# Structural Equations Modeling to Measure Variables Involved in the Interaction between Mathematics and Computer

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## Abstract

*The aim of the study was to analyze if the interaction between mathematics and computer, could be explained by two factors: the uselfulness and inconvenient of technology through confirmatory factorial analysis. The sample size was 546 students' of Cristobal Colon University and Autonomous University of San Luis Potosí. The data analysis was the confirmatory factorial analysis and structural equation modeling. In order to evaluate model were considered measures of adjustment; 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). The results support a model of two components: 1) uselfulness; where the students point out that computers can help them learn better by providing several examples to work and help them to link knowledge and 2) inconvenient (disadvantages); where keyboard instructions takes care of mathematics and there is difficult to transfer understanding from the screen to themselves. Thus, finally we concluded that the model was adjusted to the data.*

**Key words:** mathematics interaction, computer, technology uselfulness, inconvenient of technology

## *1. Introduction*

### 1.1 Introduce the Problem

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 (2002, cited by Gómez, 2008) 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 (2009) 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.*

The structure of this research is as follows: the first section presents the background of the study, the highlights, the theoretical foundation and discusses the arguments that justify this research, the second section focuses on the methodology, the third section corresponds to the results and findings and finally the fourth section the conclusion, respectively.

**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 & Kaput, 1996; Hoyles & Sutherland, 1989; Dettori et al, 2001, Mariotti, 2005 cited by Ursini, Sánchez & Ramírez, 2007) have 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, 2002; Noss, 2002, cited by Gómez, y Haines, 2008).

Computers are or pertain to ICTs (Information and communications technologies), they are the most widespread and have a better 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, 1989 (cited by Tirado 2003), "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, 1989 (cited by Tirado 2003) 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, Miguell (2000) 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 (Reeves, 1997).

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, 1995; Reif, 1987, Chi et al, 1989, cited by Galbraith and Haines, 1998) 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 & Kroll,1989; McLeod, 1989b; McLeod, 1985, cited by Galbraith & Haines, 1998), 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 Minguell (2000).

It is pertinent to note that students, when they interact with the computer can only perform one activity, whether it be to pay attention to the screen or take notes. This new context adds a new dimension to the coordination processes, becoming necessary to establish different teaching strategies to provide meaningful learning. Galbraith and Haines (2000) research results show that some students have confirmed about learning, that when interacting with the computer in a math class, they mention improvement in 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 view the interaction between computers and mathematics as being inconvenient, and they state 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 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 Theroretical Foundation

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 (1973) states 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 of the educational event.

Moreover Vygotsky (1996, cited by Kozulin, 2004) 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 above, we now propose the following

### 1.4 Questions and Research Objectives

$RQ_1$. Can the interaction between mathematics and the computer be explained by two or more factors?
$RQ_2$. What factors can help explain the interaction between mathematics and computers?

The proposed questions have set the overall objective for this research as follows: identify whether the interaction between mathematics and computers can be explained by two factors and identify the elements in each factor.

Specific objectives

$So_1$. 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.
$So_3$. Evaluate the adjusted model.

The following hypotheses were established from the previously exposed questions:

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

### 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 what were 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) Characteristics

A total of 517 university students from two universities (a private univeristy, *Universidad Cristobal Colon* and a public university, *Unversidad Autonoma de San Luis Potosi*) participated in this research. Out of these two universities, 303 students were from *Universidad Cristobal Colon*, and 214 students from *Unversidad Autonoma de San Luis Potosi*. All of these students are currently enrolled in a career in economic-administrative in one of the two universities.

### 2.2 Instrument

We used an instrument proposed by Galbraith & Haines (2000) 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 (Hu & Bentler, 1995). To evaluate the adjustment we considered chi square (Chi2) 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 the Pearson correlation, we can see from Table 1, that the highest value of the average item 40 (3.93), followed by item 33 (3.89) and item 37 (3.68). Regarding the correlations, the positive values indicate a direct relationship between the variables involved, and the negative values show an inverse relationship. As expected, the items 34, 36, 38, 39 are negatively correlated with items 33, 35, 37 and 40.

