, KMO; MSA, χ^2, with p<0.01 significance. The χ^2 valued is 427.405 with 10 points of freedom, which is high. The KMO adequacy measurement is 0.678 and since it is higher than 0.5 that shows there a correlation does exist among variables.

Table 10. Correlation matrix-KMO, MSA, χ^2

Variable	MSA	KMO	Bartlett test of Sphericity (χ^2)
BEHENGAM	0.736	0.678	427.405 *df* 10 sig. 0.00
CONFTEC	0.738		
CONFMAT	0.656		
AFFEENGM	0.675		
ATTMATTE	0.573		

Source: own

The values in **Table 10** confirm that it is appropriate to carry out factorial analysis, and for this reason, the null hypothesis which expresses that the variables are not correlated, is rejected. This indicates that the variables which make up the study allow for explaining the phenomenon, and factorial analysis may be carried out.

b) *Measure of Sampling Adequacy (MSA)*

Table 11 shows the anti-image matrix in which it can be seen that the MSA values are greater than 0.5, which shows that there is a strong relationship among variables and thus it is appropriate to carry out factorial analysis.

The correlation diagonal of the anti-image matrix corresponds to values measured using Measure of Sampling Adecuacy (MSA) for each variable. The values on the diagonal of the matrix must be greater than 0.5 in order to confirm that the factorial model is appropriate for analyzing the data collected. On the diagonal, the values are between 0.573[a] and 0.738[a] which confirms that exploratory factorial analysis may be implemented in order to explain the phenomenon studied.

Table 11. Anti-image matrix

		BEHENGAM	CONFTEC	CONFMAT	AFFEENGM	ATTMATTE
Anti-image covariance	BEHENGAM	0.692	0.003	-0.225	-0.154	-0.023
	CONFTEC		0.967	-0.040	-0.040	-0.112
	CONFMAT			0.607	-0.253	0.069
	AFFEENGM				0.611	-0.179
	ATTMATTE					0.911
Anti-image correlation	BEHENGAM	**0.736[a]**	0.004	-0.348	-0.236	-0.029
	CONFTEC		**0.738[a]**	-0.052	-0.053	-0.119
	CONFMAT			**0.656[a]**	-0.416	0.093
	AFFEENGM				**0.675[a]**	-0.240
	ATTMATTE					**0.573[a]**

[a] Measure of Sampling Adecuacy

Table 12 presents the correlation matrix. It can be observed that the values reflect correlation among variables and thus factorial analysis may be carried out.

Table 12. Correlation matrix

		BEHENGAM	CONFTEC	CONFMAT	AFFEENGM	ATTMATTE
Correlation	BEHENGAM	1.000				
	CONFTEC	0.074	1.000			
	CONFMAT	0.511	0.109	1.000		
	AFFEENGM	0.462	0.132	0.550	1.000	
	ATTMATTE	0.119	0.144	0.077	0.261	1.000

(a) Determinant = 0.431

As previously described, with the transformation of the correlation matrix we obtain Bartlett's test of Sphericity which was shown in **Table 10**.

c) *Matrix of components, communalities, eigenvalue and total variance*

Upon confirming that factorial analysis is the appropriate procedure to use in analyzing the data, we will follow up with the determination of the factors and components. In **Table 13** we may see the matrix of the components, communalities, eigenvalue as well as the total variance explained.

Table 13. Matrix of components, communalities, eigenvalue and total variance

	Component 1	Component 2	Comunalities
BEHENGAM	0.764		0.650
CONFTEC		0.694	0.556
CONFMAT	0.805		0.720
AFFEENGM	0.826		0.683
ATTMATTE		0.666	0.576
Eigenvalue	2.121	1.065	
Total variance	42.422%	21.296%	

Source: own

The eigenvalues are greater than one. The component 1 has an eigenvalue of 2.121 with a total variance explained of 42.422% and component 2 has an eigenvalue of 1.065 and a total variance explained of 21.296%. In turn, **Table 13** presents the load of the five factors obtained in the main extraction of the component method.

For component 1 the AFFEENGM (0.826) has the greatest load that refers to the affective commitment to mathematics, followed by CONFMAT (0.805) for the category confidence in mathematics. The third place is held by BEHENGAM (0.764), this corresponding to commitment of behavior in mathematics. The attitude towards learning math using technology is reflected in the variable ATTMATTE (0.364) and finally trusting technology with the variable CONFTEC (0.273).

For component 2, the variable CONFTEC (0.694) has the largest load. In second place is attitude towards learning mathematics using technology which is reflected in the ATTMATTE (0.666) variable.

The proportion of explained variance by means of the communalities indicates the following values: CONFMAT (0.720) with the greatest value, followed by the variables AFFEENGM (0.683), BEHENGAM (0.650), ATTMATTE (0.576) and with the lowest valued CONFTEC (0.556).

