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Students, Computers and Mathematics: How do they interact in the Teaching-Learning Process? (An Empirical Study on Accounting, Management and Marketing Undergraduate Students)

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Abstract

This study addresses Galbraith and Hines' scale (1998, 2000) and arguments exposed by Galbraith, Hines and Pemberton (1999), Cretchley, Harman, Ellerton and Fogarty (2000), McDougall and Karadag (2009), Gómez-Chacón and Haines, (2008), Goldenberg (2003) and Moursund (2003) about mathematics confidence, mathematics motivation, computer confidence, computer motivation, computer and mathematics interaction and mathematics engagement. In the same way, it takes up the arguments of García and Edel (2008), García-Santillán and Escalera (2011), García-Santillán, Escalera and Edel (2011) about variables associated with the use of ICT as a didactic strategy in the teaching-learning process in order to establish a relationship between students' perception of the teaching-learning process and technology. Therefore, this paper examines the relationships between students' attitudes towards mathematics and technology in a study carried out at the *Universidad Autónoma* of *San Luis Potosí Unidad Zona Media.* 214 questionnaires were applied to Accounting, Management and Marketing undergraduate students. The statistical procedure used was factorial analysis with an extracted principal component. The Statistics Hypothesis: Ho: $\rho = 0$ has no correlation, while Ha: $\rho \neq 0$ does. Statistics test to prove: X^2, Bartlett's test of sphericity, KMO (Kaiser-Meyer_Olkin) Significance level: $\alpha=0.05$; $p< 0.01$, $p<0.05$ Decision rule: Reject Ho if χ^2 calculated > χ^2 tables. The results obtained from the sphericity test of Bartlett KMO (.703), Chi square X^2 92.928 > χ^2 tables, Sig. 0.00 < p 0.01, MSA (CONFIMA .731; MOTIMA .691; COMPIMA .741; CONFICO .686 and INTEMAC .694) provide evidence to reject *Ho.* Thus, the variables mathematics confidence, mathematics motivation, computer confidence, computer motivation, computer-mathematics interaction and mathematics engagement help us to understand the student's attitude toward mathematics and technology.

Keywords: mathematics confidence, mathematics motivation, computer confidence, computer motivation, computer and mathematics interaction and mathematics engagement.

1. Introduction

In the words of Galbraith *et al.,* "When students, computer and mathematics meet: *does it make the difference?* The seminal paper of Galbraith and Hines (1998) *"Disentangling the nexus: attitudes to mathematics and technology in a computer learning environment"* refers to gaining insight into students' attitudes and beliefs as a most important and crucial step in understanding how the learning environment for mathematics is affected by the introduction of computers and other types of technology. In this sense, they report on the administering of six Galbraith–Haines scales to 156 students upon entry to courses in engineering and actuarial science. This research discusses the implications of confidence, motivation, engagement and interaction with technology in the learning process environment and demonstrates that the computing and mathematics attitude scales capture distinctive properties of student behaviour in this respect. Therefore some questions could guide this research: *What is the students' attitude toward the use of computers in the teaching of mathematics? What is the students' attitude toward mathematics confidence, motivation and engagement?* How *is this interaction between computer and mathematics achieved in the teaching process?* In order to answer these questions, the objective of this study was to measure, how mathematics confidence, mathematics motivation, computer confidence, computer motivation, computer-mathematics interaction and mathematics engagement help to understand the students' attitude toward mathematics and technology. All the above is simplified in a single question: *RQ1*: *What is the underlying latent variable structure that would allow the student to understand the perception about mathematics and computers*?

2. Theoretical approach to mathematics confidence, computer confidence, engagement, motivation and interaction between mathematics, computer and students

This research takes the construct proposed by Galbraith and Hines (1998, 2000) and Galbraith, Hines and Pemberton (1999) on the “mathematics-computer” and mathematics-computing attitude in mathematics confidence, computer confidence and computer-mathematics interaction. We take the construct proposed by Cretchley, Harman, Ellerton and Fogarty (2000) about attitudes towards the use of technology for learning mathematics.

The objective of this study is to determine the structure of the underlying latent variable that would allow us to understand the student’s perception about mathematics and computers. McDougall and Karadag (2009) indicate that despite the theoretical and practical concerns in integrating technology into mathematics education, students widely use technology in their daily life at an increasing rate. Because these students were born in the information age, they are confident enough in using technology and have no idea about a life without technology, such as the internet and computer. There is no doubt that they can use technology effectively, and many studies document that they use technology as anticipated (Lagrange, 1999; Artigue, 2002; Izydorczak, 2003; Karadag and McDougall, 2008; Kieran, 2007; Kieran and Drijvers, 2006; Moreno-Armella and Santos-Trigo, 2004; Moyer, Niexgoda, and Stanley, 2005). Galbraith (2006) describes the use of “technology as an extension of oneself” as “the partnership between technology and student merge to a single identity” which is the highest intellectual way to use technology. This use of technology extends the user’s mental thinking and cognitive abilities because technology acts as a part of the user’s mind. For example, linked representation (Kaput, 1992) between symbolic and visual representation could be a relevant example for this type of use because manipulations in one of the representations affect the others.

Suurtamm and Graves (2007) state that, *“enabling easier communication, providing opportunities to investigate and explore mathematical concepts, and engaging learners with different representational systems which help them see mathematical ideas in different ways”*. They refer to the Ontario Ministry of Education which outlined the use of technology by suggesting: “students can use calculators and computers to extend their capacity to investigate and analyze mathematical concepts and to reduce the time they might need otherwise spent on purely mechanical activities,” and added that technology is conceived as a tool to extend students’ abilities with tasks which are challenging or impossible in paper-and-pencil environments. These tasks could be to perform complicated arithmetic operations or, as Galbraith and Haines (2000) propose, an Attitude Scale Toward: maths confidence, computer confidence, maths-tech attitudes, maths-tech experience, variables that are involved in our subject.

Previously exposed may identify the variables implicated, as shown in the next construct (path model).

