Journal of Applied Mathematics & Bioinformatics, vol.2, no.3, 2012, 51-67
ISSN: 1792-6602 (print), 1792-6939 (online)
Scienpress Ltd, 2012

Variables to measure interaction among mathematics and computer through structural equation modeling

Arturo García-Santillán[1], Milka E. Escalera-Chávez[2] and Arturo Córdova-Rangel[3]

Abstract

The purpose of the study was to analyze if the interaction between mathematics and computer, could be explained by two factors: the usefulness and inconvenient of technology through confirmatory factorial analysis. Were used the confirmatory factorial analysis and structural equation modeling in order to data analysis obtained of the 164 students surveyed at *Universidad Politécnica de Aguascalientes*. In order to evaluate model were considered measures of adjustment; Chi^2, Chi square/degree of freedom ratio (CMIN/Df), Roots Means

[1] Economic-Administrative Research Center at Universidad Cristóbal Colón-UCC Boca del Río Veracruz-México, e-mail: agarcias@ucc.mx
[2] Multidisciplinary Unit Middle Zone, at Universidad Autónoma de San Luis Potosí-UASLP San Luis Potosí, México, e-mail: milkaech@uaslp.mx
[3] Business Research Center at Universidad Politécnica de Aguascalientes, e-mail: arturo.cordova@upa.edu.mx

Article Info: *Received* : October 10, 2012. *Revised* : November 20, 2012
Published online : December 30, 2012

Square Error of Approximation (RMSEA), Goodness of Fit Index (GFI); Comparative of Fit Index (CFI) and Adjusted Goodness of Fit Index (AGFI). The results support a model of two components: 1) The inconvenience: where the student indicate that “I find it difficult to transfer understanding from a computer screen to my head” and “I rarely review the material soon after a computer session is finished”, and 2) The usefulness: where students reported that “By looking after messy calculations, computers make it easier to learn essential ideas” and “Computers help me to link knowledge e.g. the shapes of graphs and their equations.”

Mathematics Subject Classification: 97U10

Keywords: mathematics interaction, computer, technology usefulness and inconvenient of technology, mathematical educational technology

1 Introduction

In the process of teaching mathematics, it has been observed by the students, that one of the difficulties in the learning process is that mathematics has always been done the same way and with the same resources: chalk and the blackboard. This is why; international education systems and the Mexican education system have been interested in incorporating information technologies in the teaching of mathematics. The growing access to technology in the classrooms, has allowed students not only to use this as a mathematical tool to solve problems, but also for their learning.

The technology, as mentions Noss cited by Gómez [1], besides providing a solution to mathematical problems, students are motivated and their attitude towards mathematics changes. However, the student is confronted with conditions that contribute to a poor outcome when their learning interacts with the computers. That is why, by knowing these limitations will help the teacher to improve their way of teaching mathematics. More than often, teachers do not know the factors associated with this restriction when using technology and furthermore, under these circumstances they cannot design strategies that will enhance the formation of this subject, and at the same time reduce the negative attitude towards mathematics.

This study explores the existence of factors that students consider to be restrictive when interacting with computers, just like Camarena [2] mentions: *"the teacher should try to do educational research that will help their work raise academic quality in education, because teaching and research go hand in hand.*

By the above, the following questions emerge: RQ_1: The interaction between mathematics and the computer could be explained by two or more factors? And, RQ_2: what factors can help explain the interaction between mathematics and computers?

1.2 Background

During the last years, technology has transformed into a very useful tool in the teachings of different subjects, mathematics have not been an exception. Some authors (Balachef and Kaput; Hoyles and Sutherland; Dettori et al; Mariotti) cited by Ursini, Sánchez and Ramírez [3] investigated how new technology can improve and facilitate the teaching-learning process of mathematics in different levels. Furthermore, when this tool is used, the student's training is modified to have a positive impact on their performance (Artigue; Noss) cited by [1].

The computers pertain to ICT (Information and communications technologies) and constituting an opportunity to promote students' educational development. This has led to a new form of learning, self-taught, or also called interactive learning. This type of learning allows the students to perform procedures with the computer; this activity not only favors the student’s exposure to technology, but also their learning process.

