STUDENTS, COMPUTERS AND MATHEMATICS THE GOLDEN TRILOGY IN THE TEACHING-LEARNING PROCESS

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ABSTRACT
In this paper we examine the relationships between students' attitudes towards mathematics and technology, therefore, we take a Galbraith and Hines' scale (1998, 2000) about mathematics confidence, computer confidence, computer and mathematics interaction, mathematics motivation, computer motivation, and mathematics engagement. 164 questionnaires were applied to undergraduate students of several profiles: business and management, mecatronic engineering, industrial engineering, strategic system engineering and mechanic engineering all they in a study carried out at the *Universidad Politécnica de Aguascalientes*. The statistical procedure used was factorial analysis with an extracted principal component. The Hypothesis: Ho: ρ=0 has no correlation, while Ha: ρ ≠0 does. Statistics test to prove: X^2, Bartlett test of sphericity, KMO (Kaiser-Meyer_Olkin) Significance level: α=0.05; p<0.05 therefore reject *Ho* if $X^2_{calculated} > X^2_{tabulated.}$ The results obtained from the sphericity test of Bartlett KMO (.859), $X^2_{calculated,}$ 539.612 with 10 df > $X^2_{tabulated}$, Sig. 0.00 < p 0.01, MSA (MATH-CONFI .853; MATH-MOTI .884; MATH-ENGA .846; COMPU-CONFI .868 and INTE-MACO .848) provide evidence to reject *Ho*. Thus, the variables of Galbraith and Hines' scale help us to understand the student's attitude toward mathematics and technology.

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

Mathematics subject Classification: 97U50

1. INTRODUCTION
At present the process of teaching and learning of mathematics has been modified by the information technologies through one of its instruments the computer. This has motivated the interest in knowing if through this tool, it overcomes deficiencies attitudinal and achieves a greater student learning. For this reason this paper focuses on the following questions: *¿what is the students' attitude toward the use of computers in the teaching of mathematics? What is the students' attitude toward mathematics confidence, motivation and engagement?* H*ow is this interaction between computer and mathematics achieved in the teaching process?* In order to answer these questions, the objective of this study was to measure, how mathematics confidence, mathematics motivation, computer confidence, computer motivation, computer-mathematics interaction and mathematics engagement help to understand the students' attitude toward mathematics and technology.

Besides the introduction, this document is composed of five sections: the first shows the theoretical approach that supports the research, the second shows some empirical studies, the third shows the hypotheses proposed in this study, the fourth shows the methodology used for research, the fifth describes the results obtained about the attitude towards learning students using this tool. Finally, we present the conclusions that were reached in this study.

2. THEORETICAL APPROACH TO MATHEMATICS CONFIDENCE, COMPUTER CONFIDENCE, ENGAGEMENT, MOTIVATION AND INTERACTION BETWEEN MATHEMATICS, COMPUTER AND STUDENTS

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

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

Suurtamm and Graves (2007) state that, *"enabling easier communication, providing opportunities to investigate and explore mathematical concepts, and engaging learners with different representational systems which help them see mathematical ideas in different ways"*. They refer to the Ontario Ministry of Education which outlined the use of technology by suggesting: "students can use calculators and computers to extend their capacity to investigate and analyze mathematical concepts and to reduce the time they might need otherwise spent on purely mechanical activities," and added that technology is conceived as a tool to extend students' abilities with tasks which are challenging or impossible in paper-and-pencil environments. These tasks could be to perform complicated arithmetic operations.

The above discussion allows us to identify the variables implied in object of study, as illustrated in the following construct (path model) which describes the variables proposed by Galbraith and Hines (1998) about: maths confidence, maths motivation, maths engagement, computer confidence and the interaction among maths and computer, all this in the trilogy: student, computer and mathematics.

