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International Journal of Research in Education and Science (IJRES)

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To cite this article:

Garcia-Santillán, A., Moreno-García, E., Escalera-Chávez, M., Rojas-Kramer, C. & Pozos-Texón, F. (2016). Structural equation model to validate: Mathematics-computer interaction, computer confidence, mathematics commitment, mathematics motivation and mathematics confidence. *International Journal of Research in Education and Science (IJRES), 2*(2), 518-526.

International Journal of Research in Education and Science
Volume 2, Issue 2, Summer 2016 ISSN: 2148-9955

Structural Equation Model to Validate: Mathematics-Computer Interaction, Computer Confidence, Mathematics Commitment, Mathematics Motivation and Mathematics Confidence

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Abstract

Most mathematics students show a definite tendency toward an attitudinal deficiency, which can be primarily understood as intolerance to the matter, affecting their scholar performance adversely. In addition, information and communication technologies have been gradually included within the process of teaching mathematics. Such adoption of technology modified the educational process, thus generating a meaningful impact as presented by studies carried out by Galbraith and Haines (2000). They developed a theoretical model aiming to explain this phenomenon from the component elements of attitude toward mathematics and computers: Mathematics engagement, mathematics confidence, mathematics motivation, computer confidence, and student's interaction with mathematics and computer. The purpose of this study was validating that model against experimental data coming from a sample of undergraduates from the fields of administration and economics. The collected data was processed applying multivariate data analysis using structural equation modeling technique. The observed fit indices corroborated that the theoretical model adjusts statistically well to the empirical data, even though the observed variance stayed below the optimal value. The evidence obtained in this study validates the theoretical model while revealing that additional weightings for the indicators should still be explored.

Key words: Attitude toward mathematics; Galbraith-Haines model; Mathematics learning; Technology-assisted learning

Introduction

Students' performance in mathematics is a topic currently under discussion from the theoretical perspectives of anxiety, confidence, and other variables. In addition, the inclusion of information and communication technologies has had a meaningful impact on mathematics teaching as shown by studies carried out by Galbraith and Haines (1998). In this same vein, in a recent exploratory study, García-Santillán, Escalera-Chávez, Córdova-Rangel and López-Morales (2013) pointed out that students show a definite tendency toward an attitudinal deficiency that can be primarily understood as an intolerance toward mathematics. Numerous studies have discussed this topic. At the same time, these authors highlight the existence of creative students, who find in mathematics a means to solve real problems. Mathematics provides them with the capacity to seek, ask, inquire, and research problems they want to solve.

Children begin by exploring their world, associating objects and persons in an imaginary, which only psychology can explain as an instinctive act. Curiosity comes to be of paramount significance for teaching processes in any discipline, including mathematics, the object of this study. Students are creative in the same measure as they are curious; this becomes an essential element in the search for solutions to mathematical problems. This fact was commented out by García-Santillán et al. (2013), who reference the position on utilization of Information and Communication Technology (ICT) in the teaching-learning process of mathematics, given by Fey (1989): "… it is very difficult to determine the real impact of those ideas and development projects in the daily life of mathematics classrooms, and there is very little solid research evidence validating the nearly boundless optimism of technophiles in our field."

What is the nexus between mathematics and technology? This simple question has motivated different studies concerning the golden trilogy (learner, mathematics, and computer). The study by Galbraith and Haines (1998)

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constitutes a seminal reference work in trying to explain this phenomenon. They distinguish between the relationship of mathematics with ICT, and ICT applied to the mathematics teaching-learning process. This relationship envisions as two constructs, which must be dealt with individually, because technology deployment modifies the educational process.

Other arguments, such as those of Kaput and Thompson (1994) have contributed to this theoretical analysis. In this regard, they point out that technological innovations have been developed to solve other types of problems, not necessarily the process of teaching mathematics. What they propose is in contrast to other studies, such as those by Auzmendi (1992), and García, Edel and Escalera (2012). Nevertheless, it is true that ICT was not made explicitly for the educational process, although it has been frequently deployed in the teaching-learning process. In addition, as stated by Galbraith and Haines (1998), attempts have been made to adapt the mathematics syllabus.Please use 10-point font size. Please margin the text to the justified. Manuscripts should be single spaced. Footnotes and endnotes are not accepted. All relevant information should be included in main text. Do not indent paragraphs; leave a space of one line between consecutive paragraphs. Do not underline words for emphasis. Use italics instead. Both numbered lists and bulleted lists can be used if necessary. Before submitting your manuscript, please ensure that every in-text citation has a corresponding reference in the reference list. Conversely, ensure that every entry in the reference list has a corresponding in-text citation.