According to Barker cited by Tirado [4], "the term Interactive Learning System is often used in education literature. It can be used to cover a wide range of learning situations in which various kinds of knowledge or information exchange between systems communicators that are involved in some form of dialogue process ". The dialogues, according to Barker, [4] multiple partners can be made between communicators, can also be multimedia (involving several different communication channels) and multimodal involving a variety of conceptual modalities, perceptual and physical. He also points out that interactive systems can be man-centered and technology-based, in the latter, the dialogue process that develops between the student and technologies used in the teaching-learning process. In this sense, Minguell [5] refers to the concept of interactivity meaning, "it implicates the technical capacity to understand the maximum possibilities of communication between the user and the machine; the other part involved is reducing the respond time, in regards to the user's actions."

Importantly, a learning environment is interactive in the sense that a person can navigate or scroll through it, selecting relevant information, responding to questions using input components of a computer such as keyboard, mouse, touch screen or voice commands to solve and complete a series of tasks aimed at learning [6].

Through interactivity the student can start building their own knowledge because it may organize the process to access information and incorporate it in a way that is most meaningful to him. Given the importance of participation for meaningful learning, authors (Anderson; Reif; Chi et al; cited by Galbraith and Haines [7] indicate that it is of fundamental interest the degree to which students interact with the learning material. The importance of interactive learning and the education context has been emphasized in general by many authors (Lester, Garofalo and Kroll; McLeod), cited by Galbraith and Haines [7, 8], these authors reveal that the technological ignorance can cause difficulties similar to those found when the tool used are elementary and simple, such as the ruler and the compass [5].

It is pertinent to note that students, when they interact with the computer can only perform one activity, whether it is to pay attention to the screen or take notes. This new context adds a new dimension to the learning processes, because, it is necessary to establish different teaching strategies to provide meaningful learning.

In this way, the result of research of Galbraith and Haines [7] reveal that some students have confirmed --about learning-- that when interacting with the computer in a math class, they are obtained a improvement in their education for two situations: a) a large number of examples can be handled with this tool and b) to extend the data presented on the screen when searching for information, once the session is over.

Another group of students have seen the interaction between computers and mathematics as a inconvenient, and they notes three reasons: 1) it is difficult to interpret the data on the screen, 2) the data on the screen is unknown, and 3) there are too many distractions when following the instructions, therefore they do not take notes or review the material when the session ends. Thus, the mathematical knowledge that taught in schools through the use of technology can only be learned if the student is able to internalize it and give it personal meaning.

1.3 Theoretical Foundation

In order to support the educational approaches focused on learning from the psychological and educational point of view, as well as to understand how this knowledge is forged; it is important to consider what Ausubel [9] states, he say that meaningful learning is a process that is conceived in the human mind when incorporating new information in a non-arbitrary and substantive way, as well as conditions requiring: a) willingness to learn, b) potentially significant material and c) the presence of ideas in the cognitive structure of the learner. Meaningful learning occurs in a three-way interaction between teacher, student and educational material that outlines the responsibilities for each of the protagonists in the process.

Moreover Vygotsky cited by Kozulin [10], notes that to meet the students' goal, institutions must encourage two aspects: the action and interaction, in addition, the author mentions that there is a strong link between the level of development of an individual and their learning ability. Learning and development are social and collaborative activity that cannot be taught, it's up to the student to construct their own understanding in his own mind. With the theoretical foundation mentioned above, we now propose the following hypotheses in concordance with the research question previously exposed:

Hi_1: The interaction between mathematics and computers can be explained by two or more factors. And Hi_2: There are several elements that make up each of the factors that explain the interaction between mathematics and computers.

1.4 Objectives

The proposed questions have set the overall objective: O_1 identify whether the interaction between mathematics and computers can be explained by two factors and O_2 identify the elements in each factor. Also, specific objectives are: So_1 Develop a theoretical model that integrates the factors that interact with mathematics and computers. So_2 Evaluate the model using the elements of each factor and So_3 Evaluate the adjusted model.

1.5 Justification

Nowadays, a common argument for including technology into the curriculum of mathematics is that this tool offers an alternative to improve the attitude towards mathematics, however, in the educational process, the results were not expected and these do not allow the reasons why this occurs. This evidence indicates that it is important to investigate the interaction between mathematics and technology in the environment where computers are used in the teaching of mathematics. In addition, personal interest in this research is to contribute accurate information about the students' attitude as they interact with the computer, so that teachers have useful information to help institutions make decisions about teaching strategies in mathematics, with these new learning environments.

2 Method

2.1 Participant (Subject)

A total of 164 students were surveyed in the *Universidad Politécnica de Aguascalientes.* All of these students are currently enrolled in one of courses as: Engineering and International business.