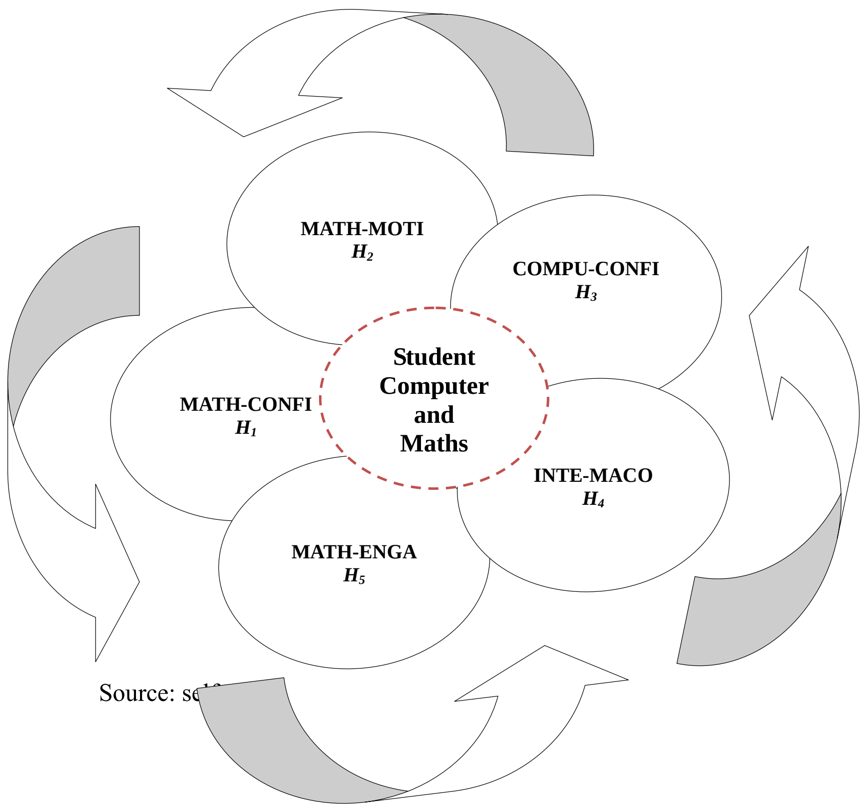

Figure 1 Theoretical Path Model

3. EMPIRICAL STUDIES

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

It is important to point out that the surveys on attitude towards mathematics have been undertaken for many years, but the studies related to attitude towards information technology has a shorter history in topics about mathematics education. The studies carried out within undergraduate programs in mathematics by Galbraith and Haines (2000) are important for this subject matter. In 1998, these authors developed instruments and several attitude scales to measure mathematics and I.T. attitudes. These instruments have been used to assess attitudes in different countries: England (e.g. Galbraith and Haines, 1998 and 2000), Australia (e. g. Cretchley and Galbraith, 2002), Venezuela (e.g. Camacho and Depool, 2002), Mexico (e.g. García-Santillán, Flores, Escalera, Chong and López, 2012; García-Santillán, Escalera and Córdova, 2012; García-Santillán, Escalera, Camarena, and García, 2012). The results offered us evidence about several of the dimensions of attitudes: 1) mathematics confidence, 2) mathematics motivation, 3) computer confidence, 4) computer and mathematics interaction and 5) mathematics engagement. In all these studies, the authors' findings have been similar: there is a weak relationship between mathematics and computer attitudes (both confidence and motivation) (Di and Zan, 2001) and that students' attitudes to using technology in the learning of mathematics correlate far more strongly with their computer attitudes than with their mathematics attitudes (Cretchley and Galbraith, 2002).

A study conducted by Fogarty, Cretchley, Harman, Ellerton, and Konki (2001), reports on the validation of a questionnaire designed to measure general mathematics confidence, general confidence with using technology, and attitudes towards the use of technology for mathematics learning. A questionnaire was administered to 164 students commencing a tertiary level course on linear algebra and calculus. Scales formed on the basis of factor analysis demonstrated high internal consistency reliability and divergent validity. A repeat analysis confirmed the earlier psychometric findings as well as establishing good test-retest reliability. The resulting instrument can be used to measure attitudinal factors that mediate the effective use of technology in mathematics learning.