Subdivide text into unnumbered sections, using short, meaningful sub-headings. Please do not use numbered headings. Please limit heading use to three levels. Please use 12-point bold for first-level headings, 10-point bold for second-level headings, and 10-point italics for third -level headings with an initial capital letter for any proper nouns. Leave one blank line after each heading and two blank lines before each heading. (Exception: leave one line between consecutive headings.) Please margin all headings to the left.

Justification

Knowledge of mathematics is paramount in people's lives; almost everybody needs to understand and apply mathematics correctly every day. In the United States, Moyer et al. (2005) have indicated that mathematics is now more useful than ever. In addition, its usefulness is increasing over time because mathematics is essential for life, integrates to cultural heritage, and it is necessary for work. ICT took on the relevant role in teaching and learning of mathematics. Thus, it becomes indispensable to study ICT as tools to overcome attitudinal deficiencies and to provide feedback to students learning mathematics.

Empirical Studies

"Attitude represents an emotional reaction to an object" as noted by Hart (1989) cited by Galbraith and Haines (1998). It is the belief one has in regard to an object, or it is one's behavior toward this object. Meanwhile, emotion means enthusiasm produced by a stimulus (McLeod 1989a). These dimensions, attitude and emotion, represent the affective side of the human being, and they can be present in a greater degree in an individual, decreasing the cognitive aspect. In other words, as passion increases, knowledge decreases.

Attitude can be seen as the result of emotional reactions, which have been internalized and transformed "to generate feelings of moderate intensity and reasonable stability" as noted by McLeod 1989a cited by Galbraith and Haines (1998). Marshall (1989) has proposed the hypothesis of a mechanism for cognitive development, the attitude, related to the concept of network in human memory (Anderson 1983, 1995). Here, attitude represents the evocation of stored affective memories, which implies a dispassionate response. Attitudes are expressed along a positive-negative continuum (pleasant-unpleasant). Attitude in mathematics, in the words of Gal and Garfield (1997), is the sum of emotions and feelings experienced throughout time concerning the learning of mathematics. In these contexts, it has a more stable understanding over beliefs than over cognition.

Other studies have added to the argument for technology development and its influence on the educational process of mathematics teaching. Its impact has been defined as beneficial in the field of mathematics education at all levels (Goldenberg 2000; García and Edel 2008; García-Santillán and Escalera 2011; García-Santillán, Escalera and Edel 2011; Moursund 2003). In this same regard, Gómez-Chacón and Haines (2008), Noss (2001) and Artigue (2002) have demonstrated that use of technology in mathematics teaching favors student performance. In fact, some studies highlight the existence of cognitive and affective demands present among the student population in specific programs that include technology (Galbraith 2006; Pierce and Stacey 2004; Tofaridou 2006). Derived from the above arguments, García-Santillán et al. (2013) highlight a relevant element of academic analysis. That is, precisely, the extreme care that should be given to the dialectical aspect, both technical and conceptual, within the process of mathematics teaching. It applies specifically to the fields where technology must be included, through graphing calculators or any computer-based resources.

Another research work, on the topic of attitude toward mathematics and computers, due to Cretchley and Galbraith (2006), has found evidence of the dimensions that integrate these variables: commitment, motivation, confidence, and interaction between mathematics and computers. Other studies suggest there is a fragile relationship between mathematics and attitude toward computers, in regards to confidence and motivation, versus the use of technology in the mathematics teaching-learning process (García-Santillán et al. 2013). On the other hand, other authors, such as Crespo (1997) cited in Poveda and Gamboa (2007), question whether the technology is the "magical formula," though it has been propounded as such. Of course, technology per se is not the solution to the problem of an apparent attitude of rejection of mathematics by the student. It can be, however, an important means of transforming traditional classroom with blackboards, erasers, desks, and other instruments of the old school, into interactive classrooms which generate learning spaces mediated by ICT, as has been referred by Gómez-Meza (2007). It is also cited in Poveda and Gamboa (2007) who also mention that even though technology per se is not the magical formula, nor the solution to all educational ills, it is true that the technology can be a change agent that promotes mathematics teaching and learning.

