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Math Anxiety: Its Characterization and Its Conceptual Model

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Abstract

Mathematical anxiety has been studied frequently over many years, so different scales have been developed for that purpose. The aim of this study is to assess the five-factor model of Muñoz and Mato (2007) within the context of a public school. Therefore, the scale designed by these authors, which consists of 24 items integrated in five dimensions, in a 5-point Likert format, is used. Hence, 200 Mexican high school students were surveyed from a non-probabilistic self-determination sample. The data gathered showed a Cronbach alpha score of 0.751, reflecting acceptable internal consistency and reliability. However, it showed kurtosis of 9.521, indicating the lack of normality. As a consequence, the Bootstrap technique was used for this study in addition to the exploratory factor analysis. The data were analyzed using the IBM Statistic SPSS 25 for descriptive analysis, and the AMOS 24 software was used to determine the validity of the model. The findings report that the results turn out to be different from those expected by the original authors of the scale since a significant model was obtained explaining math anxiety configured by a four-factor structure instead of a five-factor one. Given that these findings could be a consequence of the socio-cultural conditions of the students in the sample, further studies are recommended.

Keywords: Math anxiety, evaluation, temporality, numerical operations.

1. Introduction

Mathematics anxiety is still under continual analysis in several countries by many researchers. In this study, we focused on analyzing those aspects that explain math anxiety levels in students.

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The study of mathematics has led human beings to develop advances in different fields of knowledge. However, its learning implies a long road full of challenges and difficulties. In order to achieve this competence, theoretical knowledge must be transferred to practice, and therefore, the thoughts and feelings that are produced around this process continue to be of great interest since they are appreciated both positively and negatively. Among the negatives, the feeling of anxiety towards mathematics stands out, which develops in their learning.

Even though mathematics is introduced from the first years of study in primary education, generations continue to manifest irruption in their cognitive processes and associate this practice with discomfort, boredom, helplessness, frustration, anguish, stress, among other negative aspects that result in poor academic performance (Schultz, Heuchert, 1983; Wigfield, Meece, 1988; Hembree, 1990; Mato, 2006; Moreno-García et al., 2017). For this reason, it is necessary to understand how this phenomenon occurs and how it affects students in the different stages of their lives in which they absorb this knowledge. In this way, it has been identified in several studies that primary education is of great relevance to consolidate or lose any iota of confidence in mathematical skills, whose insecurities will come to light in the next stage of their education before reaching higher education (Betz, 1978; Tobías, 1980; Cockcroft, 1982; Frary, Ling, 1983; Karp, 1991; McLeod, 1993).

Due to the preceding, the following research question is posed, the objective and the hypothesis to be demonstrated: in the cultural context of a public school in the municipality of Veracruz, Mexico, does Muñoz's and Mato (2007) model of anxiety towards mathematics can be explained by the five factors on anxiety before the evaluation in Mathematics; anxiety about temporality; anxiety before understanding problems; anxiety about numbers and mathematical operations; and anxiety about mathematical situations in real life? Therefore, the study's objective is to verify that, in the cultural context of a public school, the model of Muñoz and Mato (2007) can be explained by the five factors they propose.

The hypothesis to be tested is: In the cultural context of a public school, the Muñoz and Mato model (2007) can be explained by the five factors on evaluation anxiety in Mathematics; anxiety about temporality; anxiety before understanding problems; anxiety about numbers and mathematical operations; and anxiety about mathematical situations in real life.

2. Literature review

The OECD Program for International Student Assessment (PISA) has evaluated the knowledge of compulsory formal education since 2000 in three areas of knowledge: reading, mathematics, and science. The results on mathematical knowledge indicate that Mexicans students fail to demonstrate proficiency in basic activities and to achieve level 2 (OECD, 2012).

Furthermore, even though two cycles of that evaluation have been carried out with a specific focus on the mathematical area, and whose time intervals were significant for the results to reflect a positive change, they continue to be far from going better. On the other hand, the Center for Research in Public Policy (IMCO, 2021) has reported that the current contingency for COVID-19 generated a delay in the development of student learning, equivalent to two years of schooling. Therefore, it would be interesting to know how the current population responds to the PISA test corresponding to 2021 that is expected to be carried out in 2022 when students are more present in the classrooms.

