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Technology-assisted Undergraduate Mathematics Learning.

Evaluation of Galbraith-Haines Model

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***Abstract*— Most of the mathematics students evidence a definite tendency toward an attitudinal deficiency, which can be understood as intolerance to the matter, affecting their scholar performance. Information and communication technologies have been gradually included within the process of teaching mathematics. Such adoption of technology changed the educational process, thus generating a meaningful impact as shown by studies carried out by Galbraith and Haines. They developed a theoretical model aiming to explain this phenomenon, based on the component elements of attitude toward mathematics and computers: Mathematics engagement, mathematics confidence, mathematics motivation, computer confidence, and student's interaction between mathematics and computer. The purpose of this study is to validate such a model against experimental data coming from a sample of undergraduates from the fields of administration and economics. The observed fit indices, computed by structural equation modeling, corroborated that the theoretical model adjusts well to the empirical data.**

***Keywords*— attitude toward mathematics, Galbraith-Haines model, mathematics learning, technology-assisted learning**

I. Introduction

Students' performance in mathematics is a topic under discussion from the theoretical perspectives of anxiety, confidence, and other variables. In addition, including Information and Communications Technology (ICT) has had a meaningful impact on mathematics teaching as shown by studies carried out by Galbraith and Haines [1].

In this same vein, in a recent exploratory study, García-Santillán et al. [2] pointed out that students show a definite tendency toward an attitudinal deficiency that can be understood as an intolerance toward mathematics. Many studies have discussed this topic. 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.

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Children begin by exploring their world, associating objects and persons in an imaginary, which psychology can explain as an instinctive act. Curiosity is of paramount significance for teaching processes in any discipline, including mathematics, the object of this study. Students are as creative as curious; this becomes an essential element in the search for solutions to mathematical problems. It was commented out by García-Santillán et al. [2], who reference the position of Fey [3] about using ICT in the teaching-learning process of mathematics: "… 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 about the golden trilogy (learner, mathematics, and computer). The study by Galbraith and Haines [1] makes up 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 individually dealt with, because technology deployment changes the educational process.

Other arguments, such as those of Kaput and Thompson [4] have contributed to this theoretical analysis. They point out that technological innovations have been developed to solve other types of problems, not primarily the process of teaching mathematics. What they propose is in contrast to other studies, such as those by Auzmendi [5], and García-Santillán et al. [6]. ICT was not created explicitly for the educational process, although it has been often deployed in the teaching-learning process. As stated by Galbraith and Haines [1], attempts have been made to adapt the mathematics syllabus.

II. 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. [7] have shown that mathematics is now more useful than ever. Its usefulness is increasing over time because mathematics is essential for life, integrates to cultural heritage, and 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 offer feedback to students learning mathematics.

This study was carried out among students from a private university in the Mexican state of Veracruz. It provides evidence to confirm the use of ICT -specifically computers- in the teaching and learning process influences the students' attitude toward mathematics. Thus, the findings of this study will contribute to existing knowledge on the topic, concerning constraints and scope. This work intends to get information, which will allow, as much as possible, to have sustainable arguments to guide both teachers and students to improve the process of teaching and learning mathematics.

III. Empirical Studies

"Attitude represents an emotional reaction to an object" as noted by Hart (1989) cited by Galbraith and Haines [1]. It is the belief one has regarding an object or one's behavior toward this object. Meanwhile, emotion means enthusiasm produced by a stimulus [8]. 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. 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 (1989) cited by Galbraith and Haines [1]. Marshall [9] proposed the hypothesis of a mechanism for cognitive development, the attitude, related to the concept of network in human memory [10] [11]. Here, the attitude is the evocation of stored affective memories, which implies a dispassionate response. Attitudes are expressed along a positive-negative continuum (pleasant-unpleasant).

According to Gal and Garfield [12] attitude in mathematics is the sum of emotions and feelings experienced throughout time about 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 mathematics education at all levels [13-17]. In this same regard, Gómez-Chacón and Haines [18], Noss [19] and Artigue [20] have demonstrated that use of technology in mathematics teaching favors student performance. In fact, several studies highlight the existence of cognitive and affective demands present among the student population in specific programs that include technology [21-23].

Derived from the above arguments, García-Santillán et al. [2] highlight a relevant element of academic analysis. That is 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 attitude toward mathematics and computers, due to Cretchley and Galbraith [24], 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, regarding confidence and motivation versus technology in the mathematics teaching-learning process [2].