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

The results offered evidence about several dimensions of attitudes: mathematics confidence, mathematics motivation, mathematics engagement, computer confidence, computer motivation and mathematics-computer interaction. The authors of these studies come to a similar conclusion, that 'there is a weak relationship between mathematics and computer attitudes (both confidence and motivation) and that students' attitudes to using technology in the learning of mathematics correlate far more strongly with their computer attitudes than with their mathematics attitudes' (Cretchley and Galbraith, 2002).

On the other hand, studies by Goldenberg (2003), Moursund (2003), García and Edel (2008), García-Santillán, Escalera and Edel (2011), García-Santillán and Escalera (2011) report that at present the teaching-learning processes are favourably influenced in the evolution and growth of ICT, which contributes significantly to the educational process of mathematics in general. Regarding the use of technology to support the teaching process, Crespo (1997), cited in Poveda and Gamboa (2007), claimed that even though "buying and selling" the idea that technology is the magic formula that will transform classrooms into an authentic, perfect teaching and learning setting, in reality this is not true. However, Gomez Meza (2007), cited by Poveda and Gamboa, (2007), indicates that although technology is not the magic formula, nor probably the solution to all educational problems, it is true that technology could be an agent of change that favours the mathematics teaching-learning process. With these arguments, the hypothesis to be proved is:

3.1. Hypothesis

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

Null Hypothesis H_O: There are no factors that contribute to understand the students' attitude towards mathematics and technology.

Alternative Hypothesis H_1: There are factors that contribute to understand the students' attitude towards mathematics and technology.

A particular way, the hypotheses are:

H1: Mathematics confidence is the factor that most explain the variance of model
H2: mathematics motivation is the factor that most explain the variance of model
H3: computer confidence is the factor that most explain the variance of model
H4: computer and mathematics interaction is the factor that most explain the variance of model
H5: mathematics engagement is the factor that most explain the variance of model

So, statistics hypothesis is: Ho: $\rho = 0$ does not have correlation Ha: $\rho \neq 0$ has correlation. Statistical test to probe: $\chi 2$, sphericity test of Bartlett, KMO (Kaiser-Meyer-Olkin), MSA (measure sample adequacy) and significance level: α =0.05; $p< 0.01$, *p<0.05 load factorial of .70 Critical* values: $\chi^2_{\text{calculated}} > \chi^2_{\text{tables}}$, then reject Ho. Decision rule: Reject: Ho if χ^2 calculated > χ^2 tables

4. METHODOLOGY

The Population was delimited to students majoring in: business and management, mecatronic engineering, industrial engineering, strategic system engineering and mechanic engineering who have studied the subject of financial mathematics at the *Universidad Politécnica de Aguascalientes* (UPA).

Table 1 Composition of the population studied (UPA)

Majoring	Frequency	Percentage
Business and Management	44	27
Mecatronic engineering	30	18
Industrial engineering	30	18
Strategic system engineering	30	18
Mechanic engineering	30	18
Total	164	100%

Source: Self-made

The type of sampling it is conventional. The sample obtained was of 164 students. We used the questionnaire of Galbraith and Haines (1998) which consists of 5 sections: confidence toward mathematics, mathematics motivation, engagement mathematics, the computer confidence, computer and mathematics interaction. Each section consists of 8 item measured on a Lickert scale, the range on this scale ranged from 1 (low) to 5 (very high). Therefore, in order to determine the reliability of instrument was used Cronbach alpha method. The result obtained was 0.904 (grouped variables) and 0.902 (separated variables). We can see that the reliability of instrument is more than 0.6, so we can say that the instrument applied provides the features of reliability and consistency (Hair, 1999).

5. RESULTS

The empirical research was supported by the statistical technique of factorial analysis for testing the factors that contribute to the students' attitudes towards mathematics and technology. Table 2 shows the correlation among variables, are all meaningful (>.5 sig. <0.01).

