STUDENTS' ATTITUDES TO MATHEMATICS AND TECHNOLOGY. COMPARATIVE STUDY BETWEEN THE UNITED KINGDOM AND SPAIN

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Abstract:

The use of computers in the teaching and learning of undergraduate level mathematics raises many as yet unanswered questions about the relationships between students' perceived abilities and attitudes towards mathematics and computers. This paper examines these relationships between attitudes to mathematics and technology. I will present preliminary results of two studies carried out in the United Kingdom (UK) and Spain by undergraduate students. The outcomes provide suggestions for teaching and learning mathematics in Higher Education.

Higher Education teachers and researchers in mathematics education seek ways to give life to the learning of mathematics by using scientific software. Nowadays, a common argument is that within undergraduate programmes new technology provides a good way to improve attitudes towards mathematics. There have been enthusiastic claims regarding the positive impact of technology on the teaching and learning of mathematics. Different studies describe this positive impact on students' performance (Artigue, 2002; Noss, 2002). In particular, some researchers underline the new cognitive and affective demands on students in technology programmes (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 (graphics calculators, computer-based resources).

In general terms, we could say that research into learning sequences using computers does not usually distinguish those elements related to the emotional command from those exclusively related to the acquisition of knowledge through software. We hold the view that in order to generate comprehension and mathematical meaning an emotional component is required, which needs to be studied so we can determine the ways or experiences through which technologies can be used to achieve better mathematical learning. So, with this purpose of gaining better understanding of the affective, cognitive and behavioural factors of undergraduate students within programmes rich with technology we developed a large project at the Complutense University (Spain) since 2006. This project focuses on several objectives:

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- To develop and validate a theoretically sound measure of students' attitudes towards computers- specifically operationalized within the context of undergraduate students.
- To devise a set of targeted "attitude" measures that would better enable the impact of computer based teaching programs to be addressed in terms of students' characteristics.
- To compare the results with other countries. To investigate the interaction between computers and mathematics in classrooms in different cultural contexts where learning takes place with scientific software.

For this study the method of research was multi-methods. An empirical-analytical research design was proposed using Liker attitudes scales and complemented with the quality method (observations in the classroom, audio-video-recordings, productions of pupil's mathematics work, etc).

For this paper we selected one part of this research. More specifically, the part of the study which aimed to provide answers to the following questions: Which interaction occurs between attitudes towards mathematics and attitudes to technology in undergraduate students? For the study of this interaction, are the instruments used in previous studies (for instance, Galbraith and Haines (1998)) still valid? What differences exist between our results and the results in the UK in which the same instrument of measurement of attitudes was used?

In summary, the purpose of this paper is to study the relation between attitudes to mathematics and technology of undergraduate students and to verify if attitudes towards mathematics and technology are two different dimensions. I will present preliminary results of the two studies carried out in the United Kingdom (UK) and Spain.

The paper begins by reviewing some of the issues currently relating to attitudes towards technology. Secondly, it compares two studies carried out in the UK and in Spain. Finally, I will conclude by showing how the case studies may provide advice for the design of measuring instruments to evaluate attitudes.

2. RESEARCH RELATING TO ATTITUDES AND THE USE OF NEW TECHNOLOGY IN MATHEMATICAL LEARNING

Studies of attitudes towards mathematics have developed significantly in recent decades: from the first studies focusing on possible relationships between positive attitude and achievement (Leder, 1985), to studies highlighting several problems linked to measuring attitude (Kulm, 1980), a meta-analysis, up to recent studies which question the very nature of attitude (Ruffell et al., 1998), or search for 'good' definitions (Di Martino & Zan, 2001, 2002), or explore observation instruments very different from those traditionally used, such as questionnaires (Hannula, 2002).

Although the study of attitudes towards mathematics has been developed over a long time, the study of attitudes towards information technology has a shorter history in mathematics education. In this area, the studies carried out within undergraduate programmes in mathematics by Galbraith and Haines (2000) are relevant. These authors, in 1998, built 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), etc. The results offered us evidence about several of the dimensions of attitudes: mathematics confidence, mathematics motivation, mathematics engagement, computer confidence, computer motivation and interaction between mathematics and computers. 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, p. 8).

We consider that the awareness of students' attitudes towards computers is a central criterion in the evaluation of computer courses and in the development of computer based curricula. It is important to monitor students' reactions and decide how best to use forms of technology, mathematics analysis tools and real world interfaces. The belief systems of our students as learners of mathematics are assumed reasonably stable because they have completed a preparatory program of secondary mathematics. Their experience with computer technology is more variable but here it is assumed that their affective responses are essentially cognitively based and determined on the basis of assimilated experience. Hence the use of questionnaires is an appropriate means of gathering data.