With these results it is now possible to draw the following conclusions based on the existing theory, as well as empirical evidence on which the study was based.

CONCLUSION

The data analysis allows us to begin with a discussion of the results of the study. Anxiety towards mathematics is found in students from different educational levels and it is necessary to carry out a broader study in order to establish strategies to attenuate this anxiety. Similarly, growing technology has made more digital resources available for the teaching-learning process. Therefore, determining students' attitudes towards the use of technology for learning mathematics has become an aspect which merits more attention.

The scales applied to students at the Instituto Tecnológico de Sonora presented appropriate indicators of internal consistence. Cronbach's alpha scores for all items of the RMARS scale (0.941) and for MTAS (0.839); Cronbach's alpha scores for RMARS (0.640) and for MTAS (0.607).

These kinds of scales have been implemented in various studies with favorable results when the object is searching for explanations and understanding levels of anxiety towards mathematics and students' attitudes towards using technology to learn mathematics. Studies have been carried out in various contexts and at various academic levels (Richardson and Suinn, 1972; Fennema and Sherman, 1976; Muñoz and Mato, 2007; Muñoz and Mato, 2008; Galbraith and Haines, 1998; Gómez-Chacón, 2010; García-Santillán, Flores-Serrano, López-Morales & Ríos-Álvarez, 2014; García-Santillán, Escalera-Chávez, Moreno-García & Santana-Villegas, 2015).

With respect to the values obtained with Bartlett's test of Sphericity with KMO (0.689 and 0.678), $\chi^2$with 3 degrees of freedom (603.529) for the RMARS scale and 10 degrees of freedom (427.405) for the MTAS scale. The significance was 0.000 in both cases, showing a significant result which allows for rejecting the null hypothesis. On the RMARS scale the null hypothesis established the non-existence of a set of latent variables which explain the level of anxiety towards mathematics. Upon rejecting this hypothesis, we confirm the existence of a set of latent variables. In the same way, on the MTAS scale, upon rejecting the null hypothesis it can be affirmed that there is no set of latent variables which explain student's attitude towards the use of technology for learning mathematics, thus confirming the existence of a set of latent variables which explains said attitude. These tests validate the pertinence of carrying out exploratory factorial analysis.

With respect to anxiety, the results show great anxiety between mathematics classes and numerical tasks (0.707). Less anxiety is shown by students between mathematics class and exams (0.596) and between numerical tasks and exams (0.520). In turn, attitude presents greater correlation between affective commitment and confidence in mathematics (0.550), following the correlation between the commitment to behavior and confidence in mathematics (0.511). We find the correlation between the affective commitment and the commitment to behavior to be slightly lower (0.462).

In both scales the determinant was greater than 0.05 (0.313 and 0.431) which is the theoretical maximum desirable value because the closer the value of the determinant is to zero, the higher the correlations between variables under study. Even when the values of the determinants are not lower than the theoretical desirable value (<0.05), all of the variables correlate positively for both scales, which indicates the presence of a significant correlation in the set of variables under study of the constructs developed by Alexander and Martray (1989) and Pierce, Stacey and Barkatsas (2007).

The total variance explained for both scales is acceptable (73.955% and 63.718%) which indicates that Alexander and Martray's scale (1989) and Pierce, Stacey and Barrkatsas' scale (2007) are appropriate for explaining the level of students' anxiety towards mathematics and their attitude towards the use of technology for learning mathematics, respectably. This affirmation may only be made for university students within the Latin American context, specifically for the population where the scales were applied.

In the RMARS scale, the analysis by dimension indicates that a single component is formed that integrates the three dimensions, with 73.955% of the total variance explained. In turn, studies by Bowd and Brady (2002) and Baloglu and Zelhart (2007) show the formation of three factors with 73%, and 66.08% of the total variance explained, respectively, coinciding with Alexander and Martray (1989).

In the MTAS scale, the results show that the analysis by dimension is formed by two components with eigenvalue greater than one. In the study by Pierce et al. (2007) in the analysis of all the items, we had five components with a total explained variance of 65%, with almost 26% of the variance in the first component (confidence in mathematics). Similarly, Barkatsas, Kasimatis and Gialamas (2009) obtained five components with 67% of the total variance explained and the first component was confidence in mathematics with approximately 16% of the total variance explained.

In the present study, the total variance explained was 63.718% for the MTAS scale. The first component groups the commitment factors of behavior, confidence and affective commitment towards mathematics, with a total variance explained of 42.422%. The second component integrates the confidence factors in technology and attitude toward technology for learning mathematics, with a total variance explained of 21.296%.

