Secondary students' attitudes to learning mathematics with technology: Exploring the interrelationship between gender, engagement, confidence and achievement

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Abstract

The aim of this study was to investigate the complex relationship between the students' mathematics confidence, confidence with technology, attitude to learning mathematics with technology, affective engagement and behavioural engagement, achievement, gender and year level. The participants were 1068 Year 9 and Year 10 students form 27 state co-educational schools in Athens, Greece. A factor analytic data reduction method was used, followed by a Cluster Analysis. Gender differences as well as differences between Year levels and the seven resulting clusters were investigated by using a MANOVA. It was found that boys expressed more positive views towards mathematics and more positive views towards the use of technology in mathematics, compared to girls. It was also found that high achievement in mathematics was associated with high levels of mathematics confidence, strongly positive levels of affective engagement and behavioural engagement, high confidence in using technology and a strongly positive attitude to learning mathematics with technology. Low levels of mathematics achievement was associated with low levels of mathematics confidence, strongly negative levels of affective engagement and behavioural engagement, low confidence in using technology, and a negative attitude to learning mathematics with technology.

The aim of the study was to investigate the interrelationship between the students' mathematics confidence, confidence with computers, attitude to learning mathematics with computers, affective engagement and behavioural engagement, achievement, gender and year level. The *Mathematics and Technology Attitudes Scale* (MTAS) was used to examine the role of the affective domain in learning mathematics with technology, and it reports some results from the use of MTAS in Year 9 and 10 classrooms in Athens, Greece. According to the scale developers (Pierce, Stacey & Barkatsas, 2007) MTAS can be used in schools which aim to track changes in the attitudes and engagement of students in their learning of mathematics, in response to the altered learning environment and to consider how best this use of technology can be implemented. Pierce, Stacey & Barkatsas (2007) claimed that:

> For learning and doing mathematics, technology in the form of 'mathematics analysis tools' (such as certain computer software, calculators, graphics calculators, computer algebra systems, spreadsheets, statistics programs) can assist students' problem solving, support exploration of mathematical concepts, provide dynamically linked representations of ideas and can encourage general metacognitive abilities such as planning and checking…With substantial investment in providing information technology to assist in teaching and learning mathematics, it is important to monitor students' reactions and decide how best to use both forms of technology, the mathematics analysis tools and the real world interfaces (p. 286).

Reports of a number of teaching innovations of the last thirty years include data on students' attitudes to the innovation as well as their mathematical achievement. McLeod (1992) put forward a strong position that affective issues play a central role in mathematics learning. McLeod's (1992) definition of beliefs has been considered adequate for this study, since it makes clear the distinction between the cognitive and affective dimensions of beliefs:

> Beliefs are largely cognitive in nature, and are developed over a relatively long period of time. Emotions, on the other hand, may involve little cognitive appraisal and may appear and disappear rather quickly, as when the frustration of trying to solve a hard problem is followed by the joy of finding a solution. Therefore we can think of beliefs, attitudes and emotions as representing increasing levels of affective involvement, decreasing levels of cognitive involvement, increasing levels intensity of response, and decreasing levels of response stability. (p. 579)

Student engagement with the intellectual work of learning is, according to Marks (2000), an important goal for education, leads to achievement and "contributes to students' social and cognitive development" (p.154). In this paper it is argued that engagement, mathematics confidence, confidence with technology and achievement are interrelated, as far as high achievers in secondary school mathematics are concerned. Marks (2000) claimed that

> Although research examining effect of engagement on achievement is comparatively sparse, existing studies consistently demonstrate a strong positive relationship between engagement and performance across diverse populations (p. 155)

This claim is supported by the results of the cluster analysis results in this study.

There are a number of theories of student engagement. A theory of student academic engagement has been articulated by Newmann (1989). The researcher proposed three dimensions of student engagement: (1) students' need to develop and express competence, (2) students' full participation in school activities, and (3) students being immersed in authentic academic work. It is believed that most students commence their school life being inherently motivated but for many of them this motivation diminishes or entirely disappears, because the students are involved in routine and boring activities ad they try to get by with as little effort as possible.

Fredricks, Blumfield & Paris (2004) assumed that school engagement as a concept that is malleable, responsive to contextual features and amenable to environmental change. They claimed that research literature considers engagement as a multidimensional concept or even as a "meta" construct. They proposed the following three dimensions: *Behavioural engagement*, which draws on student participation, *emotional engagement*, encompassing both positive and negative reactions to staff and the school in general, and (3) *cognitive engagement*, which draws on the principle of students making an investment in learning (p. 60).