The questionnaires which we use in this research were formulated from the perspective, the *multidimensional definition of attitude* and they took into account the main dimension with respect to influences on mathematics learning, *mathematics confidence and mathematics motivation.*

Below we explain our attitude concept, a *multidimensional definition of attitude*. We agree with Di Martino and Zan (2001, 2003) when they clarify the variety of (explicit or implicit) definitions of attitude present in research. They identify two important typologies in this variety:

a) A 'simple' definition of attitude, which describes it as the positive or negative degree of affect associated with a certain subject. According to this point of view attitude toward mathematics is just a positive or negative emotional disposition toward mathematics (McLeod, 1992; Fischbein and Ajzen, 1974). Accepting this definition, it is quite clear that 'positive attitude' means 'positive' emotional disposition, and 'negative attitude' means 'negative' emotional disposition.

b) A ‘multidimensional’ definition, which recognizes three components in attitude: an emotional response, beliefs regarding the subject, behaviour towards the subject (Breckler 1984, Hart, 1989; Gómez-Chacón, 1997; Di Martino & Zan, 2001, 2003) From this point of view an individual’s attitude towards mathematics is defined in a more articulated way by the emotions that he/she associates with mathematics (which, however, have a positive or negative value), by the beliefs that the individual has regarding mathematics, and by how he/she behaves (Hart, 1989). If we choose this point of view, a negative attitude is not only an attitude characterized by a negative emotional disposition (“I don’t like mathematics”), but also an attitude characterized by an epistemologically incorrect view of the discipline, (i.e. a vision of the discipline that is not shared among experts). We adopt a multi-faceted definition, where attitude “represents an emotional reaction to an object, to beliefs about the object, or to behaviour towards the object”. So in this study I can define as ‘negative’ the attitude of a student who likes mathematics, if this positive emotion is associated with a vision of mathematics as a set of rules to be memorized.

From this approach we identify distinct constructs on which to base assessment of computer attitudes: affects (feelings towards computers); cognition (perceptions and information regarding computers); conation or behavioural (behavioural intentions and actions with respect to computers, and perceived behavioural (perceived ease, or difficulty, of using computers) and perceived usefulness (the degree to which an individual believes using computers will enhance their job performance).

3. . CONTEXT AND METHODOLOGY

The data has been taken from an English study conducted in 1997, which was published in Galbraith and Haines (1998 and 2000) and the Spanish study carried out in 2006. In both studies the method of research of attitudes was the same, the Liker-style scales attitudes elaborated by Galbraith and Haines in 1998 (Appendix). These scales were administered to first year students in mathematical sciences on a variety of degree courses, 140 students at City University (London) and 120 students at the Complutense University (Madrid). Both groups of students had taken part in a special course combining ordinary classroom sessions and laboratory practice sessions using the DERIVE Computer Algebra System (CAS), MathLab or other graph plotting packages. Concepts and procedures are introduced through practical contexts within which the students learn, and from which they can anchor and generalize their learning. Hence the programme involves not only linkages between application contexts and mathematical manipulations, but between computer and pen and paper representations of knowledge. With such integrated computer usage it is highly relevant to examine the extent to which reported reactions are associated with attitudes towards mathematics as distinct from the technological means introduced into the programme.

Defining the composition of attitudes is not simple. In the literature referenced in this paper there is general agreement that confidence, motivation and engagement are important but certainly not precise agreement as to their measurable features. So, we describe the meaning of the dimensions measured with the scales: *mathematics confidence* (Mathsconf), *mathematics motivation* (Mathsmot), *mathematics engagement* (Mathseng), *computer confidence* (Comconf) and *student interaction between mathematics and computers* (Inter-comp-math). Each one of these scales includes 8 items.

Galbraith and Haines (1998) see *mathematics confidence* as dimension evidenced by students "who believe they obtain value for effort, do not worry about learning hard topics, expect to get good results, and feel good about mathematics as a subject" (p. 278). Also they see *computer confidence* as evidenced by students who "feel self-assured in operating computers, believe they can master computer procedures required of them, are more sure of their answers when supported by a computer, and in cases of mistakes in computer work are confident of resolving the problem themselves" (p. 278).

For theses authors *computer motivation* is shown when "students demonstrating high computer motivation find computers make learning more enjoyable, like the freedom to experiment provided by computers, will spend long hours at a computer to complete a task, and enjoy testing out new ideas on a computer" (p. 279).

This scale includes the concept of "mathematics engagement", which is related to behavioural engagement. The ''students who score highly on this scale [mathematical engagement] prefer to work through examples rather than learn given material, like to test understanding through exercises and problems, try to link new knowledge to existing knowledge, like to elaborate material with notes, and review their work regularly'' (p. 280).

