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Factors that Explains Student Anxiety toward Mathematics

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The aim of this research is to test whether anxiety toward mathematics is made up of a five-factor structure: anxiety toward evaluation, anxiety toward temporality, anxiety toward understanding of mathematical problems, anxiety toward numbers and operations, and anxiety toward mathematical situations in real life. Our study sample was formed of one thousand students from the *Centro de Estudios Tecnológicos Industrial y de Servicios* No. 15 in Veracruz City. The statistics technique used was structural equation modeling. The results of goodness of fit indices are meaningful when applied to students in High School Education, which indicates that the hypothetical model fits the theoretical model.

Keywords: theoretical model, anxiety toward mathematics, student

INTRODUCTION

The principal indicators of academic performance in the European Union are obtained through two types of evaluations, the PISA test (Programme for International Student Assessment) and the TIMSS test (Third International Mathematics and Science Study). The TIMSS test for European Union countries seeks to know the student's level of academic performance in order to compare it to results in other countries and, based on the characteristics of the different educational systems try to explain the observed differences. This test focuses on four levels, with a maximum score of 625 points; the median score is 519 points.

The results demonstrate the little progress of European Union countries in subjects as important as mathematics, considering these as a key to the development of a country. This is evident in the Eurydice network report *Mathematics Education in Europe: Common Challenges and National Policies* (2011), where one of the stated objectives for the European Union is to reduce the percentage of youngsters under 15 with a low level of competence in reading, mathematics and science. The goal is for this number to be under 15%.

In 2011, the results of the TIMSS showed that countries such as Spain, Italy,

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Poland and Austria, among others, are below the median 519 points. The most significant result is that, of the 35 participant countries, 22 placed below the median. 19 countries placed in level 3 (54%); 14 countries placed in level 2 (40%), and only two countries placed in level 1 (6%), the optimal level. Similar behavior can be observed in the last PISA reports, from 2012. The European Union is below the average (498 points) of the Organization for Economic Cooperation and Development (OECD), with 494 points, and countries such as Spain, Portugal, and Italy score below the European Union average (fewer than 489 points).

In the case of Latin America, Chile and Mexico, both OECD member countries, occupied the last places on the PISA test in 2012. In the case of Mexico, the country obtained 413 points in mathematics. This is especially disturbing, since the median is 494, and more so because it shows a regression, since the previous test in 2009 had shown a score of 419 points on the mathematics test. Mexico also assesses with a national test, the ENLACE (National Evaluation of Academic Achievement in Educational Centers). Secondary schools which were evaluated with ENLACE in 2013, showed a level of achievement of 78.1% in the indicator "insufficient and elementary", whereas in the indicator "good and excellent" the percentage was 21.9%. Furthermore, there was no statistically significant improvement. In the Mexican context, but specifically in the southeast region, we have the case of Oaxaca, whose results on the ENLACE test were the following: the achievement level "good and excellent" was 4.7%, percent, much lower than the annual mean (21.9%).

These data serve to justify the present study, given that it seeks evidence to help understand this educational phenomenon, explaining, at the same time, why the level of mathematics learning is so low, especially in some regions of southeastern Mexico, concretely, the case of Oaxaca. While it is true that there is sufficient evidence to indicate that this phenomenon of study is a global problem (according to the results of the tests referred to above), the situation is especially serious in some regions of third world countries, such as the case of Oaxaca in Mexico.

Some studies have shown that low academic performance in mathematics is not only cognitive in nature, rather, that there is an emotional aspect that appears in the form of mathematics anxiety. To this respect, the EURDYCE network report (2011) highlights the concept of "motivation" and distinguishes intrinsic motivation from extrinsic motivation (Deci & Ryan, 1985). Intrinsic motivation leads to self-efficacy, which predicts capacity for success (Bandura, 1986). In mathematics, self-efficacy is a predictor of academic performance (Mousoulides & Phillippou, 2005; Pintrich, 1999). Thus, motivation is related to repercussions on the students, especially: self-esteem, stress and anxiety, among others (Lord *et al.,* 2005).

State of the literature

- In the last thirty years, studies about anxiety towards mathematics have offered different explanations, if it is emotional, attitudinal or a belief problem. In all cases, the studies agree that anxiety has a negative effect on student performance.
- Mandler (1989), Mc Leod & Adams (1989) have shown that poor academic performance in mathematics is an emotional problem.
- Fennema & Sherman (1976, 1978), Whitley (1979), García-Santillán, Moreno, Castro, Zamudio and Garduño (2012) have shown it to be attitudinal. In 1992, McLeod pointed out that attitude is placed somewhere in between beliefs and emotions.