2.2 Instrument

We used an instrument proposed by Galbraith & Haines [7] that includes the following scales: Scales to measure the attitude: confidence in mathematics, computer confidence, attitude to the teaching of mathematics and experience in teaching mathematics. The instrument used has 40 indicators on a Likert scale, 8 of which belong to the interaction between Mathematics and Computer (items 33 to 40; were used for this study).

2.3 Statistic Procedures

The data were processed using SPSS v.17 and the AMOS (Analysis of Moment Structure) and the estimation method used was the Maximum Likelihood [14]. To evaluate the adjustment we considered chi square (Chi^2) and chi-square ratio of the degrees of freedom (CMIN / DF), goodness-of-fit index (GFI), adjusted index of goodness-of-fit (AGFI) and comparative fit index (GFI) and root mean square error of approximation (RMSEA).

3 Results

Considering the data obtained by averaging and Pearson correlation in table 1 we can see that the highest value is the average of the item 33 (3.77), followed by item 40 (3.74) and item 37 (3.63). Regarding the correlations can be observed positive values that indicate a direct relationship, also, we can see negative values that show an inverse relationship between the variables involved (item 36 versus item 37).

Table 1 Matrix correlation among variables

Items*	Mean	S.D.	item33	item34	item35	item36	item37	item38	item39	item40
item33	3.77	.993	1.000	.206	.142	.109	.396	.235	.085	.450
item34	2.57	1.199		1.000	.323	.314	.225	.560	.350	.441
item35	3.20	1.140			1.000	.177	.348	.410	.130	.431
item36	3.14	1.140				1.000	-.416	.431	.283	.139
item37	3.63	1.081					1.000	.251	.144	.344
Item38	2.77	1.225						1.000	.402	.490
Item39	2.62	1.006							1.000	.333
Item40	3.74	1.077							.	1.000

Correlación de Pearson =p<0.01

*33.- Computers help me to learn better by providing many examples to work through.
34.- I find it difficult to transfer understanding from a computer screen to my head.
35.- By looking after messy calculations, computers make it easier to learn essential ideas.
36.- When I read a computer screen, I tend to gloss over the details of the mathematics.
37.- I find it helpful to make notes in addition to copying material from the screen, or obtaining a printout.
38.- I rarely review the material soon after a computer session is finished.
39.- Following keyboard instructions takes my attention away from the mathematics.
40.- Computers help me to link knowledge e.g. the shapes of graphs and their equations.

To verify the internal structure of interaction between mathematics and computer, we performed an exploratory factor analysis (principal components, Varimax rotation) and confirmatory (Maximum Likelihood). The values obtained of the measure of sampling adequacy Kaiser-Mayer-Olkin (.594 and Bartlett test of sphericity (425.386, df = 28, p <.000) suggested that it was appropriate to use factor analysis, therefore, was used Principal Component's extraction and Varimax rotation method.

With the Kaiser-Guttman rule of eigenvalues greater than 1, identified two factors that explained 58.125% of the variance of the test response: Factor 1 consists of items 34, 36, 38, 39 and has been called disadvantages of technology. Factor 2 includes the items 33, 35, 37.40, and has been named as "usefulness of the technology" for the application of mathematics.

In order to confirm the fit of the data of two-factor model, we decided to conduct a confirmatory factor analysis, considering that in this type of analysis --in addition to ratifying the factors-- we should compare the fit index of several alternative models to choose the better, as Thompson (2004) notes, that in the confirmatory factor analysis type, we might corroborate the theoretical model fitting, and besides, it is advisable to compare the fit index of several alternative models to choose the best.

Then, we proceeded to verify the model obtained from exploratory factor analysis, which included paths between latent variables (Figure 1) and estimate the model (Figure 2).

The model shows the standardized regression weights in which we can see that the variables with a weight less than 0.5 correspond to the items 36, 39 and 37. First two belong to factor 1 named "inconveniences of technology" and item 37 corresponds to factor 2 called "usefulness of technology", these values may cause problems in the model fit.

The results of the model were (Chi^2 = 151.067, df = 19, p <0.000, CMIN / DF = 7.951), the value of the indexes (GFI =0.867 AGFI =0.748, CFI =0.675, RMSEA =0.207), even when the values of the first three indexes tend to 1, this are low and the index RMSEA value is greater than 0.05 therefore proceeded to modify the indexes for a better fit of the model. The obtained model is shown in Figure 3 and Table 2 presents a summary of the fit indexes of the two models.