To study the attitude towards use of technology for learning mathematics Galbraith and Haines (1998) define a construct which they call "*computer and mathematics interaction*". They claim that in their context "students indicating high computer and mathematics interaction believe that computers enhance mathematical learning by the provision of many examples, find note-making helpful to augment screen based information, undertake a review soon after each computer session, and find computers helpful in linking algebraic and geometric ideas" (p. 279).

For the study of the data similar analyses were conducted for both study groups. The scale results were analysed with the SPSS statistical analysis suite (version 11.0) by means of the technique of exploratory factorial analysis (using oblimin rotation, following a principal components analysis). The reliability of the questionnaire was calculated by the Cronbach alpha value. For the Spanish study we considered a single instrument composed of those five scales. A factorial analysis was carried out to confirm if the items of this population really were grouped in factors which coincided with the scales which had been previously defined.

4. RESULTS

In this paper the points of comparison are:

A. Dimensions measured by scales

B. Interaction between dimensions: confidence and motivation

4.1. Dimensions measured by scales

Mathematics confidence. The data revealed that both English and Spanish students have an acceptable confidence in mathematics (above average scores). All students agree that effort is essential to obtain good results; although they also show that there are worries about mathematics and that it makes them nervous. The students emphasise that this subject is an area of concern for them. As in the UK, in Spain the analyses of data point to a group of students who are not confident with their personal competence in mathematics. It is interesting to stress that in spite of the fact that students are aware of different learning difficulties in their experience with Mathematics, the attitude highlighted is homogeneous and positive.

Mathematics Motivation. In this dimension, the data highlight different results in the UK and Spain. In the UK, students with a high motivation towards mathematics are interested in solving problems and students with low motivation towards mathematics are averse to problem solving. In this group the high scoring indicates that the students give a high value to mathematics motivation. In the Spanish data the level of mathematics motivation is slightly lower than in the English data. In these students, their motivation is lower than their level of confidence and their commitment to mathematics. Regarding some low items of scale (lower than average) we notice that they find mathematics unpleasant and so they do not spend a lot of time on mathematical problems.

Mathematics engagement. British and Spanish students have an average middle commitment towards mathematics (quite acceptable). But the Spanish data indicate that they do not like taking and revising notes, or to create new material integrating the teacher's explanation. In contrast, the UK students like taking notes and checking these notes with other materials.

Computer confidence. Both groups have a high computer confidence. In the case of Spain, the students related that they did not use the computer in doing mathematics very much. Computer use time is low.

Student interaction between mathematics and computers. Both groups have a high score in this area. They indicated that the computer helps them to establish links between knowledge of Mathematics, i.e. between geometric and algebraic concepts. However, Spanish students' scores are low in aspects which have a relationship with the manner of working with the computer, as are the English students' scores. They do not take notes of data from the computer screen and they do not review their activities carried out on the computer.

4.2. Interaction between dimensions: confidence and motivation

Table 1 shows the results relative to the correlation between scales. The London data is indicated in the first place and the Madrid data is in parenthesis in the table.

- Mathematics confidence (Mathsconf),
- Mathematics motivation (Mathsmot),
- Mathematics engagement (Mathseng),
- Computer confidence (Comconf) and
- Student interaction between mathematics and computer (Int-com-math)

Table 1: Inter-scale correlation

	Mathsconf	Mathsmot	Mathseng	Comconf	Int-com-math
Mathsconf	-	0.47 (.52)	0.08 (.27)	0.29 (.015)	0.13 (.20)
Mathsmot		-	0.46 (.53)	0.25 (.12)	0.35 (.32)
Mathseng			-	0.06(.18)	0.26 (.35)
Comconf				-	0.61 (.42)
Int-com-math					-

This data indicates that for both groups the confidence and motivation scales are strongly associated within mathematics, and also with confidence with computers for the English students. In the case of the English data this is considerably lower than in the Spanish data. For these students we can observe a weak correlation between Mathematics confidence and computer confidence (.015). In both groups of students, their engagement is strongly associated with motivation, the Spanish students scoring higher.

The interaction between computers and mathematics is associated with computer confidence and their engagement with mathematics in the case of the Spanish students, whereas we appreciate that the English students' score is slightly higher than the Spanish students' in the interaction between computers and mathematics associated with the computer and, in contrast, it is less associated with the mathematics scales. One interpretation of these results is that the level of commitment to computers for mathematical learning is more determined by computer attitudes than mathematical attitudes.