Anxiety is a feeling that produces the desire to avoid it, hence reducing in mathematics, to those interested, the possibility of entering professional careers related to this area. In addition, various studies associate the presence of this feeling to school failure and poor performance in the student community (Schultz, Heuchert 1983; Marsh, 1988; Puteh, 2002; Mato, 2006; Immordino-Yang, Damasio, 2007; Swars, Daane, Giesen, 2010). Additionally, anxiety towards mathematics has for some years now presented substantial differences in terms of gender in the different stages of study (Ernest, 1976; Hilton, 1980; Tobías, 1980; Shibley et al., 1990). Furthermore, anxiety towards mathematics has been widely studied since the concept took shape in the middle of the 20th century (Gough, 1954), finding a clear relationship with the original concept of anxiety since it is characterized by somatic and cognitive factors given as a result of an aversive stimulus (American Psychiatric Association, 2013). Specifically, for anxiety towards mathematics, the meaning of anxiety is transferred to the specific rejection stimulus that occurs when facing a situation related to said subject.

So it is not surprising that over the years, a series of scales have been developed on the subject that has attempted to measure the phenomenon with two, three, and even five dimensions that explain the influence of anxiety towards mathematics in aspects related to assessment, number operations, and mathematical learning, among other components (Richardson, Suinn, 1972; Rounds, Hendel, 1980; Plake, Parker, 1982; Resnick et al., 1982; Alexander, Cobb, 1984; Suinn et al., 1988; Alexander, Martray, 1989; Brown, Gray, 1992; Kazelskis, Reeves, 2002; Hopko et al., 2003; Muñoz, Mato, 2007; Nuñez-Peña et al., 2013).

Therefore, at present, the phenomenon of anxiety towards mathematics has been consolidated as a multidimensional construct that is closely related to the negative cognitive/affective attitudes that are formed in the face of this matter (Fennema, Sherman, 1976; Frary, Ling, 1983; Wigfield, Meece, 1988). In addition, it highlights the relevance of the evaluation of mathematics, as the most important dimension to give an explanation to this type of anxiety (Muñoz, Mato, 2007; Zeidner, 2007; García-Santillán et al., 2014; García-Santillán et al., 2015; Moreno-García, Larracilla-Salazar, 2016; García-Santillán et al., 2017; Larracilla-Salazar et al., 2019).

Likewise, the demographic aspects of the population studied should be considered due to the existence of evidence that opposes the fact that evaluation is the most crucial dimension (García-Santillán et al., 2016). Finally, emphasis is also placed on differentiating the evaluation process from the application of an exam, that is, separating what pertains to the type of evaluative process used and the exam to evaluate knowledge since this also implies a different symbolic load in the students to identify what the detonation of anxiety towards mathematics itself would be implying (Larracilla-Salazar et al. 2019; Soneira, Mato, 2020).

3. Method and procedure

This non-experimental design study is approached from the hypothetical deductive paradigm. For this, a quantitative approach, the statistical methodology of structural equations (SEM), was used, which adopts a confirmatory approach with "causal" processes that generate observations on multiple variables (Bentler, 1988). In this idea, Byrne (2010) states that the hypothesized model in this methodology is statistically tested in simultaneous analysis of all the variables to determine to what extent it is consistent with the data (p. 27). If the goodness of fit is adequate, the model is defined by the relationships between postulated variables; if it is inappropriate, the viability of such relationships is rejected.

In addition, the Bootstrap Technique was used, which allows the researcher to create multiple sub samples of an original database. The importance of this action is that the parameter distributions relative to each of these generated samples can then be examined. The bootstrapping sampling distribution is concrete and allows the comparison of parametric values on repeated samples that have been drawn (with replacement) from the original sample.

3.1. Population and sample

The study was carried out in mid-2021, and the information was obtained in the third quarter of that year. The type of sampling is non-probabilistic by self-determination since it was considered to apply the sample for convenience to the groups of the first and second grades of high school, which were previously agreed with the campus authorities and the research group. The sample size consisted of 200 students, who were duly enrolled in the school year, one of the inclusion criteria being that they were regular students to be able to participate in this study.

Of 200 participants, 50.5 % were male students, and 49.5 % were female. The age ranged between 13 and 16 years, with the highest concentration being 13 and 14 years (40.5 % and 43 % respectively). Most of the participants were in the first year (69 %), and the remaining 31% were in the second year.

3.2. Instrument

For data collection, the scale designed by Muñoz and Mato (2007) comprises questions about the participant's profile and 24 items on a five-point Likert scale ranging from 1 totally disagree to 5 totally agree.

The 24 items of the test are integrated into five dimensions or factors: anxiety before the evaluation in mathematics, anxiety about temporality, anxiety before understanding problems, anxiety about numbers and mathematical operations, anxiety about mathematical situations in real life.