Contribution of this paper to the literature

- This study contributes to ratifying the validity of the scale used by Muñoz and Mato in 2007 with secondary level students. The analysis identifies that anxiety is a factor which prevents achieving good performance from students in the learning process, even students from different cultures. Initially this scale was applied in European students, and authors replicated this work with one thousand Mexican students.
- Results support Akey (2006) in demonstrating that, at the secondary level of education, attitudes toward mathematics are related to performance.
- The evidence contributes to redirect research looking for new evidence in different environments and study levels.

Now, if we consider the argument put forth by the EURIDYCE report, with the results of the PISA test, and the results of the ENLACE test (in the case of Mexico), all indicators of poor academic performance in basic subjects such as Spanish, and mathematics, we can see there is a recurrent problem in student achievement in these disciplines. Thus, the political agenda of these countries reflects the importance and relevance of mathematics in education.

Finding the cause for poor academic performance in mathematics has been a recurring theme in different investigations. Some studies have shown that the problem is emotional (Mandler, 1989; Mc Leod & Adams, 1989) while other studies have shown it to be attitudinal (Fennema & Sherman, 1976, 1978; Whitley, 1979; García-Santillán, Escalera & Córdova 2012; García-Santillán, Moreno, Castro, Zamudio & Garduño, 2012; Moreno, García-Santillán & Cristóbal, 2014) among others. These studies coincide that mathematics anxiety has a negative effect on students. In 1992, McLeod pointed out that attitude is placed somewhere in between beliefs and emotions. Most educators used attitude as one of the reasons determining the success or failure of students in mathematics (Kwan & Nathan, 2014).

According to Akey (2006), there is a positive correlation between attitude and mathematics performance in students at the secondary level of education. Auzmendi (1992) posits that one learns better what one likes; thus, a negative attitude correlates to poor achievement (Aliaga & Pecho, 2000), and to higher levels of anxiety (Magalhaes, 2007).

In regards to the constructs of attitudes toward mathematics and mathematics anxiety, the past two decades have seen an increase in publications related to the affective dimensions of the individual (beliefs, attitudes, and emotions) and the teaching-learning of mathematics (Gairín, 1990; Schoenfeld, 1992; Mcleod, 1992, 1994; Miranda, Fortes and Gil, 1998; Gómez-Chacón, 1997, 1999, 2000). Attitude toward mathematics has been addressed by researchers in a variety of countries, and an important majority considers that affective aspects in mathematics teaching should be a priority.

Watt's study (2000) shows an existing relationship between attitude and academic performance, and that this relationship has a negative growth as the educational level increases, making the negative attitude even stronger. Other studies find that, as the learner advances from basic to secondary education, his or her attitude toward mathematics becomes even more negative (Utsumi & Méndez, 2000).

It is important for students to select their field of study according to their vocation, rather than on their feelings toward a specific subject, such as mathematics. A negative attitude toward mathematics can have an important impact on the final results (Polya, 1945). An example of this is when students avoid taking courses related to mathematics, (Richardson & Suinn, 1972; Fennema & Sherman, 1976; Ho et al. 2000; Tobías & Weissbrod, 1980) and later, when they are deciding on a field of studies at the university, they discover their options are limited because they have been avoiding numeric subjects.

Gender studies also contribute important findings which must be considered in mathematics anxiety; for example, Goh and Fraser (1998) found that girls in their study generally perceived their math classroom learning environments more favorably than boys did (Yang, 2013). Other studies into elementary and middle school students, as well as adults, show that girls are more susceptible to physical symptoms, including, nervousness, tension, and discomfort (Wigfield & Mecce, 1988), though Perina (2002) questions this affirmation arguing that women are more open in admitting mathematics anxiety than men.

An important fact to consider is the seminal reference embodied in the theory of Piaget, who notes that since birth the child begins building knowledge through a dialectical process of interaction with the surrounding world, hence, no number sense begins until four or five years of age. Dantzing (1930) however, posits the existence of innate cognitive faculties in the human brain.