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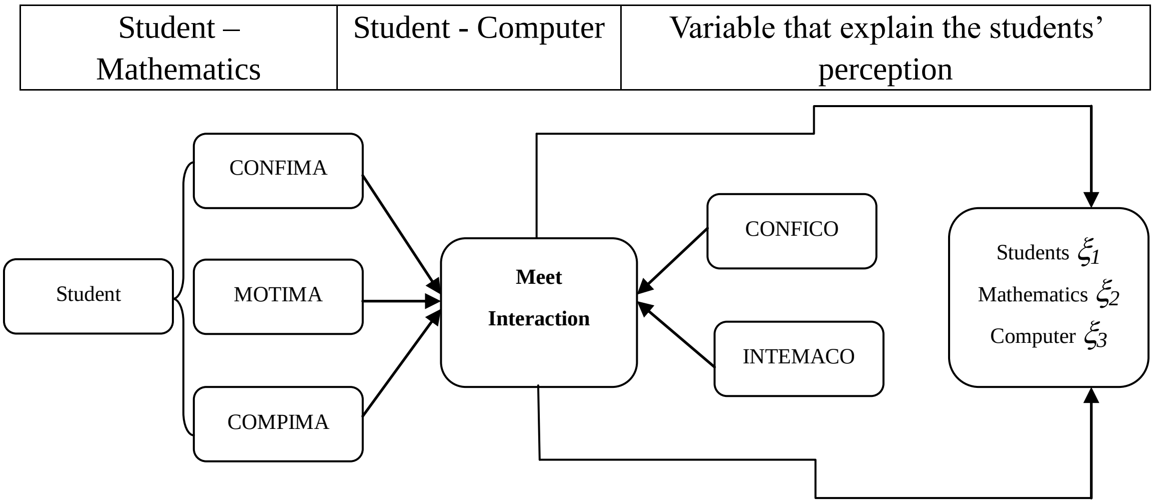
Figure 1 Theoretical Path Model



Source: self-made

3. Empirical studies

Some surveys on attitudes toward mathematics have been undertaken and have developed significantly in the past few years. The first ones focused on possible relationships between positive attitude and achievement (Leder, 1985), surveys highlighting several problems linked to measuring attitude (Kulm, 1980), a meta-analysis, and recent studies which question the very nature of attitude (Ruffell et al., 1998), or search for 'good' definitions (Di Martino and Zan, 2001, 2002), or explore observation instruments that are very different from those traditionally used, such as questionnaires (Hannula, 2002).

It is important to point out that the surveys on attitude towards mathematics have been undertaken for many years, but the studies related to attitude towards information technology has a shorter history in topics about mathematics education. The studies carried out within undergraduate programs in mathematics by Galbraith and Haines (2000) are important for this subject matter. In 1998, these authors developed instruments and several attitude scales to measure mathematics and I.T. attitudes. These instruments have been used to assess attitudes in different countries: England (e.g. Galbraith and Haines, 1998 and 2000), Australia (e. g. Cretchley and Galbraith, 2002), Venezuela (e.g. Camacho and Depool, 2002), etc. The results offered us evidence about several of the dimensions of attitudes: 1) Mathematics confidence, 2) Mathematics motivation, 3) Mathematics engagement, 4) Computer confidence, 5) Computer motivation and 6) Interaction between mathematics and computers. In all these studies, the authors' findings have been similar: there is a weak relationship between mathematics and computer attitudes (both confidence and motivation) (Di and Zan, 2001) and that students' attitudes to using technology in the learning of mathematics correlate far more strongly with their computer attitudes than with their mathematics attitudes (Cretchley and Galbraith, 2002).

A study conducted by Fogarty, Cretchley, Harman, Ellerton, and Konki (2001), reports on the validation of a questionnaire designed to measure general mathematics confidence, general confidence with using technology, and attitudes towards the use of technology for mathematics learning. A questionnaire was administered to 289 students commencing a tertiary level course on linear algebra and calculus. Scales formed on the basis of factor analysis demonstrated high internal consistency reliability and divergent validity. A repeat analysis confirmed the earlier psychometric findings as well as establishing good test-retest reliability. The resulting instrument can be used to measure attitudinal factors that mediate the effective use of technology in mathematics learning.

Gómez-Chacón and Haines, (2008) indicate that there are several studies describing the positive impact of technology on students' performance (Artigue, 2002; Noss, 2002). In particular, some researchers underline the new cognitive and affective demands on students in technology programs (Galbraith, 2006; Pierce and Stacey, 2004; Tofaridou, 2007). This evidence suggests that it is important to undertake research topics which make a careful study of the dialectic aspects of technical and conceptual work, and of the attitudes towards mathematics and technology in the setting where the learning of mathematics uses technology (graphing calculators, computer-based resources).

The results offered evidence about several dimensions of attitudes: mathematics confidence, mathematics motivation, mathematics engagement, computer confidence, computer motivation and mathematics-computer interaction. The authors of these studies come to a similar conclusion, that 'there is a weak relationship between mathematics and computer attitudes (both confidence and motivation) and that students' attitudes to using technology in the learning of mathematics correlate far more strongly with their computer attitudes than with their mathematics attitudes' (Cretchley and Galbraith, 2002).
On the other hand, studies by Goldenberg (2003), Moursund (2003), García and Edel (2008), García-Santillán, Escalera and Edel (2011), García-Santillán and Escalera (2011) report that at present the teaching-learning processes are favourably influenced in the evolution and growth of ICT, which contributes significantly to the educational process of mathematics in general. Regarding the use of technology to support the teaching process, Crespo (1997), cited in Poveda and Gamboa (2007), claimed that even though "buying and selling" the idea that technology is the magic formula that will transform classrooms into an authentic, perfect teaching and learning setting, in reality this is not true. However, Gomez Meza (2007), cited by Poveda and Gamboa, (2007), indicates that although technology is not the magic formula, nor probably the solution to all educational problems, it is true that technology could be an agent of change that favours the mathematics teaching-learning process. With these arguments, the hypothesis to be proved is:

3.1. Hypothesis

Considering that the correlation matrix is an identity matrix, Ho: $R_p=1$ the variables are not inter-correlated, Hi: $R_p \neq 1$ the variables are inter-correlated

Null Hypothesis HO: The latent variables mathematics confidence, mathematics motivation, computer confidence, computer motivation, computer-mathematics interaction and mathematics engagement do not help to understand the students' attitude toward mathematics and technology.

Alternative Hypothesis H1: The latent variables mathematics confidence, mathematics motivation, computer confidence, computer motivation, computer-mathematics interaction and mathematics engagement help to understand the students' attitude toward mathematics and technology.