Table 1 Correlation Matrix between variables

| | Media | S. D. | Item33 | Item34 | Item35 | Item36 | Item37 | Item38 | Item39 | Item40 |
|---|---|---|---|---|---|---|---|---|---|---|
| Item33* | 3.89 | .949 | 1 | -. 132 | .264 | -.132 | .108 | .036 | -.082 | .362 |
| Item34 | 2.29 | 1.061 | | 1 | -.080 | .282 | -.070 | .180 | .359 | -.144 |
| Item35 | 3.46 | 1.018 | | | 1 | -.030 | .090 | -.016 | -.043 | .288 |
| Item36 | 2.99 | 1.016 | | | | 1 | .007 | .203 | .294 | -.146 |
| Item37 | 3.68 | 1.053 | | | | | 1 | .018 | -.053 | .286 |
| Item38 | 3.02 | 1.034 | | | | | | 1 | .172 | .014 |
| Item39 | 2.55 | 1.114 | | | | | | | 1 | -.162 |
| Item40 | 3.93 | .999 | | | | | | | | 1 |

Pearson Correlation = $p< 0.01$

*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 check the internal structure of interaction between mathematics and computer, an exploratory factor analysis (Principal Components, Varimax rotation) and confirmatory (Maximum Likelihood) was performed. The values of the measure of sampling adequacy Kaiser-Mayer-Olkin (.672) and Bartlet's sphericity test (385.590, df = 28, $P<0.000$) suggested that it was appropriate to use factor analysis. The method of Principal Component extraction and Varimax rotation method were used.

The Kaiser-Guttman rule of eigenvalues greater than 1 identified two factors that accounted for 45,073% of the variance in response to the test. Factor 1 is composed of the items 34, 36, 38 and 39 have been referred to as being inconvenient to technology. Factor 2 includes items 33, 35, 37 and 40, have been referred to as usefulness to technology for the application of mathematics.

In order to confirm the adjusted data of two-factor model, it was decided to conduct a confirmatory factor analysis. In this type of analysis in addition to ratifying the factors, we should also compare the adjusted index of several alternative models to be able to choose the best. Thompson (2004) notes that the confirmatory factorial analysis should confirm the adjustment of a theoretical model, and it is advisable to compare the adjusted indexes of several alternative models to be able to select the best.

We then verified the obtained model for the factorial analysis which included trajectories between latent variables (Figure 1) and estimated model (Figure2).