Other authors, such as Crespo (1997) cited in Poveda and Gamboa [25], question whether the technology is the "magical formula" though it has been propounded. 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, into interactive classrooms which generate learning spaces mediated by ICT, as has been referred by Gómez-Meza (2007) also cited in Poveda and Gamboa [25] who also mention that even though technology is not the magical formula, nor the solution to all educational ills, it can be a change agent that promotes mathematics teaching and learning.

IV. Theoretical Foundation

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. [2] carried out among students at the Universidad Politécnica de Aguascalientes. In that earlier 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 [26] on the component elements of attitude toward mathematics. Those are: Mathematics motivation, mathematics confidence, mathematics engagement, computer confidence, and mathematics-computer interaction. Besides this seminal referent work, they include the contribution of Cretchley et al. [27] 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 [26] fits the data gathered during the field study with students at Universidad Cristóbal Colón.

So, the preliminary question derives: Can technology improve mathematics instruction? In this respect, there have been pronouncements such as those of Karadag and McDougall [28]. They assert that, irrespective of the theoretical and practical implications of what has been proposed for teaching mathematics and including technologies in the curriculum; the majority of the population uses technology daily. It is mainly true with 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.

On this rationale from Karadag and McDougall [28], worth mentioning Galbraith [21] 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 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 efficiently, as had been foreseen [7] [20] [28-33].

García-Santillán et al. [2] cite Suurtamm and Graves [34], 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 let them 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 discuss 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 [26]: Mathematics confidence, mathematics motivation, computer confidence, computer-mathematics interaction, and mathematics engagement.

The scale developed by Galbraith and Haines [26] was built upon parallel components on the attitude scale of Fennema and Sherman [35], and on the attitude scale of Galbraith and Haines [1], but designed for undergraduates. Five constructs integrate the scale, as shown in Fig. 1. Each section is composed of eight indicators.

Galbraith and Haines [26] state, about their constructs:

• Mathematics confidence: Students with high confidence toward mathematics believe they achieve value for their effort. They face efficiently learning complex topics, are comfortable about mathematics as a subject, and expect to get sound results. Students with little confidence show wary at learning new materials, believe all mathematics will be difficult, perform naturally weak in mathematics, and their subject of most concerns is mathematics.

• 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 math challenges, 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 prefer working based on examples rather than using given materials for learning. 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 show high trust in computers believe they can master the software procedures. They are deeper convinced of their answers when they calculate on computers, so, they prefer to solve problems by themselves. 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 [36-38]. These authors have conjectured that when a student is not familiar with the technology, this can cause particular complications. Reif [39], and Anderson [11], among others, pointed out that, when interacting with learning materials - such as pencil and paper or a computer screen- the brain adds a dimension to the cognitive processes.

Several studies on “participation in mathematics learning” have contributed to understanding this phenomenon. These reveal that student commitment to learning mathematics yields efficient and valuable results. It has been showed that various experts have succeeded leveraging on mechanical concepts in mathematics teaching [39]. Likewise, other studies have shown how examples can build up a powerful framework for learning [40-41]. The students that learned committed to generating more ideas than students who did not [42].

Swing and Peterson [43] showed that integration and development processes, such as analysis, definition, and comparison are related to better learning. Reder and Anderson [44] showed that summaries support effective learning. Anderson [11] has shown that when these factors are often 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 find the variables in the object of study, as illustrated in the following constructs, where the variables proposed by Galbraith and Haines [26] 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.

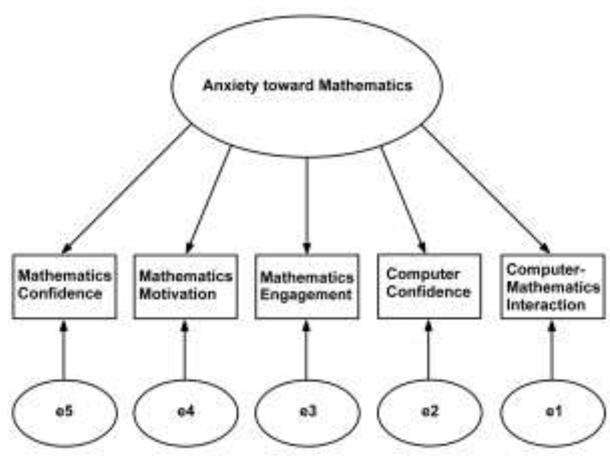

Figure 1. Theoretical Model of Galbraith and Haines. Own elaboration based on concepts from Galbraith and Haines (2000).