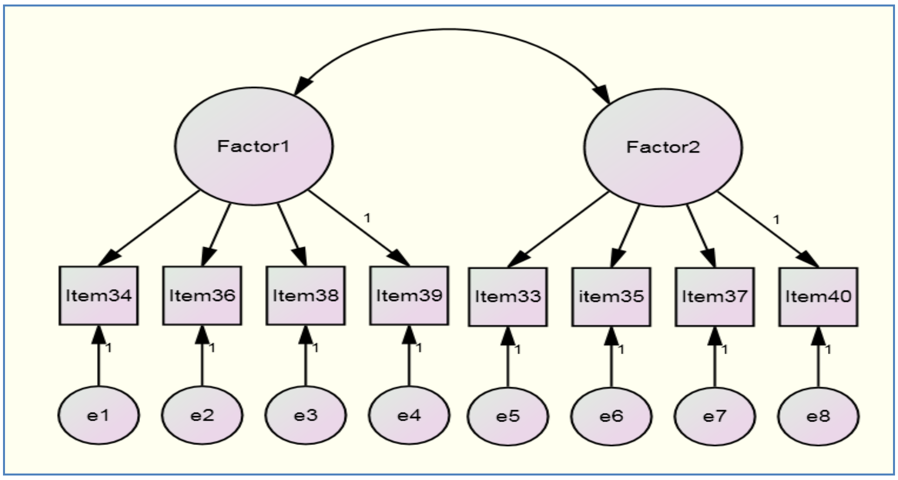

Figure 1: Model obtained from exploratory factor analysis

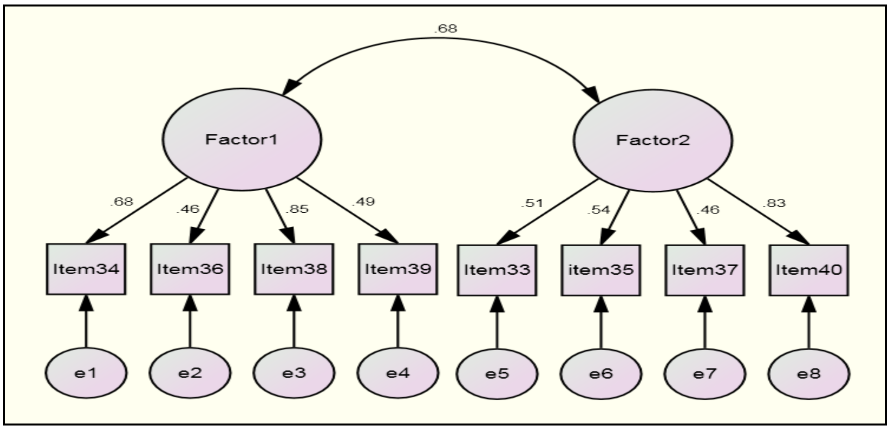

Figure 2: Standardized weights of exploratory analysis model

The results of the model were (Chi^2 = 151.067, df = 19, p <0.000, CMIN / DF = 7.951), the value of the indexes (GFI =0.867 AGFI =0.748, CFI =0.675, RMSEA =0.207), even when the values of the first three indexes tend to 1, this are low and the index RMSEA value is greater than 0.05 therefore proceeded to modify the indexes for a better fit of the model. The obtained model is shown in Figure 3 and Table 2 presents a summary of the fit indexes of the two models.

We can see in Figure 3 that there exist two principal factors that have been identified in "attitude toward the interaction between mathematics and the computer": 1) The inconvenience: where the student indicate that "is difficult for me to transfer the understanding of the screen to my head" and “rarely review the material as soon as the computer session ends”, and 2) The usefulness: where students reported that when they view disorderly the calculations, the computer will sort them facilitates also learning essential ideas allowing them to link the knowledge.

While it is true that, from a technical standpoint, would be enough two indicators per factor, it is recommended at least three factors to avoid problems of identification and convergence [12]. Therefore, the modifications of the proposed model are only theoretical.