Table 1 shows the factors of the scale and the items associated with each one. The conceptualization of each of the constructs is defined as follows according to Muñoz & Mato (2007):

- Anxiety about the evaluation: Feelings of anxiety when being evaluated; fear of exams and having to do math in public.
- Anxiety about temporality: It is related to the time left to take an exam or to take exercises done for class.
- Anxiety about understanding math problems: The student fears not understanding math problems.
- Anxiety about numbers and mathematical operations: The student manifests anxiety when doing exercises, operations, and when working with numbers.
- Anxiety about real-life mathematical situations: Having to face Mathematics in everyday life.

Table 1. Anxiety toward mathematics scale (factors)

Factor	Items
Anxiety toward evaluation (AE)	1, 2, 8, 10, 11, 14, 15, 18, 20, 22 and 23
Anxiety toward temporality (AT)	4, 6, 7 and 12
Anxiety toward understanding mathematical problems (ATUMPM)	5, 17 and 19
Anxiety toward numbers and mathematical operations (ATNMO)	3, 13 and 16
Anxiety toward real-life mathematical situations (ATRMS)	9, 21 and 24

3.3. Data collection and statistical analysis

The data were collected through a questionnaire and analyzed using the IBM Statistic SPSS 25 for descriptive analysis, and the AMOS 24 software was used to determine the validity of the model. The data gathered showed a Cronbach alpha score of 0.751, reflecting acceptable internal consistency and reliability.

4. Results

This section presents the results that contrast the proposed hypothesis, reported in two parts. The first one reports the results of the exploratory factor analysis based on the theoretical model of Muñoz and Mato (2007) on anxiety towards mathematics. The second part checks the model's validity through structural equations and the Bootstrap Technique.

4.1. Exploratory factor analysis

To validate the model proposed by Muñoz and Mato, in the context of high school students from a school in Veracruz, Mexico, exploratory factor analysis was carried out in order to define the factors that are highly correlated with each other, according to the perception of the students who participated in this study. Table 2 shows the results in four factors, each grouping the intercorrelated items, which are at the same time relatively independent of the remaining items.

The Bartlett test of Sphericity values are significant, p is less than 0.05, and the Kaiser-Meyer-Olkin Measure (.837), both tests they corroborate that the variables are not correlated. Of the 24 items proposed in the Muñoz and Mato (2007) scale, only 14 were estimated. The total variance (61 %) of the factors is greater than .500, which indicates that the model would be explained to 61 % by these variables.

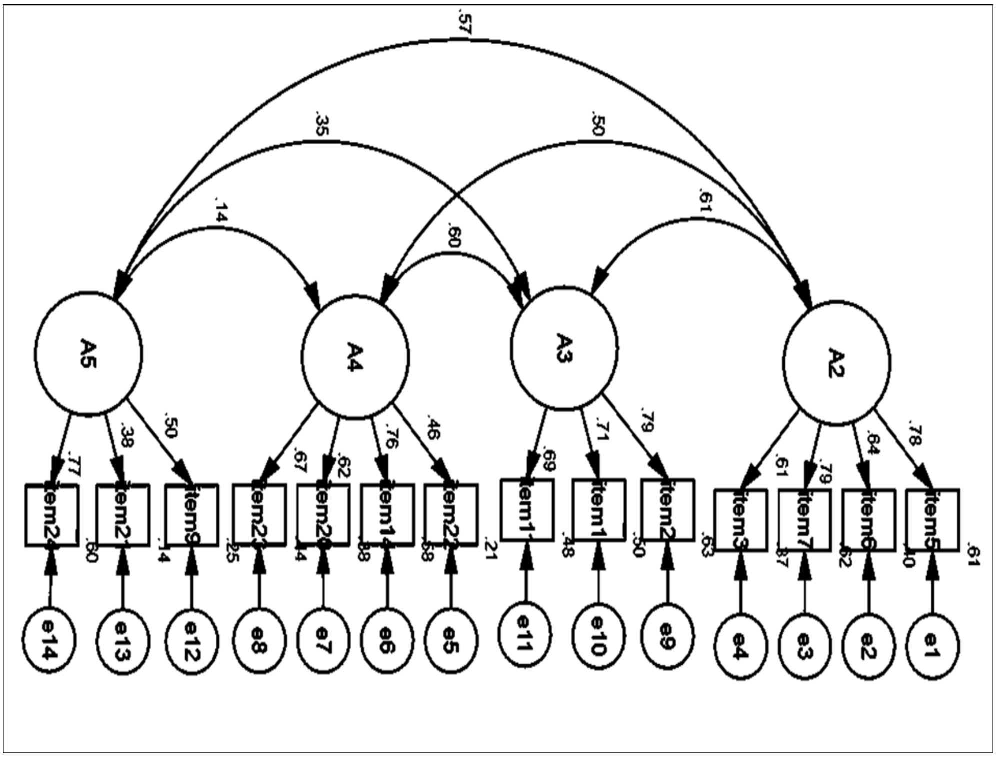
4.2. Exploratory Factor Analysis with the Bootstrap Technique