Only two of the dimensions of this framework, i.e. behavioural engagement and emotional engagement form part of the MTAS instrument.

Middleton (1999) put forward a number of reasons that provide a rationale as to why intrinsic motivation for achievement in mathematics is desirable in contemporary mathematics classrooms. He claimed that:

> When students engage in activities in which they are intrinsically motivated they tend to exhibit a number of pedagogically desirable behaviors including time on task, persistence in the face of failure, more elaborative and monitoring of comprehension, selection of more difficult tasks, greater

> creativity and risk taking, selection of deeper and more efficient performance and learning strategies, and choice of an activity in the absence of an extrinsic reward (p. 66).

The researcher also argued that intrinsic motivation is more complex than the additive effects of student ability, perceived competence and achievement desire, even though they significantly contribute to the students' desire to successfully participate in mathematical activities and to do well in mathematics.

Newmann (1989) however, adopted a somehow different position. He argued that "only when students perceive that academic achievement will lead to rewards they value and, further, believe that their own hard work will result in academic achievement will their engagement increase" (p. 35).

The importance of intrinsic motivation for achievement and participation in advanced mathematics courses, and the apparent differences between boys and girls' views has been demonstrated by Watt's (cited in Vale and Bartholomew, in print) argument that:

> Boys maintained higher intrinsic value for maths and higher maths related self-perceptions than girls throughout adolescence…We need to understand how it is that boys come to be more interested and like maths more than girls; and also why girls perceive themselves as having less talent, even when they perform similarly.

The authors also cited a finding from the Program of International Student Assessment (PISA) 2003 study relating to girls' confidence in mathematics: "females appear to be less engaged, more anxious and less confident in mathematics than males.

It is our contention however, that computer (and technology) confidence is a very different construct to that of mathematical confidence. Mathematical confidence is an affective dimension closely associated with mathematics achievement.

Weglinsky (1998) evaluated the educational technology and student achievement in mathematics with a USA national sample of 7,146 Year 8 (second year junior high school) students. He reported the following findings: (1) Year 8 students who used technology (simulation and higher order thinking software) gained up to 15 weeks above grade level or about one-third of a year level increase, in mathematics scores. He also reported that "high-achieving students are more likely to use technology in certain ways rather than these uses of technology promote high levels of academic achievement" (p.4).

Aims of the study

The aims of the study were:

- To investigate the factorial structure of the following variables: Secondary students' mathematics confidence, confidence with computers, attitude to learning mathematics with computers, affective engagement and behavioural engagement, and
- To investigate the influence of demographical data and biodata on students' mathematics confidence, confidence with technology, attitude to learning mathematics with computers, affective engagement and behavioural engagement

- The interrelationship between the attitude, engagement, confidence and achievement variables

Sample

The participants were 1068 Year 9 (final year of Junior High school) and Year 10 (first year of Senior High school) students form 27 state co-educational schools in Metropolitan Athens, Greece (Table 1). The schools were randomly selected. In each school one classroom from each year level was randomly selected. These schools are typical of the range of secondary schools in Greece and they vary from upper middle to low socio-economic status.

Table 1
Sample by Year level and gender

		Year level		Total
		Year 10	Year 9	
Gender	Male	263	286	549
	Female	257	262	519
Total		520	548	1068

Students' mathematics achievement was provided by their teachers, and it represented their mathematics grades during the year of the study (2004-05). The grade categories were the following: A (80-100%), B (70-79%), C (60-69%), D (50-59%) and E/F (<50%).

Research instrument

For our research we used the Mathematics and Technology Attitudes Scale (MTAS) developed by Pierce, Stacey & Barkatsas (2007). The instrument consists of 20 items. A Likert-type scoring format is used for each of the subscales: *Mathematics Confidence [MC], Confidence with Technology [TC], Attitude to learning Mathematics with Technology (whether computers, graphics calculators or computer algebra systems in the original scale – computers in this study) [MT], Affective Engagement [AE].* Students are asked to indicate the extent of their agreement with each statement, on a five point scale from strongly agree to strongly disagree (scored from 5 to 1).