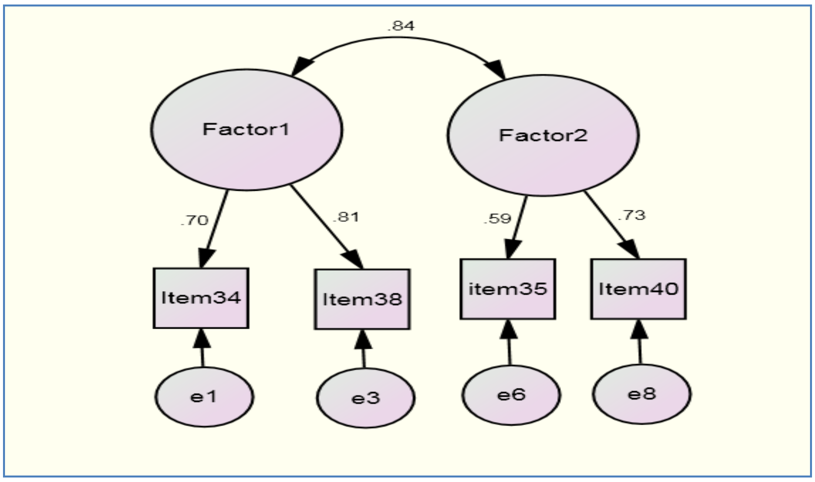

Figure 3: Standardized weights of final model

Table 2: Adjustment indexes of models for measuring of the interaction between computer and Mathematics

	Chi^2	df	CMIN/DF	RMSEA	GFI	CFI	AGFI
Model 1	151.067	19	7.951	.207	.867	.675	.748
Model 2	.444	1	.444	.000	.999	.996	.986

Chi^2, Chi square/degree of freedom ratio (CMIN/df), roots means square error of approximation (RMSEA), Goodness of Fit Index (GFI); Comparative of Fit Index (CFI) and Adjusted Goodness of Fit Index (AGFI).; p<0,001

To evaluate the adjustment of the models was used a several indicators, specifically was used chi-square statistic, the chi-square ratio of the degrees of freedom (CMIN / DF), the comparative fit index (CFI), the index of overall goodness of fit (GFI), root mean square error of approximation (RMSEA) and the adjusted goodness of fit index (AGFI).

The chi square ratio of the degrees of freedom should be less than 3, indicating a good adjustment, whereas in model 2 (0.444 indicates a good fit), CFI values (0.996) and GFI (0.986) as well indicates a good model fit considering that a value nearest 1 means a better fit. The RMSEA (0.000) is considered optimal when their values are 0.05 or lower. Model 2 is adjusted acceptably and significantly way to the model 1.

4 Conclusions

With the result in this research we obtained empirical evidence for:

1. - Check that the interaction between mathematics and computers can be explained by two factors: the usefulness of technology and the disadvantages of

technology.

About the results of usefulness of technology are consistent with those of Galbraith and Haines [7, 8] and more recently with García-Santillán, Escalera, Camarena and García [15] that demonstrate that there are two groups of students who appreciate a different way to interact with the computer.

One group sees an advantage for a meaningful education with the use of technology, the other; they consider the use of technology as an impediment for understanding mathematics. The first group may have had previous experience using computers; this experience serves to secure new ideas and concepts, just like Ausubel notes [9]. The second group, just like Vygotsky mentions [10], may have less o no experience with computers and their level of development or capacity to learn is lower.

2. - Identify the elements of each factor that explains the interaction between mathematics and computers.

About the factor “usefulness of technology” the item 35(By looking after messy calculations, computers make it easier to learn essential ideas) and item 40 (Computers help me to link knowledge e.g. the shapes of graphs and their equations) explain this factor, and are consistent with Galbraith and Hines [7, 8]. However, are partially different with obtained by García-Santillán, Escalera, Camarena and García [15] that demonstrate that the factor “usefulness of technology” it integrates with item 33 (Computers help me to learn better by providing many examples to work through) and item 40.

About the factor “disadvantages of technology” the item 34 (I find it difficult to transfer understanding from a computer screen to my head) and item 38 (I rarely review the material soon after a computer session is finished) explain this factor, again are consistent with Galbraith and Hines [7, 8] but, are partially different with obtained by García-Santillán, Escalera, Camarena and García [15] whose demonstrate that the factor “disadvantages of technology” it integrates with item 34 and item 39 (Following keyboard instructions takes my attention away from the mathematics).

3. - In order to evaluate the adjusted model, was formulated a theoretical model based in the Galbraith and Haines [8] proposal.

It integrates the elements of interaction between mathematics and computer. The result of the exploratory factor analysis indicated that the model is composed of two factors, however the confirmatory factor analysis reveals a pattern that make a better fit than the first model, this according to the evaluated index.