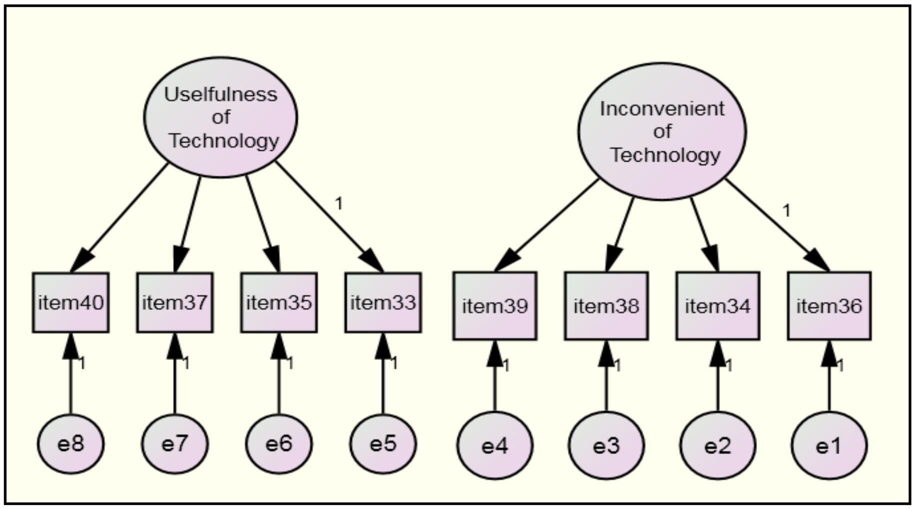


Figure 1 Obtained Model from exploratory factorial analysis

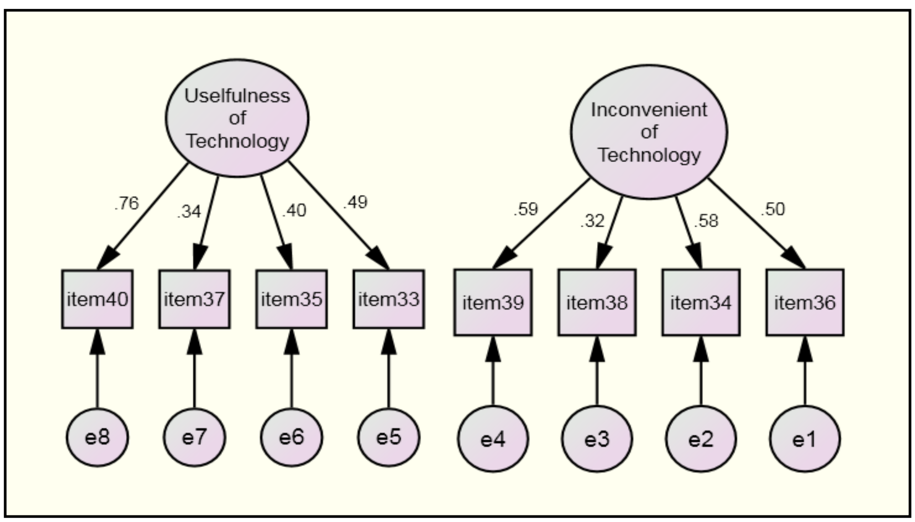


Figure 2 Standardized weights of the factorial exploratory analysis model

The model shows the standardized weights for regression that clearly shows that there are many variables with less weight, less than 0.5 that correspond to items 33, 35, 37 and 38. The first three belong to the factor named *usefulness of the technology*, and item 38 corresponds to inconvenient factors of technology. These values may cause problems when adjusting the model.

The results of $Chi^2$ in the model were ($Chi^2$=47,860, gl=20, p<0.000, CMIN/DF = 2.393), the index values were (GFI =.978, AGFI =.960, CFI=.923, RMSEA=.052), the value of RMSEA is more than 0.05; this is why we proceeded to modify the indexes to obtain a better adjusted model. The model obtained is presented in figure 3 and a summary of the adjusted index of both models are presented in table 2.

In Figure 3 that there are two main factors that students identified in the attitude of interacting between mathematics and the computer: 1) The usefulness, where students reported that computers help them learn better by providing many examples to work with, and 2) the disadvantages mentioned and that are significant are that when following the instructions on the keyboard draws away the attention or distracts the student from mathematics, and the difficulty to transmit knowledge from the screen to the mind.

While it is true that, from a technical point of view, two indicators per factor should be sufficient, it is highly recommended to use at least three factors to avoid problems of identification and convergence (Hair, Babin, Anderson and Tatham, 2006). Thus, changes to the proposed model are only theoretical.

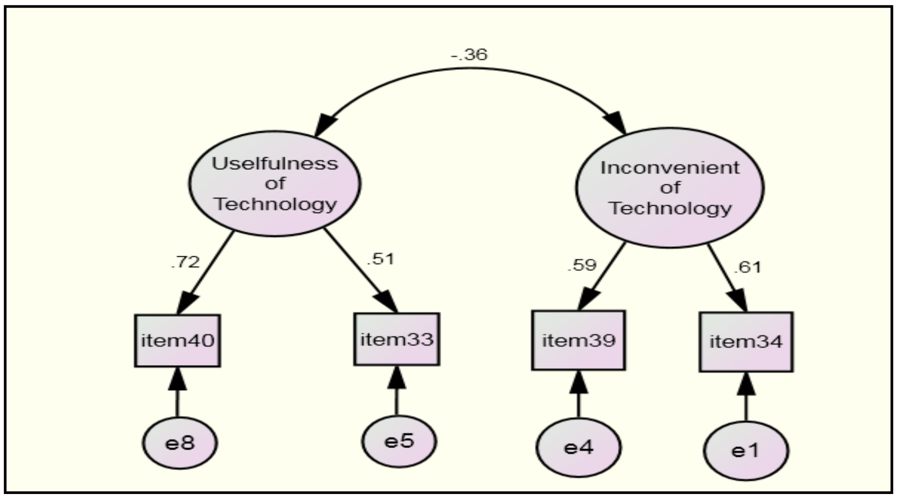


Figure 3 Standardized weights of final model CFA (confirmatory factorial analysis)