Table 2: Loadings of factor analysis using oblimin rotation (SPSS) in the UK and Spain

Scales	Components	
	1	2
Mathsconf	.71 (.55)	-.07 (-.13)
Mathsmot	.84 (.85)	.01 (.11)
Mathseng	.61 (.70)	.07 (.24)
Comconf	-.04 (-.150)	.88 (.89)
Int-com-math	.11 (.195)	.80 (.81)
Percentage of variance 63.8 % (66.2%)		

Table 2 displays the results of the Factor Analysis using the five scales and how the loadings are distributed. We can see that these results confirm for both groups that the computer and mathematics related scales define different dimensions.

5. CONCLUSION

The main goal of our research has been to study the relation between attitudes to mathematics and attitudes to computing, contrasting the data obtained in two different countries. The comparison made between two contexts confirms previous results, which concluded that there was a low relationship between mathematics and computer attitudes. Galbraith (2006). Above all, the data emphasised that in the learning of mathematics using computers there was a stronger correlation with computer attitudes than with their mathematics attitudes; particularly, if we measure the confidence and motivation towards mathematics and computers.

One of the research questions was whether this instrument, which was elaborated a decade ago, was still relevant as an instrument for the measurement of attitudes and for the Spanish context. The data indicate that if we consider three main components in attitudes (cognitive, emotional and behavioural) this instrument measures more the emotional response in the process of mathematical learning with computers on a cognition basis (beliefs).Therefore, regarding mathematical learning and computing, besides the two key dimensions in attitude mentioned before – motivation and confidence – it is important to include the beliefs about the importance of learning mathematics (in particular, the resolution of problems) and the acceptability of the specific software in use.

For example, in the Spanish analysis the global results of scale through clusters show different student profiles. These profiles showed indicators about students' manner of working with computers and that the relation between technical and emotional questions should be studied more thoroughly in order to know the interaction between attitudes to mathematics and attitudes to computing. It is necessary to complement the scales dimension with two categories in the use of computers for an emotional motivation of the student:

- The subjective *value* of this task including engagement and encouragement which entails attitudes like curiosity and interest; the credibility which adds elements of value and importance; and the value of usefulness – realizing the value of the task before providing the means to do it.

- The *expectation* of success in its technical development and in satisfaction and effectiveness works as a conductive structure of the action. This expectation of success is linked to the different behaviours using computers.

These results support and complement the work by Galbraith and Haines (2000) and invite the elaboration of new instruments taking into account profiles and focusing on the software of symbolic calculus and dynamic geometry (e.g. Derive, Maple, Geogebra, Cabri) and including other factors which contribute to an individual's personal response to computing such as subjective value and expectation of success in technical development.

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Appendix

Attitude Scales used for studies, from Galbraith, P. and Haines, C. (2000: 38-40).

Mathematics Confidence

1. Mathematics is a subject in which I get value for effort
2. The prospect of having to learn new mathematics makes me nervous
3. I can get good results in mathematics
4. I am more worried about mathematics than any other subject
5. Having to learn difficult topics in mathematics does not worry me
6. No matter how much I study, mathematics is always difficult for me
7. I am not naturally good at mathematics
8. I have a lot of confidence when it comes to mathematics.

Mathematics Motivation

1. Mathematics is a subject I enjoy doing
2. Having to spend a lot time on a mathematics problem frustrates me
3. I don’t understand how some people can get so enthusiastic about doing mathematics
4. I can become completely absorbed doing mathematics problems
5. If something about mathematics puzzles me, I would rather be given the answer than have to work it out myself
6. I like to stick at a mathematics problem until I get it out
7. The challenge of understanding mathematics does not appeal to me
8. If something about mathematics puzzles me, I find myself thinking about it afterwards.

Mathematics Engagement

1. I prefer to work with symbols (algebra) than with pictures (diagrams and graphs)
2. I prefer to work on my own than in a group
3. I find working through examples less effective than memorising given material
4. I find it helpful to test understanding by attempting exercises and Problems
5. When studying mathematics I try to link new ideas or knowledge I already have
6. When learning new mathematical material I make notes to help me understand and remember
7. I like to revise topics all at once rather than space out my study
8. I do not usually make time to check my own working to find and correct errors

Computer confidence

1. As a male/female (cross out which does not apply) I feel disadvantage in having to use computers
2. I have a lot of self-confidence in using computers
3. I feel more confident of my answers with a computer to help me
4. If a computer program I am using goes wrong, I panic
5. I feel nervous when I have to learn new procedures on a computer
6. I am confident that I can master any computer procedure that is needed for my course
7. I do not trust myself to get the right answer using a computer
8. If I make a mistake when using a computer I am usually able to work out what to do for myself

Computer-Mathematics Interaction

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