Table 2 Correlations Matrix

	Variables	COMPU-CONFI	MATH-MOTI	MATH-ENGA	INTE-MACO	MATH-CONFI
Correlation	COMPU-CONFI	1.000				
	MATH-MOTI	.624	1.000			
	MATH-ENGA	.734	.627	1.000		
	INTE-MACO	.749	.623	.785	1.000	
	MATH-CONFI	.676	.668	.569	.594	1.000
Sig. (Unilateral)	COMPU-CONFI					
	MATH-MOTI	.000				
	MATH-ENGA	.000	.000			
	INTE-MACO	.000	.000	.000		
	MATH-CONFI	.000	.000	.000	.000	
Bartlett’s test of Sphericity 539.612 (α=0.00) df 10 Measure of sampling adequacy (overall) (KMO) 0.859						
a. Determinant = .035						

Source: self-made.

The contrast values of Bartlett’s test allow us to say that the correlation matrix is significance (α=0.00) when taken all variables (table 2). The measure of overall sampling adequacy (overall) (KMO) is 0.859 which’s acceptable (>0.50). The examination of the values of each variable identifies that all variables have values greater than 0.5, table 3 shows the measures sample adequacy for each variable (MSA)

Table 3 Measure of sampling adequacy (MSA)

Variable	COMPU-CONFI	MATH-MOTI	MATH-ENGA	INTE-MACO	MATH-CONFI
COMPU-CONFI	**.868**[a]				
MATH-MOTI	-.063	**.884**[a]			
MATH-ENGA	-.283	-.191	**.846**[a]		
INTE-MACO	-.314	-.127	-.474	**.848**[a]	
MATH-CONFI	-.336	-.395	.020	-.062	**.853**[a]

Source: self- made

Table 4 denominated component matrix and communalities, shows just one factor that incorporates five variables and their explanatory power expressed by its eigenvalues (3.664). The values in the first column reflect the factor loadings of each variable and the second column reveals how each variable is explained by the components. Thus, we can see that the greatest weight variable is COMPU-CONFI (computer confidence) followed by the INTE-MACO (interaction between the computer and mathematics), and MATH-ENGA (mathematics engagement) and with the lowest weight is the MATH-CONFI (mathematics confidence) followed by the MATH-MOTI (mathematics motivation).

Table 4 Component Matrix and Communalities

	Component 1	Communalities
COMPU-CONFI	**.887**	.799
MATH-MOTI	.823	.794
MATH-ENGA	**.872**	.868
INTE-MACO	**.881**	.867
MATH-CONFI	.814	.867
Eigenvalues	3.664	
% Total variance	73.279	

Source: self-made

6. CONCLUSION

The aim of this work was to examining how mathematics confidence, mathematics motivation, computer confidence, computer motivation, computer-mathematics interaction and mathematics engagement help to understand the students' attitude toward mathematics and technology. The results provide empirical evidence to assert that there is a relationship between the factors proposed by Galbraith and Hines (1998) explaining the attitude towards mathematics and technology in college students. Furthermore, these results are according to the exposed by Galbraith and Hines (2000), Cretchley and Galbraith, (2002).

The results give empirical evidence resulting from application of the scale of Galbraith and Hines to show that the student shows a greater trend toward confidence indicator toward computers, followed by the interaction toward mathematics and computer and finally the engagement toward mathematics. Thus, a specific way H3 is accepted and the rest H1, H2, H4 and H5 are rejected. However, in general way Ho is rejected because; there are factors that contribute to understand the students' attitude towards mathematics and technology, if we consider the scale proposed by Galbraith and Hines

These outcomes are somewhat different with those obtained by García-Santillán, Escalera, Boggero and Vela (2012) in a study performed at private university in undergraduate students, whose tendency being towards indicator motivation toward mathematics, the mathematics confidence and finally mathematics and computer interaction.

In another study performed at a public university (UASLP) Garcia-Santillán, Flores, Escalera, Chong and Lopez (2012) showed that the motivating factor toward mathematics and confidence toward computers, are the main factors contributing to explanation of the phenomenon of study.