Thus, mathematics learning does not begin as Piaget conceives it, but rather by a bi-directional mechanism, both conscious and unconscious. In the conscious, the child encodes concepts by means of language and the memorization of numeric algorithms. In the unconscious, where protonumeric faculties are found, the first elementary numeric notions accumulate. If Dantzing's theory is correct, then we can understand why learners lose motivation and mathematics becomes tedious and difficult, since study programs are based on abstract concepts and the memorization of charts, instead of on graphics and the construction of mental models (Dehaene, 1999). Thom (1973) asserts that the conception of mathematics influences how one perceives the preferred way of teaching and learning of mathematics (Kwan, 2013). The variable attitude, as a psychological predisposition toward a behavior, faced with a loss of motivation, translates into an unfavorable disposition toward mathematics. In turn, when there is a high motivation, the disposition is favorable.

Recent studies by Escalera, García-Santillán and Venegas (2014) show that in the attitude of university students toward statistics there are two factors which explain the phenomenon. One of these is favorable and integrates three dimensions (usefulness, anxiety, and confidence) and other is unfavorable and integrates two dimensions (anxiety and motivation). Their findings suggest that students perceive statistics as being useful in the professional sphere, which makes them like the subject. This, in turn, gives them confidence to learn. The conclusion is interesting, as it highlights the result of a favorable attitude: the usefulness of statistics, interest in the topics, and confidence for learning give rise to motivation. This situation leads to different phenomena, some as drastic as avoiding mathematics classes (Hancock, 2001). However, according to Watt (2000), this only serves to accentuate the problem, which becomes more noticeable as the student advances to the following level of studies, leading to even more anxiety.

Considering what has been expressed above, it is possible to ask: What are the variables that explain the level of mathematics anxiety in students? Thus, the aim of this research is to test whether anxiety toward mathematics is made up of a five-factor structure: anxiety toward evaluation, anxiety toward temporality, anxiety toward understanding of mathematical problems, anxiety toward numbers and operations, and anxiety toward mathematical situations in real life

METHODOLOGY

This study is non-experimental, transectional and confirmatory, because we need to know the level of anxiety toward mathematics in high school students in public school. The sample was selected for the trial by non-probability sampling. Our study sample was formed of 1000 students enrolled in the first, third, and fifth semester of High School Education in the fall term of 2013. Therefore, 1000 students were surveyed from the *Centro de Estudios Tecnológicos Industrial y de Servicios No. 15 (CETIS 15) Epigmenio González*, in Veracruz City.

The instrument used was the anxiety toward mathematics scale proposed by Muñoz and Mato (2007). It consists of 24 items integrated into five dimensions with a global reliability of 0.9504. Its dimensions represent the following factors: test anxiety (ANSIEVAL), anxiety toward temporality (ANSIETEM), anxiety toward understanding mathematical problems (ANSIECOM), anxiety toward numbers and mathematical operations (ANSIENUM) and anxiety toward mathematics situations in real life (ANSISIMA). The scale is a Likert type, with values ranging from: SN =

Table 1. Dimensions of anxiety toward mathematics scale

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

Source: taken from Muñoz and Mato scale (2007)

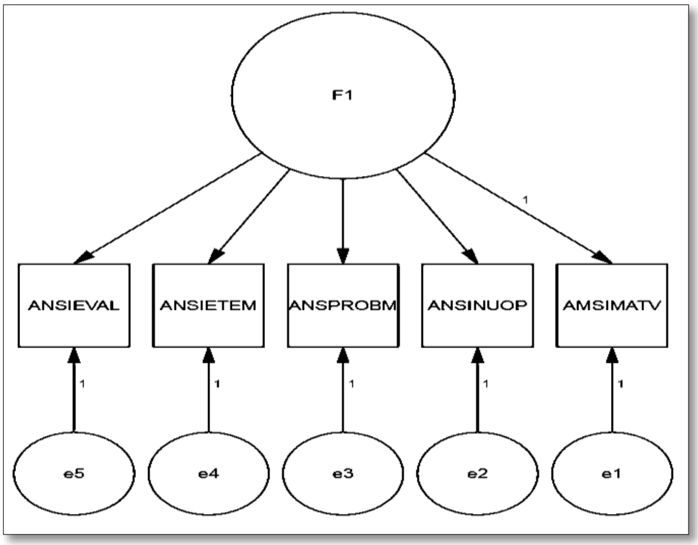

Figure 1. Hypothesized model

Never (1), PV = Rarely (2), N = Neutral (3), MV = Usually (4) SM = Always (5). Each dimension incorporates the items shown in the table 1 and figure 1 shows the graphic representation of the model:

The Anxiety toward mathematics model is made up of a five-factor structure: anxiety toward evaluation, anxiety toward temporality, anxiety toward understanding of mathematical problems, anxiety toward numbers and operations, and anxiety toward mathematical situations in real life.