Theoretical Foundations

This confirmatory study on the validation of a theoretical model explaining the construct of attitude toward mathematics extends an exploratory study by García-Santillán et al. (2013) carried out among students at the Universidad Politécnica de Aguascalientes. In that previous work, a survey was conducted among 164 students from different fields of study, such as administration and business, Mechatronics' engineering, industrial engineering, strategic systems engineering, and mechanical engineering.

Both works are based on the proposal of Galbraith and Haines (2000) on the component elements of attitude toward mathematics. Those are: Mathematics motivation, mathematics confidence, mathematics engagement, computer confidence, and mathematics-computer interaction. In addition to this seminal referent work, they include the contribution of Cretchley et al. (2000) on the deployment of engineering science in math teaching and its theoretical reality. From this theoretical construction stems the present work, which seeks to attest if the model proposed by Galbraith and Haines (2000) fits the data gathered during the field study with students at Universidad Cristóbal Colón. For this reason, the preliminary question derives: Can technology improve mathematics instruction? In this respect, there have been pronouncements such as those of Karadag and McDougall (2008). They assert that, irrespective of the theoretical and practical implications of what has been proposed in regards to teaching mathematics and the inclusion of technologies in the curriculum; the majority of the population utilizes technology daily. It is mainly true in the case of scholars, who cannot think of life without these indispensable tools - the computer and the Internet. In addition, recent generations were born in the information age (the Net generation), and they are convinced in their usage of technology.

Regarding this rationale from Karadag and McDougall (2008), it is worth mentioning that Galbraith (2006) referred to technology as "an extension of one's self." Today, more than ever, students relate directly to ICT; it has become part of their identity and, certainly, it affects the process of teaching and learning mathematics. Other theoretical arguments have added to this debate. Their postulates refer that students and the academic institutions where they study, have been capable of using technology in an efficient way, as had been foreseen (Artigue 2002; Izydorczak 2003; LaGrange 1999; Moreno-Armella & Santos-Trigo 2004; Moyer et al. 2005; Kieran & Drijvers 2006; Kieran 2007; Karadag & McDougall 2008).

García-Santillán et al. (2013) cite Suurtamm and Graves (2007), who relate that the Ontario Ministry of Education has proposed that, in order for students to improve their capacity for research and analysis of mathematics concepts, they should use technological tools such as calculators or computers, which permit them to solve problems swiftly, in the setting in which they arise; yet those problems which may be impossible to solve with paper and pencil. These projects can include performing complex arithmetic operations. To address this topic properly, it becomes essential to explain the peculiar aspect of computational mathematics attitudes. Thus, aiming to a deeper understanding of the conceptual foundation follows a review for each of the five dimensions of attitude toward mathematics described by Galbraith and Haines (2000): mathematics confidence, mathematics motivation, computer confidence, computer-mathematics interaction, and mathematics engagement.

The scales developed by Galbraith and Haines (2000) were built upon parallel components on the attitude scale of Fennema and Sherman (1976), and on the attitude scale of Galbraith and Haines (1998), but designed for undergraduate students. Five constructs integrate the scales, as shown in Figure 1, in which each section is composed of eight indicators.

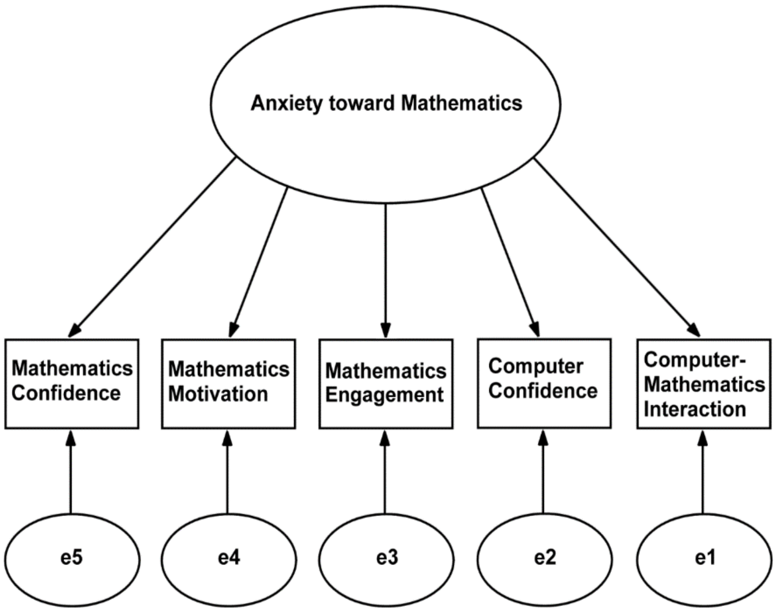

Fig. 1. Theoretical Model of Galbraith and Haines

Galbraith and Haines (2000) state, regarding the scales of this model:

- Mathematics confidence: Students with high confidence toward mathematics believe they achieve value for their effort. They face efficiently learning complex topics, feel comfortable about mathematics as a subject, and expect to obtain sound results. On the other hand, students with low confidence show wary when learning new materials, believe all mathematics will be difficult, perform naturally weak in mathematics, and mathematics is their subject of most concerns.

- Mathematics motivation: Students with high motivation toward mathematics, enjoy resolving mathematics problems, persevere until the problem is solved, think of mathematics outside classes, and become absorbed in their mathematical activities. People weakly-motivated dislike mathematics challenges. They feel frustrated by having to spend time on problems, prefer to have the answers instead of being left with a problem, and cannot understand people excited about mathematics.

- Mathematics engagement: Students with higher scores on this scale have a preference for working based on examples rather than using given materials for learning. Additionally, students with a lower score on the scale prefer to treat mathematical ideas as separate units, and prefer to learn from materials.

- Computer confidence: Students who demonstrate a high degree of trust in computers believe they can master the necessary software procedures. They feel deeper convinced of their answers when they calculate on computers. Consequently, they prefer to solve problems by themselves. On the other hand, students with little computer confidence feel disadvantaged by having to work with computers; they feel anxious about using a computer to perform calculations within their learning process. In summary, they distrust computers can produce correct answers, and panic leads them to mistakes when using a computer program.

- Computer-mathematics interaction: The importance of this partnership has been studied by different authors, including Lester et al. (1989), McLeod (1985, 1989b). These authors have conjectured that when a student is not familiar with the technology, this can cause particular complications. Reif (1987), Chi et al. (1989), and Anderson (1995), among others, pointed out that, by interacting with learning materials, such as pencil and paper, or a computer screen, the brain adds a dimension to the cognitive processes.

Concerning "participation in mathematics learning," several studies have contributed to the understanding of this phenomenon. These reveal that student commitment to learning mathematics yields efficient and valuable results. It has been demonstrated that various experts have succeeded leveraging on mechanical concepts in mathematics teaching (Reif 1987). Likewise, other studies have shown how examples can construct a powerful framework for learning (LeFavre and Dixon 1986; Reder et al. 1986). The students that learned did commit to generating more ideas than students who did not (Chi et al. 1989).

Swing and Peterson (1988) showed that integration and development processes, such as analysis, definition, and comparison are related to better learning. Reder and Anderson (1980), showed that summaries support effective learning. Anderson (1995) has demonstrated that when these factors are frequently associated with concepts in the learning process, the information received by the student can be recalled easier. Likewise, if the information is connected to a knowledge network, it can lead to superior results for the learner. The above discussion allows to identify the variables in the object of study, as illustrated in the following constructs, where the variables proposed by Galbraith and Haines (2000) are discussed. They are mathematics confidence, mathematics motivation, mathematics engagement, computer confidence, and mathematics-computer interaction. All this falls within the golden trilogy: student, computer, and mathematics.

Method

For the purposes of this study, a non-probabilistic sample was utilized. Selection of the elements depends on the causes related to the characteristics of the investigation, not on probabilities. Of course, the selected sample obeys other research criteria (Hernández et al. 2003). The study sample consisted of 303 students from Universidad Cristóbal Colón, of Veracruz, México. They were selected from various fields of study: economics, administration, accounting, marketing, and tourism business management. In addition, selection criteria to include students in the answering group were: They have completed at least one course in mathematics within their undergraduate program, and they were available on the day of the survey. The scale developed by Galbraith and Haines (2000) was adopted for this study. It consists of five sections: mathematics confidence (items 1 to 8), mathematics motivation (items 9 to 16), mathematics engagement (items 17 to 24), computer confidence (items 25 to 32), and mathematics-computer interaction (items 33 to 40). Each section consists of eight elements evaluated by a Likert scale: from 1 (lowest) to 5 (highest).