Statistics Hypothesis: Ho: $\rho = 0$ does not have correlation Ha: $\rho \neq 0$ has correlation. Statistical test to probe: $\chi 2$, sphericity test of Bartlett, KMO (Kaiser-Meyer_Olkin), MSA (measure sample adequacy) Significance level: $\alpha = 0.05$; $p < 0.01$, *p<0.05 load factorial of .70 Critical* value: $\chi^2_{\text{calculated}} > \chi^2_{\text{tables}}$, then reject Ho. Decision rule: Reject: Ho if χ^2 calculated > χ^2 tables

4. Methodology

4.1 Population, sample and test

The Galbraith and Hines (1998) scale was applied to all the groups of students that had taken mathematics courses between the second and third academic year, combining ordinary classroom sessions and other practices in the computer laboratory, at San Luis Potosí Autonomous University-SLP Mexico. Table 1 shows participants from any semester and undergraduate major. After reviewing the questionnaires, they were all accepted, thus the sample size is 214 cases.

Table 1: Population at San Luis Potosí Autonomous University-SLP Mexico (Academic programs)

Undergraduate Major (semester)	Students	Partial	Accumulated
Management 6th	30		
Management 8th	43	73	73
Marketing 6th	24		
Marketing 8th	49	73	73
Accounting 6th	28		
Accounting 8th	38	66	66
		Σ	214

Source: self-made

4.2. Statistical Procedure

The statistical procedure used is an exploratory Factor Analysis Model. First, if we consider the next variables to be measured: attitude scales toward: mathematics confidence, mathematics motivation, computer confidence, computer motivation, computer and mathematics interaction, mathematics engagement (Galbraith, and Haines, 1998), all the variables are identified as $X_1 \ldots\ldots X_{40}$ (latent variables ξ). All of them are in order to measure 214 students, and then we obtain the following data matrix for the study:

Students	Variables X_1 X_2 . . . . . X_p
1	X_{11} X_{12} …. x_{1p}
2	X_{21} X_{22} …. x_{2p}
…..	……….
214	X_{n1} X_{n2} …. x_{np}

The above mentioned is given by the following equation:

$$\begin{aligned} X_1 &= a_{11}F_1 + a_{12}F_2 + \ldots\ldots\ldots + a_{1k}F_k + u_1 \\ X_2 &= a_{21}F_1 + a_{22}F_2 + \ldots\ldots\ldots + a_{2k}F_k + u_2 \\ &\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ X_p &= a_{p1}F_1 + a_{p2}F_2 + \ldots\ldots\ldots + a_{pk}F_k + u_p \end{aligned}$$

Where $\mathbf{F_1}, \ldots \mathbf{F_k}$ (K<<p) are common factors and $\mathbf{u}_1$, …. $\mathbf{u_p}$ are specific factors and coefficients, $\{a_{ij}; i=1,\ldots,p; j=1,\ldots,k\}$ are factorial load. Besides, we suppose that the common factors have been standardized (E(F_i) = 0; Var(F_i) = 1, the specific factors have a media of zero and a correlation (E(u_i) = 0; Cov(u_i, u_j) = 0 if i≠j; j, i = 1, …..,p) and both factors have correlation (Cov(F_i,u_j) = 0, $\forall_i = 1,\ldots,k; j=1,\ldots,p$. Considering this, if the factors are correlated (Cov(F_i,F_j) = 0, if i≠j; j, i=1,…..,k) then we have a model with orthogonal factors, and if not, will have a model with oblique factors. Therefore, it can be expressed as follows: $x = Af + u \ \hat{U}\ X = FA' + U$

Where:

It is the data matrix	It is the factorial load matrix	It is the factorial punctuation matrix
$x = \begin{pmatrix} x_1 \\ x_2 \\ \ldots \\ x_p \end{pmatrix}, f = \begin{pmatrix} F_1 \\ F_2 \\ \ldots \\ F_k \end{pmatrix}, u = \begin{pmatrix} u_1 \\ u_2 \\ \ldots \\ u_p \end{pmatrix}$	$A = \begin{pmatrix} a_{11}a_{12}\ldots a_{ik} \\ a_{21}a_{22}\ldots a_{2k} \\ \ldots\ldots\ldots \\ a_{p1}a_{p2}\ldots a_{pk} \end{pmatrix}$	$F = \begin{pmatrix} f_{11}f_{12}\ldots f_{ik} \\ f_{21}f_{22}\ldots f_{2k} \\ \ldots\ldots\ldots \\ f_{p1}f_{p2}\ldots f_{pk} \end{pmatrix}$

Using the previously mentioned hypothesis, we now have:

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

Where:

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

This equation corresponds to communalities and the specificity of variable X_i respectively.

So the variance of each variable may be divided into two parts: one of their communalities h_i^2 that represents the variance explained *b* and the common factors with the specificity Ψ_I that represents the specific variance part of each variable.
So, we obtained:

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

These are common factors that explain the relationship between variables of the phenomena studied.

Finally, we have the KMO, MSA and Bartlett's test of sphericity. The Kaiser-Meyer-Olkin measures the sampling adequacy tests where the partial correlations among variables are small. Bartlett's test of sphericity examines whether the correlation matrix is an identity matrix, which would indicate that the factor model is inappropriate. The KMO is an indicator for comparing the magnitudes of the observed correlation coefficients to the magnitudes of the partial correlation coefficients. Large values for the KMO measure indicate that a factor analysis of the variables is a good idea. Bartlett's test of sphericity is used to test the null hypothesis that the variables in the population correlation matrix are not correlated, so Ho R=1 means that the determinant of the correlation matrix is 1. Bartlett's test of sphericity is given by:

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

Where:
n = sample size; Ln= neperian logharitm, λ_j(j=1,…..,p) eigenvalues of R; R = correlation matrix.

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and measure of sampling adequacy for each variable (MSA) are given by

$$KMO = \frac{\sum_{j \neq i} \sum_{i \neq j} r_{ij}^2}{\sum_{j \neq i} \sum_{i \neq j} r_{ij}^2 + \sum_{j \neq i} \sum_{i \neq j} r_{ij(p)}^2} \qquad MSA = \frac{\sum_{i \neq j} r_{ij}^2}{\sum_{i \neq j} r_{ij}^2 + \sum_{i \neq j} r_{ij(p)}^2} ; i = 1, \ldots, p$$

Where: $r_{ij\,(p)}$ is partial coefficient of correlation between variable X_i and X_j in all cases.