In the first component, the affective commitment dimension in mathematics contributes the highest value (.826), followed by the confidence dimension in mathematics (.805) and behavioral commitment in mathematics (.764), in contrast to Pierce, et al. (2007) and Barkatsas et al. (2009) where the first component was confidence in mathematics.

The result has theoretical and practical implications from the following point of view:

The theoretical implications are based on research carried out by Alexander and Martray (1989) and Pierce, Stacey and Barkatsas (2007), for levels of anxiety towards mathematics and the attitude towards using technology in learning mathematics.

In Alexander and Martray's study (1989) called "*The Development of an Abbreviated Version of the Mathematics Anxiety Rating Scale*" it is reported that the scale designed allows for identifying the variables which cause anxiety towards mathematics. The variables which emerge are: anxiety towards exams, anxiety towards numerical tasks and anxiety towards mathematics courses. In their conclusions they affirm having proved that there is correspondence between the initial structure of the factors and the findings at the theoretical level.

The dimensions which have been analyzed are: anxiety towards exams and anxiety towards numerical tasks. Among the research which include these kinds of arguments are those of Rounds and Hendel (1980), Plake and Parquer (1982), Resnick, Viehe and Segal (1982), Alexander and Cobb (1984), Chiu and Henry (1990).

In the present study, high values of correlation are shown between mathematics courses and numerical tasks (0.707). The largest load is held by ANXCOURM (0.9000) which corresponds to anxiety towards the mathematics course, followed by ANXTASKM (0.868), and finally ANTESTM (0.810). With respect to the proportion of variance explained by communalities, the following values were observed: ANXCOURM (0.809) with the highest value, followed by ANXTASKM (0.753) and with the lowest value ANXTESTM (0.656). This data suggests that the population under study shows greater anxiety towards the mathematics course, followed by anxiety towards numerical tasks and finally towards exams.

In turn, attitude presents greater correlation between the affective commitment and confidence in mathematics (0.550). In the statistical analysis two components were determined. For component 1 the highest load is held by AFFEENGM (0.826) which refers to the affective commitment to mathematics, followed by COMFMAT (0.805), confidence in mathematics. In the third place is BEHENGAM (0.764) which corresponds to the commitment to behavior in mathematics. For component 2 the highest load is held by CONFTEC (0.694). In second place we find the attitude towards learning mathematics using technology which is reflected in the variable ATTMATTE (0.666). The proportion of variance explained by means of communalities indicates the following values: CONFMAT (0.720) with the greatest value, then the variables AFFEENGM (0.683), BEHENGAM (0.650), ATTMATTE (0.576) and with the lowest value CONFTEC (0.556).

The practical implications stemming from the results obtained in the present study may be used as a referent for establishing teaching strategies applicable in the context of students in Mexico, especially in the Northwest of the country, where this study was carried out. The strategies should be designed with the objective of reducing the aspects which are causing the students anxiety towards mathematics. At the same time, the same strategies may be used to gather information which helps understand students' behavior in the process of teaching-learning mathematics. It is important to take into account technology as a tool which may bring students closer to mathematics, providing self-confidence and facilitating algorithmic processes.

It is of upmost importance to take into account that the phenomenon of anxiety towards mathematics not only affects students with low academic performance, but also those students who have good academic performance in other subjects are affected. Therefore, actions to be carried out by educational institutions must seek to correct and also prevent anxiety towards mathematics.

The findings allow us to identify that the mathematics course dimension is what causes greater anxiety, followed by arithmetic operations and finally by exams. In addition, the attitude towards technology for the learning of mathematics has been influenced by the mathematical aspects. This will serve to propose an intervention strategy in ITSON where technology is used in such a way as to facilitate the learning of mathematical objects, reducing the factors that are causing anxiety in students. The technology used within an instructional design can enable students to focus on understanding concepts and solving problems rather than arithmetic operations. In the same way, the technology applied in the exams can support with the visualization and the simulation of situations.

The study of anxiety leads to a better understanding of the phenomenon and of the variable which are at play, presenting the possibility of carrying out actions aimed at decreasing anxiety. Strategies and actions for confronting the problem should be developed by trained personnel in order to provide the appropriate tools for students as well as teachers.

At the university level, there are various subjects which include mathematics such as calculus, linear algebra, differential equations, statistics and financial mathematics, among others. These subjects require specific studies in order to determine the factors which cause anxiety for students.

Future lines of study

It would be worth extending this study as a next step to explaining the phenomenon of anxiety towards mathematics and attitude towards the process of teaching mathematics using technology. To this end, we suggest using new variables based on the relationship between both constructs, which could provide new empirical evidence to this discipline. This proposal could prove valid since the construct of anxiety has strong cognitive and affective loads which fit into the affective part of confidence and commitment towards the process of teaching mathematics through technology.

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