V. Method

For this study, a non-probabilistic sample was used. The choice of the elements depends on the causes related to the characteristics of the investigation, not on probabilities. The selected sample obeys other research criteria [45]. The study sample comprised 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. 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 [26] was adopted for this study. It comprises five sections (and items): mathematics confidence (1 to 8), mathematics motivation (9 to 16), mathematics engagement (17 to 24), computer confidence (25 to 32), and mathematics-computer interaction (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 confirm if the model proposed by Galbraith and Haines [26] fits well the empirical data. Worth mentioning that this technique was selected mainly for its high potential for broadening the development of the theory [46]. 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) [47]. AMOS v21 software was used to analyze the data.

A. *Hypothesis*

This model of anxiety toward mathematics is a five-factor structure: mathematics confidence, mathematics motivation, mathematics engagement, computer confidence, and mathematics-computer interaction. (Fig. 1 depicts the model.)

VI. 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.

The 15 elements of the model 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 (X^2) can be estimated 5.399 with a level of probability of 0.369, which shows that the model is significant.

The parameters to test the model are 10, which correspond to the regression weights, plus six variances, for 16 parameters to estimate. Regarding 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. To estimate whether the hypothetical model fits, these were evaluated the reliability of the estimated parameters and the global fit of the complete model.

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

Of the global fitness model, Table IV provides the quality measurement for absolute fit. The index sample Chi-square is a satisfactory fit (X^2 = 5.399, df = 5, sig = 0.369). The values of GFI (0.993), AGFI (0.979), CFI (0.995) and RMSEA (0.016) are also satisfactory (Byrne 2000).

TABLE I. WEIGHT AND SIGNIFICANCE OF VARIABLES

Variable		Weight	Significance
Mathematics-Computer Interaction	X1	0.513	4.15
Computer Confidence	X2	0.325	3.59
Mathematics Commitment	X3	0.323	3.58
Mathematics Motivation	X4	0.597	4.43
Mathematics Confidence	X5	0.397	4.07

Source: own

TABLE II. INDICATOR MEASUREMENT ERROR

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

Source: own

TABLE III. 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	***

Source: own

TABLE IV. 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

Source: own

TABLE V. RELIABILITY AND VARIANCE EXTRACTED

Indicator	Reliability	Mean Variance Extracted
Anxiety toward mathematics	0.5365	0.350

Source: own

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.

VII. Conclusion

The results offer 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 previous studies: Technology stimulates mathematics learning. In addition, worth pointing out that the outcomes of the study have academic implications as they corroborate Galbraith and Haines [26]. The considered constructs have statistical and practical significance for the participating students.

In addition, the evidence got in this study contributes to predicting the reality described by the authors concerning attitudes toward mathematics. They give light to set up further questions in the search for knowledge. For instance, to explore other weightings for the indicators since the observed variance values 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 ICT. It implies the relevance of both: conducting a larger effort by the teachers of the matter and encouraging them to deploy the technological tools in such a way they increasingly strengthen the students' attitude toward mathematics.

References

[1] 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.

[2] 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.

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

[4] 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.

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

[6] García-Santillán, A., Edel-Navarro, R., Chávez, M. E., Aldana, D., & Cornejo, P. (2012). Students' perceptions toward financial mathematics teaching process: An empirical study on engineering undergraduate students. *International Journal of Business and Social Science, 3*(14), 73-82.

[7] 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.

[8] McLeod, D. B. (1989). 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.

[9] 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.

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

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

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

[13] Goldenberg, E. P. (2000). Thinking (and Talking) About Technology in Math Classrooms. *Education Development Center*. http://www2.edc.org/

[14] 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.

[15] García-Santillán, A. & Escalera, 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, I, (6), 122-138.

[16] 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.

[17] Moursund, D. (2003). Editorial: The Spreadsheet. *Learning & Leading with Technology, 26*(5). http://www.iste.org/LL/

[18] 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.

[19] Noss, R. (2001). For a Learnable Mathematics in the Digital Culture. *Educational Studies in Mathematics*(48), 21-46.

[20] 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.

[21] 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.

[22] 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.

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

[24] 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.

[25] Poveda, R., & Gamboa, R.. (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

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

[27] 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.

[28] 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.

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

[30] 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.

[31] 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.

[32] 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.

[33] 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.

[34] 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/

[35] 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.

[36] 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.

[37] 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.

[38] 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.

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

[40] LeFavre, J.-A., & Dixon, P. (1986). Do Written Instructions Need Examples? *Cognition and Instruction*(3), 1-30.

[41] 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.

[42] 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.

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

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

[45] Hernández, R., Fernández, C., & Baptista, P. (2003). *Metodología de la investigación*. México, D.F.: McGraw-Hill.

[46] 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.

[47] Hair, J. F., Tatham, R. L., Anderson, R. E., & Black, W. C. (1999). *Multivariate data analysis*. Spain: Prentice Hall.