One of the requirements of factor analysis makes sense, the variables are highly correlated. Different methods to verify the degree of association between variables can be used, one of which is: The determinant of the correlation matrix. A very low determinant indicates a high inter-correlation between variables, but it must not be zero (non-singular matrix), as this would indicate that some variables are linearly dependent and their calculation in the factor analysis might not be accurate.

5. Findings and Discussion

In order to answer the main question, first the test used in the field research to collect data was validated, obtaining Cronbach's alpha coefficient (table 2 and 3).

5.1 Test validation

Table 2. Case Processing Summary

		N	%
Cases	Valid	214	100.0
	Excluded[a]	0	.0
	Total	214	100.0

a. Listwise deletion based on all variables in the procedure.

Table 3. Reliability Statistics

Cronbach's Alpha	N of Items
0.629	40

It can be observed that the reliability of the instrument is more than 0.6, and based on Cronbach's Alpha >0.6 (Hair, 1999), then we can say that the applied instruments have all the characteristics of consistency and reliability required, (Hair, 1999).

It is important to mention that the Cronbach's Alpha is not a statistical test, but rather a reliable coefficient. Therefore, the AC can be written as a function of the same item number.

$$\alpha = \frac{N * \check{r}}{1 + (N - 1) * \check{r}}$$

Where:

N = number of items (latent variables), ř = correlation between items.

Within this order of ideas, we can now describe table 4, its mean and its standard deviation in order to determine the coefficient's variance and make it possible to identify the variables with the most variance with respect to others.

Table 4. Descriptive Statistics

	Mean	Std. Deviation	Analysis N	Variation coefficient VC=mean/sd
CONFIMA	24.6869	3.38599	214	13.72%
MOTIMA	24.4766	3.46910	214	14.17%
COMPIMA	25.2991	4.30136	214	**17.00%**
CONFICO	24.6916	3.47874	214	14.09%
INTEMACO	25.8084	3.41575	214	13.24%

Source: self made

Based on the results described in Table 4, it can be seen that the variable COMPIMA (17%) is the largest compared to the rest of the variables that show similar behaviour.

After collecting the data, and in order to validate whether the statistical technique of factor analysis can explain the phenomena studied, we first conducted a contrast from Bartlett's test of sphericity with Kaiser (KMO) and Measure Sample Adequacy (MSA) to determine whether there is a correlation between the variables studied and whether the factor analysis technique should be used in this case. Table 5 shows the results.

Table 5. Correlation Matrix- KMO, MSA

Variable	Correlation	Sig	MSA	KMO	Bartlett's Test of Sphericity, KMO (X^2)
CONFIMA	0.38	0.000	0.731	0.703	92.928 df 10
MOTIMA	0.43	0.000	0.691		
COMPIMA	0.23	0.000	0.741		
CONFICO	0.49	0.000	0.686		
INTEMAC	0.39	0.000	0.694		

Source: self-made

As we already know, Bartlett's test of sphericity allows the null hypothesis that the correlation matrix is an identity matrix, whose acceptance involves rethinking the use of principal component analysis as the KMO is <0.5, in which case the factor analysis procedure should not be used. Now, observing the results in the table above, the KMO statistic has a value of 0.703 which is close to one, indicating that the data is adequate to perform a factor analysis and, in contrast to Bartlett (X^2 92.928 $_{\text{Calculated}}$ with 10 df> X^2_{table}) with a p-value=0.000, there is significant evidence to reject the null hypothesis (*Ho*) acceptance *Hi*, considering that the initial variables are correlated. Therefore, the statistical procedure of factor analysis allows us to answer the research question: RQ1: *What is the underlying latent variable structure that would allow the student to understand the perception about mathematics and computer*?

Table 6 shows the results obtained from the correlation matrix, which will observe the behaviour of each variable with respect to the others. With low determinant criteria the correlation is higher, while with a higher determinant, the correlation is low. Therefore we can predict the degree of inter-correlation between the variables.

Table 6. Correlation Matrix[a]

		CONFIMA	MOTIMA	COMPIMA	CONFICO	INTEMACO
Correlation	CONFIMA	1.000				
	MOTIMA	0.280	1.000			
	COMPIMA	0.125	0.220	1.000		
	CONFICO	0.261	**0.311**	0.167	1.000	
	INTEMACO	0.232	0.180	0.177	**0.332**	1.000
Sig. (1-tailed)	CONFIMA					
	MOTIMA	0.0000*				
	COMPIMA	0.034**	0.001*			
	CONFICO	0.0000*	0.000*	0.007*		
	INTEMACO	0.0000*	0.004*	0.005*	0.000*	

a. Determinant = 0.643 p<0.01*, p<0.05**

In the above table we can observe that the determinant is high (0,643), indicating a low degree of inter-correlation between the variables (<0.5). However, if there is a positive correlation, this should be taken with caution on drawing conclusions. Just to point out some examples of significant correlations (the highest) must be correlated: CONFICO vs MOTIMA (0.311) CONFICO vs INTEMACO (0.332) and the rest of the variables are presented in the order of 0.125 to 0.280, the respective correlations between the variables involved in this study.

The percentage of variance that explains the case studied is obtained primarily from the removal of the major components. This is achieved because the communalities represent the proportion of the extracted variance component (table 7) to be analyzed under the criteria of eigenvalues > 1, which are the latent root criteria (> 1). A single component > 1 is obtained as shown in the graph. Moreover, the sum of the square root of the loads, of the initial extraction the eigenvalues of each component is shown in Table 8; where we can see that the component removed (only one) explain 38.57% of the variance of the studied phenomena. The following are tables and sedimentation graphs:

Table 7. Component Matrix and variance

Factors	Component 1	Communalities
CONFIMA	1.000	38%
MOTIMA	1.000	43%
COMPIMA	1.000	23%
CONFICO	1.000	49%
INTEMAC	1.000	39%
Total variance		38.579%