The study allowed us to test the interaction between mathematics and computer can be explained by two or more factors, were also identified and described what these factors are, therefore, we can answer the research questions RQ_1 and RQ_2 and consequently we achieves the object O_1 and O_2. Subsequent to run the new model (Figure 3 and Table 2) the specific objectives SO_1 and SO_2 are met, and with the evaluating the model, we achieves the specific goal SO_3.

Thus, with the evidence obtained, enabled us to test the assumptions: Hi1 and Hi2 regarding: The interaction between mathematics and computers can be explained by two or more factors and there are several elements that make up each of the factors that explain the interaction between mathematics and computers.

Finally, one could say that even if mathematics seems like a difficult subject for the student, it actually is a really nice and easy discipline when there is a mutual relationship between a computer and the learner.

Regarding the limitations of this research, it is not feasible to generalize the results in different educational levels; the teaching of mathematics regularly is not using technology.

In fact, in the higher level public institutions, the teaching of mathematics is not given by interacting with technology. On the other hand, in the case of private universities where is known the greater investment is in technology for education, all this, leads us to think that there are more likely to the use of this tool in the teaching of mathematics.

Acknowledgements. The authors are very grateful to the anonymous reviewer for suggestions and *Universidad Politécnica de Aguascalientes* for all their help and support.

Appendix

Attitude scales toward: Computer-Mathematics Interaction (Galbraith, P. & Haines, C. 1998-2000). (Lowest 1, low 2, neutral 3, high 4, highest 5)

Computer-Mathematics Interaction	code
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	

References

[1] I. Gómez and Ch. Hines, Students' attitudes to mathematics and technology. Comparative study between the United Kingdom and Spain, *Proceedings of the conference* ICME-11, 11th *International Congress on Mathematical Education*. Retrieved from: http://tsg.icme11.org/document/get/924.

[2] P. Camarena, La matemática en el contexto de las ciencias, *Innovación Educativa*, **9**(46), (1999), 15-25.

[3] S. Ursini, G. Sanche and M. Ramirez, Using technology in the mathematics class: how this affects students' achievement and attitudes. Retrieved from: biblioteca.cinvestav.mx/.../texto.../156948_1.pdf. (2007)

[4] R. Tirado, El diseño de sistemas interactivos multimedia de aprendizaje: aspectos básicos, *Revista PIXEL_BIT*, **7**, (2003), 1-15.

[5] M. Minguell, Interactividad e interacción, *Revista Interuniversitaria de Tecnología Educativa*, (2000), 92-97.

[6] T. Reeves, Introducing the Scope and Standards of the Journal of Interactive Learning Research, *Educational Technology Review*, **7**, (1997), 5-8.

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

[8] P. Galbraith and C. Haines, *Mathematics-computing Attitudes Scales*, *Monographs in Continuing Education*, London, City University, 2000.

[9] D.P. Ausubel, Algunos aspectos psicológicos de la estructura del conocimiento, En Elam, S. (Comp.), *La educación y la estructura del conocimiento. Investigaciones sobre el proceso de aprendizaje y la naturaleza de las disciplinas que integran el currículum*. Ed. El Ateneo. Buenos Aires. Págs. 211-239, 1973.

[10] A. Kozulin, Vygotsky's theory in the classroom: Introduction. *European Journal of Psychology of Education*, **19**1, (2004), 3-7.

[11] B. Thompson, *Exploratory and confirmatory factor analysis*, Washington,

DC: American Psychological Association, 2004.

[12] J.F. Hair, W.C. Black, B.J. Babin, R.E. Anderson and R. L. Tatham, *Multivariate data analysis* (6ª ed.), Upper Saddle River, New Jersey, Pearson-Prentice Hall, 2006.

[13] A. García-Santillán, M. Escalera, R. Edel, Variables Associated with the use of ICT as a Didactic Strategy in Financial Mathematic Teaching-Learning Process. An Experience from the Classroom, *Revista Iberoamericana de Evaluación Educativa*, **4**(2), (2011), 118-135.

[14] L.T. Hu and P. Bentler, *Evaluating model fit*, in R. H. Hoyle (Ed.), *Structural Equation Modeling, Concepts, Issues, and Applications*, London, Sage, pp. 76-99, 1995.

[15] A. García-Santillán; M. Escalera-Chávez; P. Camarena-Gallardo and A. García-Díaz Mirón, Structural equations modeling to measure variables involved in the interaction between mathematics and computer. *International Journal of Humanities and Social Science*, **2**(24), (Special Issue-December, 2012).