Structural equation modeling technique was utilized in the multivariate analysis, to validate if the model proposed by Galbraith and Haines (2000) fits well the empirical data. Indeed, it is worth mentioning that this technique was selected mainly for its high potential for broadening the development of the theory (Gefen et al. 2000). The model was evaluated by goodness of fit measures, to assess how well the empirical data support the theoretical model. Thus, the following measures were used: statistical likelihood ratio Chi-square (X2) and Mean Squared Residue (RMSEA), GFI (Goodness of Fit Index), AGFI (Adapted Goodness of Fit Index), and CFI (Comparative Fit Index) (Hair et al. 1999). Data was processed and analyzed with the aid of AMOS v21 software.

Hypothesis

This model of anxiety toward mathematics is a five-factor structure: mathematics confidence, mathematics motivation, mathematics engagement, computer confidence, and mathematics-computer interaction. Figure 1 shows a graphic representation of the model.

Results

The results are presented beginning with a summary of the model, followed by a description of variables and parameters, and finally the evaluation of the model. With respect to the summary of the model, 15 elements are registered in the covariance matrix. Of these, 10 are estimated parameters with positive degrees of freedom (5 = 15 - 10). It means that the model is over-identified, and the Chi-square (X2) can be estimated 5.399 with a level of probability of 0.369, which indicates that the model is significant. The parameters to evaluate the model are 10, which correspond to the regression weights, plus six variances, for a total of 16 parameters to estimate. With respect to the variables, it can be seen that there are 11 variables in the model, of which five correspond to the number of observed variables, and six to non-observed variables. In order to estimate if the hypothetical model fits adequately, the reliability of the estimated parameters and the global fit of the complete model were evaluated.

Table 2 shows the reliability of the parameters of Table 1. In addition, the parameters of the weights and variances resulted viable, as shown in Table 3, and the value of reliability is 0.5365. There are no negative variances, and all of them are significant (greater than 1.96). Additionally, Table 2 shows the values for error measurement of each indicator, and all resulted positive, meaning that the variables are related to their constructs.

Table 1. Weight and significance of variables

Variable	Weight	Significance
Mathematics-Computer Interaction X_1	0.513	4.15
Computer Confidence X_2	0.325	3.59
Mathematics Commitment X_3	0.323	3.58
Mathematics Motivation X_4	0.597	4.43
Mathematics Confidence X5	0.397	4.07

Table 2. Weight and significance of variables

Variable	X1	X2	X3	X4	X5
X1	0.737				
X2	0.000	0.894			
X3	0.000	0.000	0.896		
X4	0.000	0.000	0.000	0.644	
X5	0.000	0.000	0.000	0.000	0.842

Table 3. Variances

Parameter	Estimation	S.E.	C.R.	P
F1	3.444	1.065	3.233	0.001
e1	9.616	1.109	8.671	***
e2	18.547	1.660	11.175	***
e3	24.193	2.163	11.183	***
e4	7.253	1.055	6.875	***
e5	12.941	1.234	10.486	***

With respect to the global fitness model, Table 4 provides the quality measurement for absolute fit. The index sample Chi-square is a satisfactory fit (X2 = 5.399, df = 5, sig = 0.369). Similarly, the values of GFI (0.993), AGFI (0.979), CFI (0.995) and RMSEA (0.016) are also satisfactory (Byrne 2000).

Table 4. Goodness of fit measures: revised model and null

CMIN	CMIN/DF	GFI	AGFI	CFI	RMSEA
5.399	1.080	0.993	0.979	0.995	0.016

Upon acceptance of the model as a system, the construct required for checking the internal consistency of all indicators to measure the concept was evaluated. Thus, Table 5 shows the extracted variance, which should be greater than 0.50. In this case, the value 0.350 fails to this condition, which means that above a half of the variance indicator is not taken into account for the construct. Likewise, Table 5 shows that the reliability, value associated with the construct is 0.5365, less than recommended (0.70), revealing insufficiency on the indicators to represent each of the dimensions.

Table 5. Reliability and variance extracted

Indicators	Reliability	Mean Variance Extracted
Anxiety toward mathematics	0.5365	0.350

Upon acceptance of the model as a system, the construct required to check the internal consistency of all indicators to measure the concept was evaluated. Thus, Table V shows the extracted variance, which should be greater than 0.50. In this case, the value 0.350 fails to this condition, so above a half of the variance indicator is not taken into account for the construct. Likewise, Table V shows that the reliability, value associated with the construct is 0.5365, less than recommended (0.70), revealing insufficiency on the indicators to represent each of the dimensions.