Source: self made

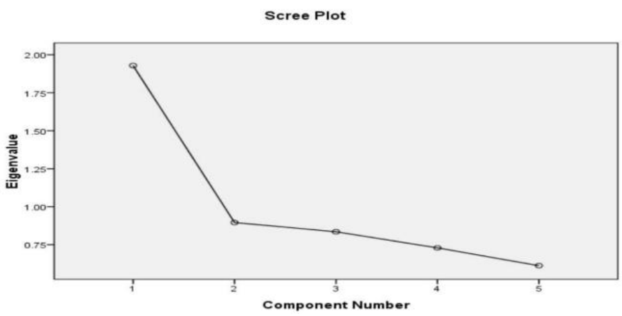


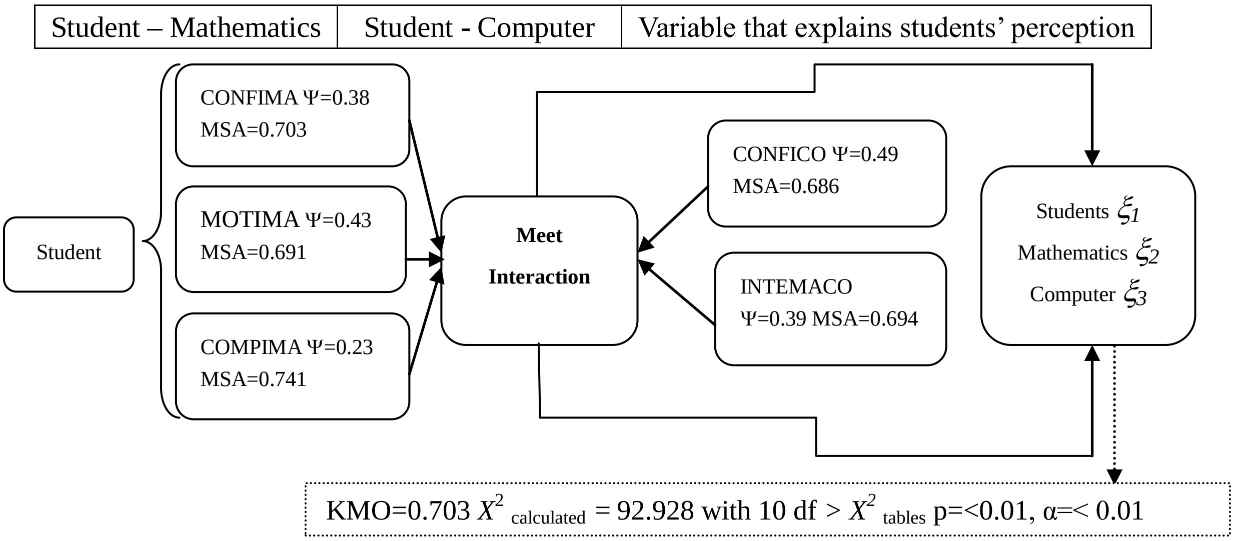
Table 8. Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.929	38.579	38.579	1.929	38.579	38.579%
2	0.896	17.911	56.490			
3	0.835	16.696	73.186			
4	0.729	14.579	87.764			
5	0.612	12.236	100.00			
Extraction Method: Principal Component Analysis.						

Table 7 shows that the first component, CONFIMA (> 1), has an eigenvalue of 1.929 and can explain the phenomenon studied in a 38.579%. The rest of the auto settings for each component (2 to 5) do not contribute significantly. However, there is new evidence to perform factor rotation. Although the percentage varies for a particular explanation, the accumulated remains the same. This is because in the time of rotation the component variables change, but the goal remains the same, which is to minimize the distances between each group losing as little information as possible while increasing the ratio of the remaining variables in each factor. In this way, and based on the theory behind this work, we can say that the factor analysis technique of the observed variables explains 38.579% of the total variation, which can be seen in the sedimentation graph.

Finally, the theoretical model is validated and includes the following indicators: proportion of variance and the measurement of sample adequacy for each variable and its coefficient correlation.

Figure 2 Theoretical Path Model validated



6. Conclusion

In summary, we can say that the research does provide evidence to answer the main research question, *RQ1*: *What is the underlying latent variable structure that would allow the student to understand the perception about mathematics and computer*?, the hypothesis that seeks to prove: *H1: The latent variables mathematics confidence, mathematics motivation, computer confidence, computer motivation, computer-mathematics interaction and mathematics engagement help to understand the students' attitude toward mathematics and technology* versus *Ho* that refers to the opposite, and the aim of the study about how these variables help us to understand the attitude of undergraduate students toward mathematics and technology.

In order to prove the hypothesis, the attitude scales were used for: maths confidence, computer confidence, maths-tech attitudes, maths tech experience (Galbraith, P. & Haines, C. 1998-2000). The reliability items analysis obtained was >0.6 thus, under the criteria of Cronbach Alpha, we can say that the Galbraith and Hines test is reliable according to Hair (1999).

Based on the results described in Table 4, the variable COMPIMA (17%) has a greater dispersion compared with the rest of the variables that display a similar behaviour. The KMO statistic had a value of 0.703 (table 5), which is close to one, indicating that the data were adequate to perform a factor analysis and contrast of Bartlett (X^2 92.928 $_{\text{Calculated}}$ with 10 df> X^2_{table}) with p-value= 0.000 generated significant evidence to reject the null hypothesis (Ho), which established that the initial variables were not correlated. Having proven that variables are correlated, therefore we could make a factor analysis which made it possible to answer the research question. Also, Table 6 showed that the determinant was high (0.643) indicating a low degree of inter-correlation between the variables (<0.5).

However, it should be noted that the variables show a positive correlation, but these results should be taken with caution. For example, significant correlations (the highest) were taken from CONFICO vs. MOTIMA correlated (0.311) CONFICO vs. INTEMACO (0.332) and the rest of the variables are presented in order from 0.12 to 0.28 with their respective correlations between the variables involved in this study. And with respect to the variance obtained, Table 7 shows that the first component, CONFIMA, may explain the phenomenon with 38.57%. Thus, we can say that although the results were not optimal in terms of correlation values, the variables involved in the model proposed by Galbraith and Hines (1998) do make a difference when students learn mathematics mediated by computers. This evidence helps the understanding of learning environments in mathematics and how they are favoured by the introduction of computers and technology.

Finally, with this research, we seek to demonstrate the implications of confidence, motivation, engagement and interaction with technology in the learning process environment, like Galbraith-Haines, and we concluded that our alternative hypothesis *H1*: The latent variables mathematics confidence, mathematics motivation, computer confidence, computer motivation, computer-mathematics interaction and mathematics engagement, help us to understand the students' attitude toward mathematics and technology.