It is important to note that the Bootstrap technique is used because the data from this research do not conform with normality. This fact was observed when evaluating the multivariate normality of the data, finding that the critical value of kurtosis was 9,521, while according to Byrne (2010), a value greater than 5 indicates that the data does not behave normally. Hence, bootstrapping was used to test the hypothesis that the model extracted from Muñoz and Mato (2007) fits the data. Figure 1 depicts the model.

Table 2. Factorial weight, commonalities and variance

	Component				Commonalities
Variables	A2	A3	A4	A5	
item5	.801				.700
item6	.771				.628
item7	.749				.659
item3	.621				.659
item2		.814			.728
item1		.780			.673
item11		.693			.620
item22			.726		.649
item14			.720		.643
item20			.693		.554
item23			.683		.566
item9				.771	.608
item21				.691	.491
item24				.621	.569
Eigenvalues	4.535	1.772	1.259	1.032	
% Variance	18.181	15.729		15.611	11.894
% Total variance				61.415	

* A5 (Anxiety toward real-life mathematical situations), A4 (Anxiety toward evaluation of the mathematical problems), A3 (Anxiety toward evaluation of the test), A2 (Anxiety about temporality)



* A5 (Anxiety toward real-life mathematical situations), A4 (Anxiety toward evaluation of the mathematical problems), A3 (Anxiety toward evaluation of the test), A2 (Anxiety about temporality)

Fig. 1. Adjusted model of anxiety toward mathematics

If the data is assumed to behave normally, the χ^2 values of the model are: χ^2= 91.974 with 71 degrees of freedom and a probability of 0.48, which is less than 0.50, indicating that the null hypothesis and that the model data do not fit the data would be rejected. However, since the data is not normal when doing a Bootstrap ML and the Bollen-Stine Bootstrap with a sample of 2000, the values provided by this test yield a value of p = .389, which shows that the model is correct since the value of *p* is greater than 0.05.

		|--------------------
	37.616	|*
	46.505	|*
	55.395	|***
	64.284	|**********
	73.173	|***************
	82.062	|*******************
	90.952	|********************
N = 2000	99.841	|*************
Mean = 88.614	108.730	|*********
S. e. = .413	117.619	|*****
	126.508	|**
	135.398	|**
	144.287	|*
	153.176	|*
	162.065	|*
		|--------------------

Fig. 2. The Bollen-Stine Bootstrap

Figure 2 shows the mean χ^2 value and the general shape of the distribution of the χ^2 values in the 2000 samples. An expected χ^2 value of 88,614.

The χ^2 mean of the bootstrap samples serves as the critical χ^2 value, which allows comparison to the obtained χ^2 of 91.974. When the χ^2 obtained is compared with 88.614, the p-value associated with that hypothesis test is .389 and, therefore, is statistically significant (see Table 3).

Table 3. χ^2 value for the sample

Model	NPAR	CMIN	*df*	*p*
Sample data	34	91.974	71	.048
Bootstrap	34	88.614	71	.389

To corroborate the statistical significance of the coefficients and their values, Table 3 shows the coefficients, which are also statistically significant, as shown in Table 4.

Table 4. Coefficients

Items	Factor	Estimate	SE	SE	SE-SE	Mean	Bias	SE-Bias
item5	A2	1		0	0	1	0	0
item6	A2	0.784	0.09	0.091	0.001	0.78	-0.005	0.002
item7	A2	0.993	0.1	0.067	0.001	0.993	0.001	0.001
item3	A2	0.79	0.1	0.096	0.002	0.787	-0.003	0.002
item22	A4	1		0	0	1	0	0
item14	A4	1.72	0.3	0.347	0.005	1.763	0.044	0.008

item20	A4	1.407	0.27	0.269	0.004	1.437	0.03	0.006
item23	A4	1.488	0.27	0.319	0.005	1.523	0.035	0.007
item2	A3	1		0	0	1	0	0
item1	A3	0.91	0.1	0.087	0.001	0.91	0	0.002
item11	A3	0.889	0.1	0.118	0.002	0.898	0.009	0.003
item9	A5	1		0	0	1	0	0
item21	A5	0.766	0.2	0.21	0.003	0.778	0.011	0.005
item24	A5	1.617	0.35	0.635	0.01	1.741	0.124	0.014