A different but similar response set is used for the *Behavioural Engagement [BE]* subscale. Students are asked to indicate the frequency of occurrence of different behaviours. A five-point system is again used – Nearly Always, Usually, About Half of the Time, Occasionally, Hardly Ever (scored again from 5 to 1).

Pierce, Stacey & Barkatsas (2007) defined the subscales of the MTAS scale as follows:

- *Mathematics Confidence [MC]:* Students' perception of their ability to attain good results and their assurance that they can handle difficulties in mathematics.
- *Confidence with Technology [TC]:* technology 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. Confidence with technology was also considered as a construct relating to life outside as well as inside the classroom.

- *Attitude to learning Mathematics with Technology (whether computers, graphics calculators or computer algebra systems – computers in this study) [MT]:* Students indicating high computer/graphics calculators/CAS and mathematics interaction believe that computer/graphics calculators/CAS 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/graphics calculators/CAS session, and find computer/graphics calculators/CAS helpful in linking algebraic and geometric ideas.
- *Affective Engagement [AE]:* How students feel about mathematics
- *Behavioural Engagement [BE]:* How students behave in learning mathematics

The rationale for the selection of the MTAS items and the naming of the subscales, as well as the psychometric properties of the scale, may be found in Pierce, Stacey & Barkatsas (2007). The data analysis is presented next.

Data Analysis

(I) Factor Analysis

The questionnaire items were initially subjected to a factor analysis (extraction method: Maximum Likelihood). Given that the structure could vary, four factor analyses - one for each of the possible combinations between the gender categories (male and female) and the two year levels (Year 9 and Year 10) - were performed in order to investigate possible differences between year levels and gender.

Since no differences were observed in the four initial analyses, a final factor analysis using data from 1068 complete students' responses to the twenty items forming the MTAS indicates that the data satisfy the underlying assumptions of the factor analysis and that together five components (each with eigenvalue greater than 1) explain 67% of the variance, with almost 16% attributed to the first factor - *Mathematics Confidence* (MC).

The five factors that were extracted were identical to the five factors of the original MTAS study (Pierce, Stacey & Barkatsas, 2007): *Mathematics Confidence [MC], Confidence with Technology [TC], Attitude to learning Mathematics with Technology (a choice of computers, graphics calculators or computer algebra systems is available to the researcher – computers in this study) [MT], Affective Engagement [AE] and Behavioural Engagement [BE].*

Reliability analysis yield satisfactory Cronbach's alpha values for each subscale: MC, 0.92; MT, 0.89; TC, 0.87; BE, 0.77 and AE, 0.68. This indicates a strong or acceptable degree of internal consistency in each subscale. The lowest value was that of the AE subscale (0.68), a result that is in agreement with the initial study (Pierce, Stacey & Barkatsas, 2007). Further, the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy was greater than .6 (KMO=.906) and the Bartlett's Test of Sphericity was significant (<.001) and therefore factorability of the correlation matrix was assumed.

(II) Cluster Analysis

Cluster analysis was used to determine homogeneous and clearly discriminated classes of students. The results of cluster analysis have been used in this study to confirm the results of the factor analysis and to enhance the depth of the analysis by developing more interpretable classes of the participating students. The cluster analysis method used in this study is the K-means method.

Following a careful examination of the clusters, we hypothesized that there will be a 7 cluster partition. Our initial seven clusters were formed by using a hierarchical cluster analysis (Ward criterion). The cluster analysis was performed using the SPAD software (Lebart, Morineau, Lambert, & Pleuvret, 2001), which uses as input the students' scores on the first ten factors (by default). A summary of each cluster is provided in Table 3.

Table 3
Cluster analysis summary

Cluster	*Mathematics Achievement*	*TC*	*MT*	*MC*	*AE*	*BE*	*% of cases*	*% of boys*	*% of girls*
1	Low (D)	Very high	Positive	Very low	Strongly negative	Strongly negative	15.82	65.87	34.13
2	Average (C)	Low	Strongly negative	Average	Neutral	Negative	16.47	45.71	54.79
3	Excellent (A)	Very high	Strongly positive	Very high	Strongly positive	Strongly positive	13.04	67.63	32.37
4	Average (C)	Average	Strongly positive	Low	Neutral	Positive	12.12	36.22	63.78
5	High (B)	Very low	Strongly negative	Very high	Strongly positive	Strongly positive	9.90	40.78	59.22
6	High (B)	High	Strongly negative	Very high	Strongly positive	Strongly positive	12.67	60.15	39.85
7	Very low (E/F)	Low	Negative	Very low	Strongly negative	Strongly negative	19.98	41.98	58.02

Legend: Shaded = Mostly Boys, Unshaded = Mostly Girls
Note: The grade categories were the following: A (80-100%), B (70-79%), C (60-69%), D (50-59%) and E/F (<50%).