7. Recommendation

As mentioned beforehand, the purpose of the study focuses on measuring the interaction between students, mathematics and computer use, in order to try to understand how these elements interact with each other, and to know whether the construct proposed by Galbraith and Hines can be applied to a Latin-American context, specifically higher education institutions in Mexico.

The results clearly show that student-computer interaction for learning mathematics is positive. However, it is important to consider in future research advances in educational technology for the mathematics teaching-learning process, as the computer and educational software development industry is constantly innovating to make the teaching and learning processes more efficient.

Importantly, this work was developed with cross-sectional data; it would be advisable to conduct a similar study in the future for comparison and longitudinal results. This could help us to understand better the phenomenon studied.

Likewise, further research is recommended in order to consider situations such as space infrastructure for executing the learning experience, cultural background, the students' nationalities, their socio-economic level and past experiences with mathematics, as well as conducting a qualitative study of the interaction between students, mathematics and computers.

The importance of understanding the interaction between the student, mathematics and computers is certainly a current topic, as computers play an active and leading role in education on a daily basis. The development of new, enhanced techniques is vital to all those who are directly or indirectly involved in the process.

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References

Artigue, M. (2002). Learning mathematics in a CAS environment: The genesis of a reflection about instrumentation and the dialectics between technical and conceptual work. *International Journal of Computers for Mathematical Learning, 7*, 245-274.

Anderson, J. R. (1983). *The architecture of cognition.* Cambridge: MA Harvard University Press.

Anderson, J. R. (1995). *Cognitive Psychology and Its Implications.* New York: 4th. ed. W.H. Freeman and Company.

Camacho, M., & Depool, R. (2002). Students' attitudes towards mathematics and computers when using derive in the learning of calculus concepts. *The International Journal of Computer Algebra in Mathematics Education, 9 (4)* , 259-283.

Chi, M. H., Lewis, M. W., Reimann, P., & Glaser, R. (1989). Self explanations: How students study and use examples in learning to solve problems. *Cognitive Science 13* , 145-182.

Cretchley, P., & Galbraith, P. (2002). Mathematics or computers? Confidence or motivation? How do these relate to achievement? *Proceedings 2nd International Conference on the Teaching of Mathematics (Undergrad),* , CD and online, Wiley, Crete.

Di, M., & Zan, R. (2001). Attitude toward mathematics: Some Theoetical issues. *Proceedings of PME 25 (Utrecht, Netherlands), vol. 3* , 351-358.

Fennema, E. & Sherman, J. A. (1976). Fennema-Sherman Mathematics Attitudes Scales: Instruments designed to measure attitudes toward the learning of mathematics by males and females. Catalog of Selected Documents in Psychology, 6(1), 31.

Fennema, E., & Peterson, P. L. (1985). Autonomous learning behavior: A possible explanation of gender-related differences in mathematics. En L. C. Wilkinson, & C. B. Marret, *Gender-related Differences in Clasroom Interactions* (págs. 17-35). New York: Academic Press.

Fennema, E., & Sherman, J. (1976). Sex-related differences in mathematics achievement and related factors: A further study. *Journal for Research in Mathematics Education 9* , 189-203.

Fey, J. T. (1989). Tecnology and Mathematics Education: A survey of recent developments and important problems. *Educational Studies in Mathematics 20* , 237-272.

Fogarty, G., Cretchley, P., Harman, C., Ellerton, N. and Konki, N. (2001)Validation of a Questionnaire to Measure Mathematics Confidence, Computer Confidence, and Attitudes towards the Use of Technology for Learning Mathematics *Mathematics Education Research.Journal*, Vol. 13, No.2, pp.154-160

Galbraith (2006) Students, mathematics, and technology: assessing the present challenging the future, *International Journal of Mathematical Education in Science and Technology*, vol. 37, nº 3, 277-290.

Galbraith, P. and Haines, C. (2000). Mathematics-computing Attitudes Scales. Monographsin Continuing Education. London: City University.

Galbraith, P. L., & Haines, C. R. (1996). Students perceptions of computing, mathematics, and their interaction. En C. Keitel, U. Gellert, E. Jablonka, & M. Müller, *Mathematics (Education) and Common Sence* (págs. 290-296). Berlin 23-29 July 1995: Proceedings of CIEAEM 47.

Galbraith, P., & Haines, C. (1998). Disentangling the nexus: Attitudes to mathematics and technology in a computer learning environment. *Educational Studies in Mathematics 36* , 275-290.

Galbraith, P., & Haines, C. (2000). Mathematics-computing Attitude Scales. *Monographs in Continuing Education. London: City University.*.

Galbraith, P., Haines, C. (1998). Disentangling the nexus: Attitudes to mathematics and technology in a computer learning environment, *Educational Studies in Mathematics* ,36, 275-290.

Garcia-Santillán, A. and Edel R. (2008): Education-learning of the financial mathematics from the computer science platforms (Simulation with ICT). Main Theme: Application of ICT (information and communications technologies), in education-learning process. Annual Meeting Nova Southeastern University "Beyond the Classroom" Fischler School of Education & Human Service. NOVA EDUC@2008. March 17-19, 2008. Miami Beach, Florida USA.

García-Santillán, A. and Escalera-Chávez, M. (2011) IT applications as a didactic tool in the teaching of math's (using of spreadsheet to programming) *Journal of Knowledge Management, Economics and Information Technology, Volume I, Issue 6,* pp.122-138.

García-Santillán, A., Escalera-Chávez, M., Edel-Navarro, R. (2011) Associated variables with the use of ICT as a didactic strategy in teaching-learning process of financial mathematics. An experience from the classroom. *Revista Iberoamericana de Evaluación Educativa, 4* (2) pp.118-135.

Gómez-Chacón, M. I., & Haines, C. (2008). Studentes' attitudes to mathematics and technology. Comparative study between the United Kingdom and Spain . *International Congress on Mathematical Education* , 1-12.

Hart, L. E. (1989). Describing the Affective Domain: Saying what we mean. En D. B. McLeod, & V. M. Adams, *Affect and Mathematical Problem Solving: A New Perspective* (págs. 37-48). New York: Springer-Verlag.