Conclusions

The results of this work provide experimental evidence that the structure specified in the hypothetical model is significant when applied to students of Universidad Cristóbal Colón. It means the model fits the data. These results are consistent with those of other authors who show that the presence of technology stimulates mathematics learning. In addition, it is worth pointing out that the outcomes of the study have academic implications as they support the theoretical foundation proposed by Galbraith and Haines (2000). The constructs considered here, have statistical and practical significance for the students who were the object of this work.

Additionally, the evidence obtained in this study contributes to predicting the reality described by the authors concerning attitudes toward mathematics. At the same time, they give light to establish further questions in the search for knowledge. For instance, it is necessary to explore additional weightings for the indicators since the variance values obtained were below optimum. As a practical implication of this study, the results seem valuable for higher-education institutions to carry out teaching strategies focused on the utilization of ICT. It traduces on the relevance of both: conducting a larger effort by the teachers of the subject, and encouraging them to deploy the technological tools in such a way that they increasingly strengthen the students' attitude toward mathematics.

References

Anderson, J. R. (1983). The Architecture of Cognition. Cambridge, MA: Harvard University Press.

Anderson, J. R. (1995). Cognitive Psychology and Its Implications. New York: Freeman.

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.

Auzmendi, E. (1992). Las Actitudes hacia la Matemática-Estadística en las Enseñanzas Medias y Universitarias. Características y Medición. Bilbao: Mensajero.

Byrne, B. M. (2000). Structural Equation Modelling with AMOS: Basic Concepts, Applications, and Programming. Canada: Routledge.

Cretchley, P. C., & Galbraith, P. (2002). Mathematics or Computers? Confidence or Motivation? How do these Relate to Achievement? Paper presented at the Proceedings on the 2nd International Conference on the Teaching of Mathematics (at the undergraduate level) CD and online, Crete.

Cretchley, P. C., Harman, C., Ellerton, N., & Fogarty, G. (2000). MATLAB in Early Undergraduate Mathematics: An Investigation into the Effects of Scientific Software on Learning. Education Research Journal, 12(3), 219-233.

Chi, M. T. H., Bassok, M., 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.

Fennema, E., & Sherman, J. A. (1976). Fennema-Sherman Mathematics Attitudes Scales: Instruments Designed to Measure Attitudes toward the Learning of Mathematics by Females and Males. Journal for Research in Mathematics Education, 7(5), 324-326.

Fey, J. T. (1989). Technology and Mathematics Education: A Survey of Recent Developments and Important Problems. Educational Studies in Mathematics, 20(3), 237-272.

Gal, I., & Garfield, J. B. (1997). The Assessment Challenge in Statistics Education. Amsterdam: IOS Press.

Galbraith, P. (2006). Students, Mathematics, and Technology: Assessing the Present Challenging the Future. International Journal of Mathematical Education in Science and Technology, 37(3), 277-290.

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.

Garcia-Santillán, A., & 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. Paper presented at the Annual Meeting Nova Southeastern University "Beyond the Classroom" Fischler School of Education & Human Service, Miami Beach, Florida, USA.