In Table 4, the first and second columns show the estimated values of the data and their standard error (SE), the third (SE) shows standard errors of the sample bootstrap, the fourth (SE-SE) provides an approximate standard error for the estimation of the standard error bootstrap to each other, and the fifth column (Mean) represents the estimate of the average parameter. The column labeled BIAS shows the difference between the original estimate and the mean of the estimates in the starter samples.

If the mean estimate through Bootstrap is greater than the original estimate, then BIAS will be a positive value (Arbuckle, 2016). It is observed that there are two negative values, denoting that the estimate of the mean of the original data is greater than that of the data generated with Bootstrap. Table 5 shows the values that refer to the hypothesis tests. They are performed according to the upper and lower limits (Byrne, 2010). When observing the values of the parameters, they can be evaluated individually, according to the upper and lower limits. If the values between these limits do not include zero, there is no significant difference between the original data and that generated by Bootstrap.

Table 5. Values for hypothesis testing

Parameter			Estimate	Lower	Upper	*p*
item5	<---	A2	1.000	1.000	1.000	...
item6	<---	A2	.784	.610	.968	.001
item7	<---	A2	.993	.863	1.133	.001
item3	<---	A2	.790	.603	.987	.001
item22	<---	A4	1.000	1.000	1.000	...
item14	<---	A4	1.720	1.231	2.594	.001
item20	<---	A4	1.407	1.016	2.082	.001
item23	<---	A4	1.488	.980	2.247	.001
item2	<---	A3	1.000	1.000	1.000	...
item1	<---	A3	.910	.747	1.091	.001
item11	<---	A3	.889	.674	1.133	.001
item9	<---	A5	1.000	1.000	1.000	...
item21	<---	A5	.766	.379	1.229	.001
item24	<---	A5	1.617	1.039	3.215	.001

5. Discussion

From the results obtained from the parameters of the four-factor confirmatory model, it is now possible to answer if the five factors can explain the Anxiety towards mathematics model of Muñoz and Mato (2007) in a population of high school students. The scale used to obtain the data from the study population is made up of the 24 items grouped into the five factors described in Table 1 and the data from the profile of the respondents. The five factors of the scale were reported in the investigations carried out by Muñoz and Mato (2007) in Spanish students.

Regarding the result of this study, it turns out to be different from the one proposed by the original authors of the scale since a significant model was obtained (.389) configured by a four-factor structure, as shown in Table 6.

Table 6. Adjusted model of anxiety towards mathematics

Temporality and understanding mathematical problems	Anxiety toward evaluation (AE) Prior to exam	Anxiety toward evaluation (AE) In the exam and after	Anxiety toward real-life mathematical situations (ATRMS)
5.- I feel nervous when I listen to how other classmates solve a math problem 6.- I get nervous when I know that in the next course I will still have math classes 7.- I feel nervous when I think about the math test that I have next week 3.- I get nervous when I open the math book and find a page full of problems	2.- I feel nervous when I get the math test questions 1.- I get nervous when I think about the math test the day before 11.- The math exams make me nervous	22.- I feel nervous when we get a problem and a partner finishes it before me 14.- I feel nervous having to explain a math problem to the teacher 20.- I am nervous to receive the final (exam) math grades 23.- I feel nervous when I have to explain a problem in math class	9.- I feel nervous when I check the purchase ticket after paying 21.- I feel nervous when I want to find out the change in the store 24.- I feel nervous when I start doing my homework

The first factor (5, 6, 7, 3) includes indicators that initially corresponded to anxiety about temporality, anxiety about understanding mathematical problems, and anxiety about numbers and mathematical operations. A similar case is of the second factor (2, 1, 11), where three indicators corresponding to the evaluation are grouped, which could be interpreted as anxiety prior to the evaluation. The third factor (22, 14, 20, 23) groups indicators of anxiety toward the evaluation, which can be classified as the anxiety that the student suffers when evaluated. Hence, according to this result, two factors inherent to the evaluation would be obtained. Finally, the fourth factor fully corresponds with the original model by Mato and Muñoz (2007).