In this sense, Garcia-Santillán, Escalera and Edel (2011), Garcia-Santillán and Escalera (2011) in another studies, they have shown that the processes of teaching-learning are favored by the presence of ICT, contributing significantly to the education of mathematics, whatever the classification of mathematics.

Finally, the results show overall a positive attitude towards mathematics and technology by the student. In addition the professors that impart this matter must do not only have the knowledge, but also abilities which make it possible the implementation of didactic actions, so that the teaching-learning process can be better, in order to strengthen the student's attitude. Furthermore, with this research we seek to demonstrate the implications of: confidence, motivation, engagement and the interaction with technology in the learning process. As Galbraith-Haines (1998, 2000), we conclude that the latent variables: Math confidence, Mathematics Motivation, Mathematics Engagement, Computer confidence, Computer-Mathematics Interaction, help us to understand the students attitude towards mathematics and technology.

REFERENCES

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

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

Education, 9 (4), 259-283.
Cretchley, P. & Galbraith, P. (2002). Mathematics or computers? Confidence or motivation? How do these relate to achievement? *Proceedings 2nd International Conference on the Teaching of Mathematics (Undergrad),* , CD and online, Wiley, Crete.
Di, M. & Zan, R. (2001). Attitude toward mathematics: Some Theoetical issues. *Proceedings of PME 25 (Utrecht, Netherlands), vol. 3*, 351-358.
Fennema, E. & Sherman, J. A. (1976). Fennema-Sherman Mathematics Attitudes Scales: Instruments designed to measure attitudes toward the learning of mathematics by males and females. *Journal for Research in Mathematics Education*, 7, (5), 324-326
Fogarty, G., Cretchley, P., Harman, C., Ellerton, N. & Konki, N. (2001).Validation of a Questionnaire to Measure Mathematics Confidence, Computer Confidence, and Attitudes towards the Use of Technology for Learning Mathematics *Mathematics Education Research Journal*, 13, (2), 154-160.
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 Attitudes Scales. Monographsin Continuing Education. London: City University.
Galbraith, P. & Haines, C. (2000). Mathematics-computing Attitude Scales. *Monographs in Continuing Education. London: City University.*
Galbraith, P. & Haines, C. (1998). Disentangling the nexus: Attitudes to mathematics and technology in a computer learning environment, *Educational Studies in Mathematics* , 36, 275-290.
Galbraith, P., Haines, C. & Pemberton, M. (1999). A tale of two cities: When mathematics, computers, and students meet. In J. M. Truran & K. M. Truran (Eds.),*Making a difference* (Proceedings of the 22nd annual conference of the Mathematics Education Research Group of Australasia, Adelaide, pp. 215–222). Sydney: MERGA.
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. Annual Meeting Nova Southeastern University "Beyond the Classroom" Fischler School of Education & Human Service. NOVA EDUC@2008. March 17-19, 2008. Miami Beach, Florida USA.
García-Santillán, A. & 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.
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.
García-Santillán, A.; Flores-Zambada, R.; Escalera, M.; Chong, I. and López, S (2012): Students, computers and mathematics. How do they interact in the teaching-learning process? Empirical study on accounting, management and marketing undergraduate students. *International Journal of Learning and Development Vol. 2, Issue 2 pp.177-200*
García-Santillán, A.; Escalera, M.; and Córdova, A.; (2012). Variables to measure interaction among mathematics and computer through structural equation modeling. *Journal of Applied Mathematics and Bioinformatics Vol 2, No. 3 pp 51-6*
García-Santillán, A.; Escalera, M.; Camarena, P. & García, A. (2012). Structural equations modeling to measure variables involved in the interaction between mathematics and computer: an empirical study in undergraduate students. *International Journal of Humanities and Social Science Vol 2, No. 24 special issue December 2012 pp 6-13*
Gómez, D. (1998). Tecnología y educación matemática. Revista Informática Educativa, 10 (1). Colombia.
Gómez-Chacón, M. I., & Haines, C. (2008). Studentes' attitudes to mathematics and technology. Comparative study between the United Kingdom and Spain . *International Congress on Mathematical Education* ,1-12.
Hair**,** J. F. Jr.; Anderson, R. E.; Taltham, R. L. Y Black, W. C. (1999). ***Análisis multivariante.*** 5a. Edición. Madrid: Prentice Hall.
Hannula, M., Evans, J., Philippou, G., & Zan, R. (2004). Affect in mathematics education-exploring theoretical framework. Procceding of PME 28 (Bergen, NW) 1, 107.136.
Izydorczak, A. E. (2003). *A Study of Virtual Manipulatives for Elementary Mathematics*. Unpublished doctoral dissertation, State University of New York, Buffalo, New York.
Kaput, J. J. (1994). Technology in Mathematics Education Research: The first 25 years in the JRME. *Journal of Research into Mathematics Education,*25,(6), 676-684.
Kaput, J. J. & Thompson, P. W. (1992). Technology and Mathematics Education. En D. A. Grouws, *Handbook of*