Table 2 Adjusted indexs of measuring interaction computer-mathematics models

| | $Chi^2$ | df | CMIN/DF | RMSEA | GFI | CFI | AGFI |
|---|---|---|---|---|---|---|---|
| Model 1 | 47,860 | 20 | 2.393 | 052 | .978 | .923 | .960 |
| Model 2 | 1.619 | 1 | 1.619 | .035 | .998 | ,996 | .984 |

$Chi^2$, 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

A variety of indicators were employed to evaluate the adjusted models, specifically, chi-square statistic was used, chi-square ratio on 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 ratio of chi-square on the degrees of freedom should be less than three indicating a good fit, the change in model two (indicating a good fit 1,619). The values of CFI (.996) and GFI (0.998) also indicate the good fit of the model since a value closer to 1 indicates a better fit. The RMSEA (.035) is considered optimal when the values are 0.05 or lower.

## *4. Conclusion*

In general, the objectives and questions raised in this research were met and provide 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.

The results are consistent with those of Galbraith & Haines, (2000) whose 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; 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 Ausel (1973) states. The second group, just like Vygotsky (1996, c.p. Kozulin, 2004) mentions, 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. Regarding the factor of the usefulness of technology, we observed that computers help -in a better way- the students by providing more examples to work with. These components influence the students' attitude, in a positive way, by perceiving the usefulness of technology. The results partially coincide with those of Galbraith & Haines, (2000) where they point out that the interaction between mathematics and computers help the students by providing examples to work with, but differ from in the way students extend there search for information, once the session is over. As for the elements corresponding to the disadvantage of the use of technology, it is concluded that following the instructions on the keyboards distracts the students from learning mathematics. Furthermore, the difficulty in comprehending what is on the screen may influence in the students' attitude towards mathematics. These results concur with those of Galbraith & Haines, (2000) with respect to the difficulty of interpreting the results on the screen and the distractions that may occur

3. - To evaluate the adjusted model, a theoretical model was formulated based on Galbraith and Haines (2000) 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.

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 is not given by interacting with technology.

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

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### *References*

Almerich, G., Suárez, J. M., Orellana, N., Belloch, C., Bo, R. y Gastaldo, I. (2005) Diferencias en los conocimientos de los recursos tecnológicos en profesores a partir del género, edad y tipo de centro. RELIEVE, 11 (2), pp. 127-146. Retrieved from: http://www.uv.es/RELIEVE/v11n2/RELIEVEv11n2_3.htm.

Ausubel, D. P. (1973). 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.

Camarena, P. (2009). La matemática en el contexto de las ciencias. *Innovación Educativa*, 9, (46), 15-25.

Galbraith, P. & Haines, CH. (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 Attitudes Scales. Monographs in Continuing Education*. London: City University.

García-Santillán, A., Escalera, M. y Edel, R. (2011). 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),*** pp. 118-135. Retrieved from: http://www.rinace.net/riee/numeros/vol4-num2/art7.pdf.

Gómez, I. & Haines, Ch. (2008). Students' attitudes to mathematics and technology. comparative study between the United Kingdom and Spain. In ICME-11, 11th International Congress on Mathematical Education. Retrieved from: http://tsg.icme11.org/document/get/924.

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2006). *Multivariate data analysis* (6ª ed.). Upper Saddle River, NJ: Pearson-Prentice Hall.

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

Minguell, M. (2000). Interactividad e interacción. *Revista Interuniversitaria de Tecnología Educativa.* P. 92-97. Retrieved from: http://web.udg.edu/pedagogia/images/gretice/INTERACT.pdf.

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

Thompson, B. (2004). *Exploratory and confirmatory factor analysis*. Washington, DC: American Psychological Association.

Tirado, R. (2003). El diseño de sistemas interactivos multimedia de aprendizaje: aspectos básicos. *Revista PIXEL_BIT*, 7,1-15. Retrieved from: http://www.sav.us.es/pixelbit/articulos/n7/n7art/art74.htm.

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

### Appendix

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