The bootstrap technique was used in the item selection process to estimate the standard error of the statistics used to obtain the appropriate items. The results show two negative items, indicating that the original data's mean value is greater than the one generated by bootstrapping. Nevertheless, according to the upper and lower limits of each of the items, it can be observed that their contribution is significant since the values reported in Table 5, as no item has zero included.

The population participating in this study is similar to the population of the study that gave rise to the scale; that is, in both cases, secondary school students were evaluated. Therefore, the only difference is the context in which the studies were carried out.

The scale has been used to study different populations whose results have not always corresponded with the original reference model. For example, the work of García-Santillán, Moreno-García and Hernández-Utrera (2014) evaluated the five-factor model in an EFA with extracted principal components under the criterion of eigenvalues greater than 1, where the obtaining of a single factor is reported, as well as the anxiety dimension to the evaluation with the greatest commonality.

A similar case is the work of Moreno-García, García-Santillán and Cristóbal-Hernández (2014), which reported a single factor in their results, as well as the evaluation factor, as a factor with the highest commonality value. In another study, using a structural equations model, the five-factor model was validated in García-Santillán, Santana-Villegas, Téllez-Mora and Moreno-García

(2015), where anxiety towards real-life situations was the variable with the highest weight showed, followed by anxiety towards numbers and math operations.

Anxiety towards the evaluation seems to be the variable that has shown the highest commonality in studies conducted in Latin contexts, specifically in the states of Oaxaca and Veracruz, both in Mexico (García-Santillán et al., 2015; Moreno-García, Larracilla-Salazar, 2016; García-Santillán et al., 2016).

Singular behavior of a student population that was reported in the work of García-Santillán, Mato-Vázquez, Muñoz-Cantero and Rodríguez-Ortega (2016). Their study surveyed students from an upper secondary level educational institution in both shifts: evening and morning. The result shows that the highest level of anxiety presented by the students of both shifts is similar in relation to the evaluation, followed by anxiety towards numbers and mathematical operations. In the remaining three factors, they showed differences. In contrast, the morning shift presents greater anxiety towards understanding mathematical problems, temporality, and mathematical situations in real life. The evening shift reports anxiety toward temporality, mathematical situations in real life, and understanding mathematical problems.

In the study of A. García-Santillán, R.V. García-Cabrera, V.S. Molchanova and V. García-Cabrera (2018), carry out an analysis with the Varimax rotation, grouping the 24 indicators to each of their dimensions of the original scale, to determine the behavior in medical students. The rotated component matrix yielded five factors, the anxiety component towards mathematics in real-life situations, the one that showed the most significant weight, followed by anxiety toward the evaluation and toward the understanding of mathematical problems. Different the result reported by García-Santillán, Mato-Vázquez, Escalera-Chávez and Moreno-García, (2016) where anxiety towards evaluation showed the highest factorial weight followed by temporality, understanding of mathematical problems, toward numbers and mathematical operations and also toward math situations in real-life.

Recently, Soneira and Mato (2020) reclassified the original scale of 24 items to 19 due to the confirmatory analysis where five items presented low commonality. Considering that the original scale was validated with students with an average age of 12 years, compared with the population of engineering students in which they focused their study, there is a difference in personal maturity between both populations. The result of the study showed the formation of two factors: anxiety towards evaluation and anxiety towards numbers and mathematical operations.

6. Conclusion

With the results of this study and the discussion made from the results reported by other works using the scale of Muñoz and Mato, it can be concluded that the original scale has favored the understanding of the phenomenon of anxiety toward mathematics from different perspectives, depending on the populations studied and the context in which these studies were carried out.

In addition, it should be noted that the characteristics of the data matrix will define the direction of the analysis since, in the absence of multivariate normality, different measurement techniques can be developed that do not require this theoretical criterion.

7. Study limitations

The formation of the sample is often a limitation because it focuses on a specific population within a particular institution, as it was in this case, which only surveyed first and second-year students of a public institution high school.

In addition, the effort and scope were limited by the lack of economic resources to expand the sample to a greater number of students and a greater number of educational institutions in the public and private sectors. Also, the restrictions derived from confinement due to the Covid-19 pandemic imposed some limitations.

8. Future research

It is suggested to continue with confirmatory studies covering the broadest possible range of students and institutions from the public and private sectors.

It also seems convenient to develop quasi-experimental studies where a control group and a treatment group can be evaluated, gathering data before and after applying an exam with mathematical problems, and finally using a scale for measuring anxiety toward mathematics.

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