García-Santillán, A., Escalera-Chávez, M. E., Córdova-Rangel, A., & López-Morales, J. S. (2013). Attitude and behavioral among Students, Computers and Mathematics. British Journal of Education, 1(1), 14-32.
García-Santillán, A., Escalera, M., & Edel, 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), 118-135.
Gefen, D., Straub, D., & Boudreau, M.-C. (2000). Structural Equation Modeling and Regression: Guidelines for Research Practice. Communications of the Association for Information Systems, 4(7), 1-78.
Goldenberg, E. P. (2000). Thinking (and Talking) About Technology in Math Classrooms. Education Development Center. http://www2.edc.org/
Gómez-Chacón, I. M., & Haines, C. (2008). Students' attitudes to mathematics and technology. Comparative study between the United Kingdom and Spain. Paper presented at the 11th International Congress on Mathematical Education, Monterrey, México.
Hair, J. F., Tatham, R. L., Anderson, R. E., & Black, W. C. (1999). Multivariate data analysis. Spain: Prentice Hall.
Hernández, R., Fernández, C., & Baptista, P. (2003). Metodología de la investigación. México, D.F.: McGraw-Hill.
Izydorczak, A. E. (2003). A Study of Virtual Manipulatives for Elementary Mathematics (Unpublished doctoral dissertation). The State University of New York, Buffalo, NY.
Kaput, J. J., & Thompson, P. W. (1994). Technology in Mathematics Education Research: The First 25 Years in the JRME. Journal of Research into Mathematics Education, 25(6), 676-684.
Karadag, Z., & McDougall, D. (2008). Studying Mathematical Thinking in an Online Environment: Students' Voice. Paper presented at the 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, Morelia, Michoacán, México.
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.
LaGrange, J.-B. (1999). Complex Calculators in the Classroom: Theoretical and Practical Reflections on Teaching pre-calculus. International Journal of Computers for Mathematical Learning (4), 51–81.
LeFavre, J.-A., & Dixon, P. (1986). Do Written Instructions Need Examples? Cognition and Instruction (3), 1-30.
Lester, F. K., Garofalo, J., & Kroll, D. L. (1989). Self-confidence, Interest, Beliefs, and Metacognition: Key Influences on Problem-solving Behavior. In D. B. McLeod & V. M. Adams (Eds.), Affect and Mathematical Problem Solving: A New Perspective. New York: Springer-Verlag.
Marshall, S. P. (1989). Affect in Schema Knowledge: Source and Impact. In D. B. McLeod & V. M. Adams (Eds.), Affect and Mathematical Problem Solving: A New Perspective. New York: Springer-Verlag.
McLeod, D. B. (1985). Affective Issues in Research on Teaching Mathematical Problem Solving. In E. A. Silver (Ed.), Teaching and Learning Mathematical Problem Solving: Multiple Research Perspectives. Hillsdale, NJ: Lawrence Erlbaum Associates.
McLeod, D. B. (1989a). Beliefs, Attitudes and Emotions: New Views of Affect in Mathematics Education. In D. B. McLeod & V. M. Adams (Eds.), Affect and Mathematical Problem Solving: A New Perspective. New York: Springer-Verlag.
McLeod, D. B. (1989b). The Role of Affect in Mathematical Problem Solving. In D. B. McLeod & V. M. Adams (Eds.), Affect and Mathematical Problem Solving: A New Perspective. New York: Springer-Verlag.
Moreno-Armella, L., & Santos-Trigo, M. (2004). Students Exploration of Powerful Mathematical Ideas through the Use of Algebraic Calculators. Paper presented at the Proceedings of the twenty-sixth annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education, Toronto.
Moursund, D. (2003). Editorial: The Spreadsheet. Learning & Leading with Technology, 26(5). http://www.iste.org/LL/
Moyer, P. S., Niezgoda, D. A., & 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.
Noss, R. (2001). For a Learnable Mathematics in the Digital Culture. Educational Studies in Mathematics (48), 21-46.

Pierce, R., & Stacey, K. (2004). A Framework for Monitoring Progress and Planning Teaching towards the Effective Use of Computer Algebra Systems. International Journal of Computers for Mathematical Learning, 9(1), 59-93.

Poveda, R., & Ronny, G. (2007). Consideraciones, Características, Limitaciones y Clasificación de una Clase Basada en Talleres. Cuadernos de Investigación y Formación en Educación Matemática. http://cimm.ucr.ac.cr/cuadernos/cuaderno3.php

Reder, L. M., & Anderson, J. R. (1980). A Comparison of Texts and their Summaries: Memorial Consequences. Journal of Verbal Learning and Verbal Behavior(19), 121-134.

Reder, L. M., Charney, D. H., & Morgan, K. I. (1986). The Role of Elaboration in Learning a Skill from an Instructional Text. Memory and Cognition (14), 64-78.

Reif, F. (1987). Interpretation of Scientific or Mathematical Concepts: Cognitive Issues and Instructional Implications. Cognitive Science (11), 395-416.

Suurtamm, C., & Graves, B. (2007). Curriculum Implementation in Intermediate Math (CIIM): Research Project. Faculty of Education, University of Ottawa. http://www.edu.gov.on.ca/eng/studentsuccess/lms/

Swing, S., & Peterson, P. (1988). Elaborative and Integrative Thought Processes in Mathematics Learning. Journal of Educational Psychology, 80(1), 54-66.

Tofaridou, I. (2006). Learning Styles and Technology Environments in Mathematics Education (Unpublished doctoral dissertation). City University, London.