Research on Mathematics Teaching and Learning (págs. 515-556). New York: Macmillan.
Karadag, Z. & McDougall, D. (2008). Studying mathematical thinking in an online environment: Students□ voice. In Figueras, O. & Sepúlveda, A. (Eds.), *Proceedings of the Joint Meeting of the 32nd Conference of the International Group for the Psychology of Mathematics Education, and the XXX North American Chapter 1*, 350. Morelia, Michoacán, México: PME.
Kieran, C. & 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.
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.
Kulm, G. (1980). Research on Mathematics Attitude, in R.J. Shumway (ed.). *Research in mathematics education. Reston, VA: National Council of Teachers of Mathematics* .
Lagrange, J. (1999). Complex calculators in the classroom: Theoretical and practical reflections on teaching pre-calculus. *International Journal of Computers for Mathematical Learning, 4*, 51–81.
Leder,G. (1985). Measurement of attitude to mathematics. *For the learning of Mathematics,* 5(3), 18-21.
Moreno-Armella, L. & Santos-Trigo, M. (2004). Students□ exploration of powerful mathematical ideas through the use of algebraic calculators. In D. E. McDougall & J. A. Ross (Eds.), *Proceedings of the twenty-sixth annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*, *1*, 135-142. Toronto: OISE/UT.
Moreno-Armella, L., Hegedus, S. J. & Kaput, J. J. (2008). From static to dynamic mathematics: Historical and representational perspectives. *Educational Studies in Mathematics*, 68, 99-111.
Moursund, David (s/f). Editorial: The Spreadsheet. *Revista Learning £Leading with Technology*, 26 (5) disponible en http://www.iste.org/LL/
Moyer, P.S., Niexgoda, D., & Stanley, J. (2005). Young Children□s Use of Virtual Manipulatives and Other Forms of Mathematical Representations. In W. J. Masalski & P. C. Elliot (Eds.), *Technology-Supported Mathematics Learning Environment*. Reston, VA: The National Council of Teachers of Mathematics.
Noss, R. (2002). For a learnable mathermatics 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. y Gamboa R. (2007). Consideraciones, características, limitaciones y clasificación de una clase basada en talleres. UNA Costa Rica. Recuperado de: http://cimm.ucr.ac.cr/cuadernos/cuaderno3.php.
Ruffell,M., Mason, J, & Allen, B.(1998). 'Studying attitude to mathematics', *Educational Studies in Mathematics*, 35(1), 1–18.
Suurtamm, C. & Graves, B. (2007). *Curriculum implementation in intermediate math (CIIM): Research report*. Canada: Faculty of Education, University of Ottowa. Retrieved April 15, 2008, from http://www.edu.gov.on.ca/eng/studentsuccess/lms/.
Tofaridou, I.(2007). Learning Styles and Technology Environments in mathematics. Education, Ph.D. Thesis, City University, London, 286

Appendix

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

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

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