For data processing, the AMOS v 21 program was used. The technique used to prove if the theoretical model proposed by Muñoz and Mato (2007) fits the data was Structural Equations, due to its great potential to extend the development of the theory (Gefen, Straub and Boudreau, 2000). The hypothetical model was evaluated by several measures of goodness of fit to evaluate the degree to which the data support the theoretical model.

If we consider that Structural Equation Modeling (SEM) is a technique for testing hypothesized relationships among variables by estimating a series of separate, still interdependent, multiple regressions simultaneously, the use of SEM is considered appropriate for this research due to its great potential for extending the theory development and its capability of simultaneously assessing the multiple and interrelated dependence relationships (Gefen, *et al*. 2000).

Furthermore, this study integrates latent variables representing unobserved concepts, which is possible by using SEM due to its ability to include latent variables while accounting for measurement error in the estimation process (Hair, et al. 1999). If we start from the objectives that were set; So_2 Evaluate the model using the elements of each factor and So_3 Evaluate the adjusted model, this study uses a two-step approach to SEM; a measurement model and a structural model.

The measurement model involves conducting a confirmatory factor analysis (CFA) to assess the contribution of each indicator variable and to measure the adequacy of the measurement model: the first step in analyzing CFA is the model specification. The second step is an iterative model modification process for developing a more parsimonious set of items to represent a construct through refinement and retesting. The third step is to estimate the parameters of the specified model; the overall model fitness is evaluated by several measures of goodness of fit to assess the extent to which the data supports the conceptual model. Various Goodness of Fit (GOF) measures used in this study include the likelihood ratio chi-square (X^2), the ratio of X^2 to degrees of freedom (X^2 /df), the Goodness of Fit Index (GFI), the Adjusted Goodness of Fit Index (AGFI), the Root Mean Square Error of Approximation (RMSEA) and Tucker-Lewis (TLI) index (Hair, et al. 1999).

The guidelines for acceptable values for these measures are discussed below. A non-significant X^2 (p>0.05) is considered to be a good fit for the X^2 GOF measure. However it is believed that this does not necessarily consider a model with significant X^2 to be a poor fit. As a result consideration of the ratio of X^2 to degrees of freedom (X^2 /df) is proposed as an additional measure of GOF. A value smaller than 3 is recommended for the ratio (X^2 /df) to accept the model as a good fit (Chin, et al. 1995).

The GFI is developed to overcome the limitations of the sample size dependent X^2 measures as GOF. A GFI value higher than 0.9 is recommended as a guideline for a good fit. Extension of the GFI is AGFI, adjusted by the ratio of degrees of freedom for the proposed model to the degrees of freedom for the null model. An AGFI value greater than 0.9, is an indicator of good fit (Segars, et al 1993). RMSEA measures the mean discrepancy between the population estimates from the model and the observed sample values. RMSEA < 0.1 indicates good model fit (Hair, et al. 1998). TLI, an incremental fit measure, with a value of 0.9 or more indicates a good fit (Hair, et al. 1998). Except for TLI, all the other measures are absolute GOF measures. The TLI measure compares the proposed model to the null model. Based on the guidelines for these values, problematic items that caused unacceptable model fit were excluded to develop a more parsimonious model with a limited number of items.

DATA ANALYSIS

The results are presented in three sections: a) Summary of the model, b) Variables of the model and parameter c) Evaluation of the model. With regards to the summary of the model, 15 elements are registered in the covariance matrix, of which there are 15 estimated parameters and a positive number of degrees of freedom (5= 15-10) which indicates that the model is over identified and can be estimated. The chi squared value = 89.107 with a probability level of 0.00, indicating that the model is not significant.

The parameters to evaluate the model are: 10 which correspond to regression weights, 6 variances which give a total of 16 parameters to be estimated. Regarding the variables, it can be seen that there are 11 variables in the model, of which 5 are the number of observed variables, whereas 6 are unobservable variables. In order to assess whether the hypothetical model has a good fit, 1) the estimated parameters and 2) the total model were evaluated.

With regards to the first point, reliability of parameters in Table 2 was estimated. It can be observed that the parameters of weight and variances are viable, and the value of reliability is = 0.88747. There are no negative variances, and they are all significant (greater than 1.96). Furthermore, the table shows measure of error values for each indicator, and all are positive. This indicates that the variables correlate with their constructs. The global fit model in table 3 shows the measure of quality of absolute fit.