Hair**,** J. F. Jr.; Anderson, R. E.; Taltham, R. L. Y Black, W. C. (1999): ***Análisis multivariante.*** 5a. Edición. Madrid: Prentice Hall.

Izydorczak, A. E. (2003). *A Study of Virtual Manipulatives for Elementary Mathematics*. Unpublished doctoral dissertation, State University of New York, Buffalo, New York.

Kaput, J. J. (1994). Technology in Mathematics Education Research: The first 25 years in the JRME. *Journal of Research into Mathematics Education 25 (6)* , 676-684.

Kaput, J. J., & Thompson, P. W. (1992). Technology and Mathematics Education. En D. A. Grouws, *Handbook of Research on Mathematics Teaching and Learning* (págs. 515-556). New York: Macmillan.

Karadag, Z. & McDougall, D. (2008). Studying mathematical thinking in an online environment: Students‟ voice. In Figueras, O. & Sepúlveda, A. (Eds.), *Proceedings of the Joint Meeting of the 32nd Conference of the International Group for the Psychology of Mathematics Education, and the XXX North American Chapter 1*, 350. Morelia, Michoacán, México: PME.

Kieran, C. (2007). Interpreting and assessing the answers given by the CAS expert: A reaction paper. *The International Journal for Technology in Mathematics Education, 14*(2), 103-107.

Kieran, C. & Drijvers, P. (2006). The co-emergence of machine techniques, paper-and-pencil techniques, and theoretical reflection: A study of CAS use in secondary school algebra. *International Journal of Computers from Mathematical Learning, 11*, 205-263.

Kulm, G. (1980). Research on Mathematics Attitude, in R.J. Shumway (ed.). *Research in mathematics education. Reston, VA: National Council of Teachers of Mathematics* .

Lagrange, J. (1999). Complex calculators in the classroom: Theoretical and practical reflections on teaching pre-calculus. *International Journal of Computers for Mathematical Learning, 4*, 51–81.

LederG. (1985). Measurement of attitude to mathematics. *For the learning of Mathematics, vol. 5(3)* , 18-21.

LeFavre, J., & Dixon, P. (1986). Do written instructions need examples? . *Cognition and Instruction 3* , 1-30.

Lester, F. K., Garafolo, J., & Kroll, D. L. (1989). Self confidence, interest, beliefs, and metacognition: key influences on problem-solving behaviour. En D. B. McLeod, & V. M. Adams, *Affect and Mathematical Problem Solving: A New Perspective* (págs. 75-88). New York: Springer-Verlag.

Linacre, J. M. (1990). Modelling rating scales. *Paper presented at the Annual Meeting of the American Educational Research Association, Boston, M.A., USA, 16-20 April* , ED 318 803.

Mackie, D. M. (1992). An evaluation of computer-assisted learning in mathematics. *International Journal of Mathematics Education in Science and Technology 23 (5)* , 731-737.

Mandler, G.: 1989, 'Affect and learning: causes and consequences of emotional interactions', in D.B. McLeod and V.M. Adams (eds.), *Affect and Mathematical Problem Solving: A New Perspective*, pp. 3–19, New York: SpringerVerlag.

Marshall, S. P.: 1989, 'Affect in schema knowledge: source and impact', in D. B. McLeod and V. M. Adams (eds.), *Affect and Mathematical Problem Solving: A New Perspective*, pp. 49–58, New York: Springer–Verlag.

McLeod, D. B.: 1985, 'Affective issues in research on teaching mathematical problem solving', inE. A. Silver (eds.), *Teaching and learning mathematical problem solving: Multiple research perspectives*, pp. 267–279, Hillsdale, N. J.: Lawrence Erlbaum Associates.

McLeod, D. B.: 1989a, 'Beliefs, attitudes and emotions: new views of affect in mathematics education', in D. B. McLeod and V. M. Adams (eds.), *Affect and Mathematical Problem Solving: A New Perspective*, pp. 245–258, New York: SpringerVerlag.

McLeod, D. B.: 1989b, 'The role of affect in mathematical problem solving', in D. B. McLeod and V. M. Adams (eds.), *Affect and Mathematical Problem Solving: A New Perspective*, pp. 20–36, New York: SpringerVerlag.

Meyer, M. R.: 1985, 'The prediction of mathematics achievement and participation for females and males: a longitudinal study of affective variables', Unpublished doctoral dissertation, University of Wisconsin, Madison.

Moreno-Armella, L., Hegedus, S. J., & Kaput, J. J. (2008). From static to dynamic mathematics: Historical and representational perspectives. *Educational Studies in Mathematics*, *68*, 99-111.

Moreno-Armella, L. & Santos-Trigo, M. (2004). Students‟ exploration of powerful mathematical ideas through the use of algebraic calculators. In D. E. McDougall & J. A. Ross (Eds.), *Proceedings of the twenty-sixth annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*, *1*, 135-142. Toronto: OISE/UT.

Moyer, P.S., Niexgoda, D., & Stanley, J. (2005). Young Children‟s Use of Virtual Manipulatives and Other Forms of Mathematical Representations. In W. J. Masalski & P. C. Elliot (Eds.), *Technology-Supported Mathematics Learning Environment*. Reston, VA: The National Council of Teachers of Mathematics.

Pemberton, M.R.: 1995, *Introduction to Maple*. Department of Mathematics, University of Queensland.

Pemberton, M.R.: 1996. *"The Impact of Maple on Science and Engineering Students"*. Proceedings of the Second Biennial Australian Engineering Mathematics Conference, 511-519.

Reder, L.M.: and Anderson, J.R.: 1980, " A comparison of texts and their summaries: Memorial consequences", *Journal of Verbal Learning and Verbal Behaviour* 19, 121-134.

Reder, L.M., Charney, D.H., and Morgan, K.I.: 1986, "The role of elaboration in learnig a skill from an instrucrtional text", *Memory and Cognition* 14, 64-78.

Reif, F.: 1987, "Interpretation of scientific or mathematical concepts: Cognitive issues and instrumental implications", *Cognitive Science* 11, 395-416.

Schoenfeld, A.H.: 1989, "Explorations of students" mathematical beliefs and behaviour", *Journal of Educational Psycology* 71 (2), 242-249.

Suurtamm, C. & Graves, B. (2007). *Curriculum implementation in intermediate math (CIIM): Research report*. Canada: Faculty of Education, University of Ottowa. Retrieved April 15, 2008, from http://www.edu.gov.on.ca/eng/studentsuccess/lms/.