The Chi-squared index does not show a satisfactory fit (X^2 = 89.107; sig= 0.000). GFI (0.962) and CFI (0.969) are satisfactory, however, the AGFI index is not (0.885), because its value, even though it tends toward 1 and is greater than 0.5, presents a value considered medium. Furthermore, the RMSEA index value (0.130) is high. Thus, the model is re-specified to search for a better fit, and model 2 is obtained and represented in next figure:

Figure 2 shows that the correlation among error five (e5) with the error four (e4) is different from zero. The correlation among the two errors reflects a high degree of coincidence in the item content; this is because the item asks the same question. The chi-squared index shows a satisfactory fit (X^2 = 15.691; sig= 0 .003 and there is improvement in the values for GFI (0.994) and CFI (0.996), AGFI (0.977); the RMSEA index value (0.054) is greater than 0.5 (Byrian, 2009).

The global fit re-specified model in table 4 shows the measure of quality of absolute fit.

The model was re-specified once again. Figure 3 shows the new model, and table 5 shows the indices of global fit.

In the same idea, the figure 3 shows that the correlation among error one (e1) with error four (e4), which is also different from zero. The correlation among errors

Table 2. Weights, measure of error, reliability and covariance of the variables

Variable	Weight	Significance
ANSIEVAL	0.468	
ANSIETEM	0.833	15.013
ANSPROBM	0.703	14.054
ANSINUOP	0.882	15.281
AMSIMATV	0.884	15.296

Measure of error of the indicators

	Interaction	Confidence	Commitment	Motivation	Mathematical confidence
ANSIEVAL	*0.781*				
ANSIETEM	0.000	*0.306*			
ANSPROBM	0.000	0.000	*0.506*		
ANSINUOP	0.000	0.000	0.000	*0.224*	
AMSIMATV	0.000	0.000	0.000	0.000	*0.219*

Reliability = *0.88747*

Variance

	Estimation	S.E.	C.R.	P
F1	1.133	0.151	7.521	***
e_1	4.037	0.186	21.752	***
e_2	2.517	0.146	17.295	***
e_3	5.535	0.274	20.230	***
e_4	3.376	0.233	14.467	***
e_5	20.579	1.448	14.210	***

Source: Own

Table 3. Model 1 fit indices anxiety toward mathematics

Model	CMIN	DF	P	CMIN/DF	GFI	AGFI	CFI	RMSEA
1	89.107	5	0.00	17.821	0.962	0.885	0.969	0.130

Source: Own

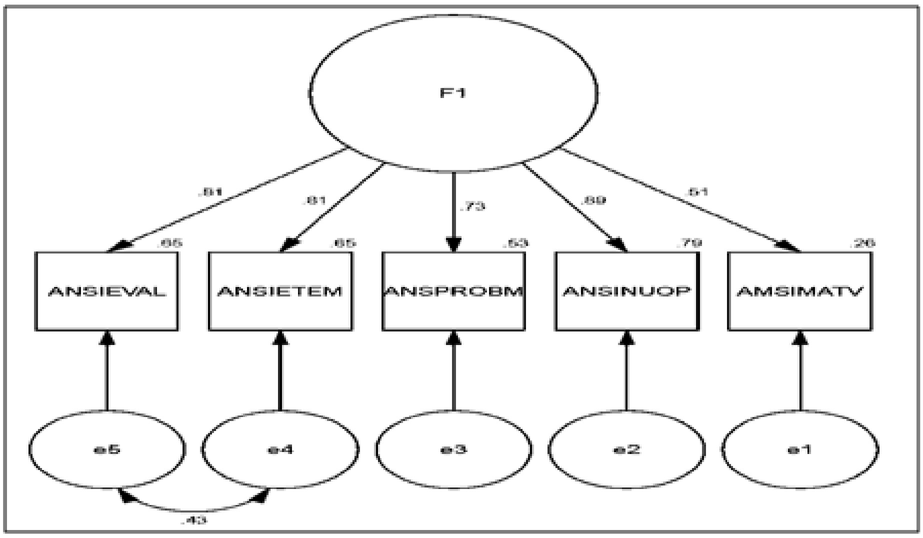

Figure 2. Model 1 re-specified anxiety toward mathematics

Table 4. Model 2 Fit indices Anxiety toward mathematics

Model	CMIN	DF	P	CMIN/DF	GFI	AGFI	CFI	RMSEA
2	15.691	4	0.003	3.923	0.994	0.977	0.996	0.054

Source: Own

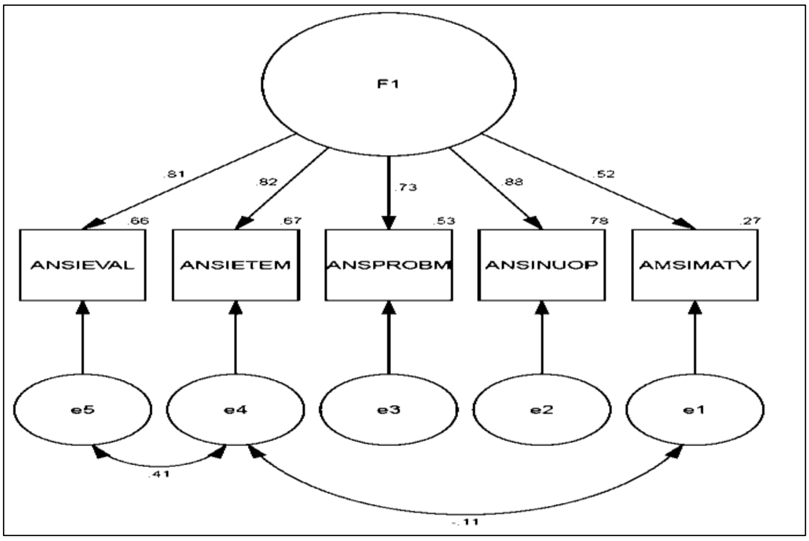

Figure 3. Model 2 re-specified Anxiety toward mathematics

Table 5. Model 3 fit indices Anxiety toward mathematics

Model	CMIN	DF	P	CMIN/DF	GFI	AGFI	CFI	RMSEA
3	5.279	3	0.152	1.760	0.998	0.990	0.999	0.028

Source: Own

reflects the following situations: 1) measurement error in responses items, 2) the characteristics of the respondents and 3) a high degree of coincidence in the item content; this is because the item asks the same question.

The chi-squared index shows a satisfactory fit ($X^2 = 5.279$; *gl* =3; sig=0.152). Values of GFI (0.998), AGFI (0.990) and CFI (0.999) have improved and are much more satisfactory because the values tend toward 1 and are greater than 0.5 and the value of the RMSEA index (0.028) also reduced its value, which should be less than 0.50.

Once the model was accepted (as a whole), the construct was evaluated in order to prove internal coherence of all indicators in measuring the concept. The results indicate that the value of reliability related to the construct (0.88747) is greater than that recommended (0.70), which shows that the indicators (anxiety toward mathematics) are sufficient to represent each of the dimensions. Results also show the extracted variance (0.650), which must be greater than 0.50. In this case the value means that more than half of the variance indicator is taken into account for the construct. Thompson (2004) notes that in confirmatory factor analysis the fit of a theoretical model should be confirmed, and that it is advisable to compare the fit indices of several alternative models to select the best.

DISCUSSION

The third re-specified model is significant when applied to students in secondary level education; i.e., it cannot be rejected because the model is a good fit. However, it must be considered that there is a correlation between error five (e_5) and error four (e_4) and a correlation between error 1 (e_1) and error 4 (e_4), because they are not equal to zero. Nevertheless, this is permissible with the aim of achieving fit in the model, and considering that the measure of covariance of the error reflects some of the following: 1) error in the measurement of item responses, 2) characteristics of the participants, 3) a high degree of coincidence in item content, because the item asks the same thing.

The results show that squared multiple correlation of factor ANSIMATV is low 27%; that is, mathematical situations in real life cause little anxiety in students. The remaining 73% of the variance can be explained by error 1. This variability affects also factors ANSIEVAL and ANSIETEM. This leads us to recommend carrying out a confirmatory factorial analysis of the data collection instrument to determine the set of items which best fits the data.

The results are consistent with those obtained by other authors (Gairín, 1990; Schoenfeld, 1992; Mcleod, 1992 and 1994; Miranda, Fortes and Gil, 1998; Gómez-Chacón, 1997, 1999, 2000) have shown that anxiety is a factor which prevents students from achieving a good performance in the learning process. Likewise, the results support Akey (2006) in demonstrating that, at the secondary level of education, attitudes toward mathematics are related to performance.

Furthermore, the evidence obtained in this study contributes to predicting the reality described by authors in regards to mathematics, while at the same time, giving light to redirect the questions in a way that gives rise to the search for new knowledge in a different environment to the one proposed by the authors.

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