Swing, J. and Peterson, P.: 1988, "Elaborative and Integrative Thought Processes in Mathematics Learning ", *Journal of Educational Psycology* 80 (1) ,54- 66.

Tall, D. and Razali, M.R.: 1993, "Diagnosting students difficulties in learning mathematics", *International Journal for Mathematical Education in Science and Technology* 24 (2), 209-222.

Appendix

Attitude scales toward: maths confidence, computer confidence, maths-tech attitudes, maths-tech experience (Galbraith, P. & Haines, C. 1998-2000).

Mathematics Confidence	Lowest 1	Low 2	Neutral 3	High 4	Highest 5
Mathematics is a subject in which I get value for effort					
The prospect of having to learn new mathematics makes me nervous					
I can get good results in mathematics					
I am more worried about mathematics than any other subject					
Having to learn difficult topics in mathematics does not worry me					
No matter how much I study, mathematics is always difficult for me					
I am not naturally good at mathematics					
I have a lot of confidence when it comes to mathematics.					
Mathematics Motivation	Lowest 1	Low 2	Neutral 3	High 4	Highest 5
Mathematics is a subject I enjoy doing					
Having to spend a lot time on a mathematics problem frustrates me					
I don't understand how some people can get so enthusiastic about doing mathematics					
I can become completely absorbed doing mathematics problems					
If something about mathematics puzzles me, I would rather be given the answer than have to work it out myself					
I like to stick at a mathematics problem until I get it out					
The defy of understanding mathematics does not appeal to me					
If something about mathematics puzzles me, I find myself find about it afterwards.					
Mathematics Engagement	Lowest 1	Low 2	Neutral 3	High 4	Highest 5
I prefer to work with symbols (algebra) than with pictures (diagrams and graphs)					
I prefer to work on my own than in a group					
I find working through examples less effective than memorizing given material					
I find it helpful to test understanding by attempting exercises and Problems					
When studying mathematics I try to link new ideas or knowledge I already have					
When learning new mathematical material I make notes to help me understand and remember					
I like to revise topics all at once rather than space out my study					
I do not usually make time to check my own working to find and correct errors					

Computer confidence	Lowest 1	Low 2	Neutral 3	High 4	Highest 5
As a male/female (cross out which does not apply) I feel disadvantage in having to use computers					
I have a lot of self-confidence in using computers					
I feel more confident of my answers with a computer to help me					
If a computer program I am using goes wrong, I panic					
I feel nervous when I have to learn new procedures on a computer					
I am confident that I can master any computer procedure that is needed for my course					
I do not trust myself to get the right answer using a computer					
If I make a mistake when using a computer I am usually able to work out what to do for myself					
Computer-Mathematics Interaction	**Lowest 1**	**Low 2**	**Neutral 3**	**High 4**	**Highest 5**
Computers help me to learn better by providing many examples to work through					
I find it difficult to transfer understanding from a computer screen to my head					
By looking after messy calculations, computers make it easier to learn essential ideas					
When I read a computer screen, I tend to gloss over the details of the mathematics					
I find it helpful to make notes in addition to copying material from the screen, or obtaining a printout					
I rarely review the material soon after a computer session is finished					
Following keyboard instructions takes my attention away from the mathematics					
Computers help me to link knowledge e.g. the shapes of graphs and their equations					

Appendix

Table 9. Component Matrix[a]

	Component
	1
CONFIMA	0.616
MOTIMA	0.657
COMPIMA	0.484
CONFICO	0.703
INTEMACO	0.624

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Table 10. Anti-image Matrices

		CONFIMA	MOTIMA	COMPIMA	CONFICO	INTEMACO
Anti-image Covariance	CONFIMA	**0.869**	-0.169	-0.029	-0.117	-0.121
	MOTIMA	-0.169	**0.836**	-0.141	-0.180	-0.029
	COMPIMA	-0.029	-0.141	**0.927**	-0.054	-0.099
	CONFICO	-0.117	-0.180	-0.054	**0.805**	-0.215
	INTEMACO	-0.121	-0.029	-0.099	-0.215	**0.854**
Anti-image Correlation	CONFIMA	**0.730[a]**	-0.199	-0.033	-0.140	-0.140
	MOTIMA	-0.199	**0.691[a]**	-0.160	-0.219	-0.034
	COMPIMA	-0.033	-0.160	**0.741[a]**	-0.062	-0.112
	CONFICO	-0.140	-0.219	-0.062	**0.686[a]**	-0.259
	INTEMACO	-0.140	-0.034	-0.112	-0.259	**0.694[a]**

a. Measures of Sampling Adequacy(MSA)

Inverse of Correlation Matrix

	CONFIMA	MOTIMA	COMPIMA	CONFICO	INTEMACO
CONFIMA	1.151	-0.233	-0.036	-0.168	-0.163
MOTIMA	-0.233	1.196	-0.182	-0.267	-0.040
COMPIMA	-0.036	-0.182	1.079	-0.072	-0.126
CONFICO	-0.168	-0.267	-0.072	1.242	-0.312
INTEMACO	-0.163	-0.040	-0.126	-0.312	1.171

Reproduced Correlations

		CONFIMA	MOTIMA	COMPIMA	CONFICO	INTEMACO
Reproduced Correlation	CONFIMA	0.380[a]	0.405	0.298	0.433	0.385
	MOTIMA	0.405	0.431[a]	0.318	0.462	0.410
	COMPIMA	0.298	0.318	0.234[a]	0.340	0.302
	CONFICO	0.433	0.462	0.340	0.494[a]	0.439
	INTEMACO	0.385	0.410	0.302	0.439	0.390[a]
Residual[b]	CONFIMA		-0.125	-0.173	-0.172	-0.153
	MOTIMA	-0.125		-0.098	-0.151	-0.230
	COMPIMA	-0.173	-0.098		-0.173	-0.125
	CONFICO	-0.172	-0.151	-0.173		-0.107
	INTEMACO	-0.153	-0.230	-0.125	-0.107	

Extraction Method: Principal Component Analysis.

a. Reproduced communalities

b. Residuals are computed between observed and reproduced correlations. There are 10 (100.0%) nonredundant residuals with absolute values greater than 0.05.