(III) Descriptive Statistics

In order to investigate the differences between the seven clusters, a Multiple Analysis of Variance (MANOVA) test was conducted with the seven clusters variable used as the independent variable and the six variables used in developing the clusters (MC, TC, MT, AE, BE and Mathematics Achievement) as the dependent variables. The multivariate test resulted in statistically significant differences between the seven clusters (Wilks' ? = .024, F (36, 4697.07) = 173.56, p < .001).

The statistical significance between the mean values of the seven clusters was tested by using Tukey's pairwise comparisons test. From the six univariate tests that followed (one for each of the dependent variables), statistically significant differences were found between the mean values of the seven clusters and each of the six dependent variables (p < .001). The mean value for each cluster and for each of the independent and the dependent variables are presented in Table 4 (the indices represent statistically significantly different mean values).

The chi-squared independence tests for gender ($\chi^2(3) = 58.86$, $p < .001$) and Year Level ($\chi^2(6) = 14.56$, $p < .05$) were both statistically significant.

Table 4
Descriptive Statistics for the seven clusters

	Cluster Number							
	1	2	3	4	5	6	7	Total
% of cases	15.82	16.47	13.04	12.12	9.90	12.67	19.98	
% boys in cluster	65.87	45.71	67.63	36.22	40.78	60.15	41.98	51.23
% girls in cluster	34.13	54.79	32.37	63.78	59.22	39.85	58.02	48.77
% Year 9 students in cluster	44.44	42.13	49.65	42.75	34.58[a]	51.82	53.24[a]	46.25
% Year 10 students in cluster	55.56	57.07	50.35	57.25	65.42	48.18	46.76	53.75
Means								
Mathematics achievement	2.34[d]	3.10[b]	4.06[a]	2.81[c]	3.79[a]	3.83[a]	1.90[e]	2.99
Confidence with technology(TC)	4.47[a]	2.12[d]	4.18[ab]	2.52[c]	1.48[e]	3.93[b]	1.97[d]	2.95
Attitude to learning mathematics with technology(MT)	3.99[b]	1.67[d]	4.65[a]	4.12[b]	1.58[d]	2.02[c]	2.24[c]	2.87
Mathematics confidence(MC)	2.33[c]	2.90[b]	4.33[a]	2.56[c]	4.11[a]	4.27[a]	1.22[d]	2.91
Affective engagement(AE)	2.30[d]	2.64[c]	4.38[a]	3.00[b]	4.39[a]	4.37[a]	1.67[e]	3.06
Behavioral Engagement(BE)	1.87[d]	2.60[c]	4.06[a]	3.20[b]	4.09[a]	3.97[a]	1.48[e]	2.84

Note: The indices represent statistically significantly different mean values (Tukey's pairwise comparisons test).

Discussion

Gender differences, Year level differences for each of the resulting seven clusters and their relation to achievement will be discussed in what follows:

- *Cluster 1* (15.82% of participants), consists of students with low mathematics achievement, low levels of mathematics confidence and low levels of affective engagement and behavioural engagement, very confident in using computers and positive attitude to learning mathematics with computers. Cluster 1 type students are *statistically significantly more likely to be boys* (65.87%) *than girls* (34.13%).
- *Cluster 2* (12.67% of participants), consists of students with average mathematics achievement, average levels of mathematics confidence, affective engagement and behavioural engagement, who are not very confident in using computers, and they have a very negative attitude to learning mathematics with computers. Cluster 2 type students *are statistically significantly more likely to be girls* (54.79%) *than boys* (45.71%).
- *Cluster 3* (13.04% of participants), consists of students with excellent mathematics achievement, very high levels of mathematics confidence, strongly positive levels of affective engagement and behavioural engagement, who are very confident in using computers, and have a strongly positive attitude to learning mathematics with computers. Cluster 3 type students are *statistically significantly more likely to be boys* (67.63%) *than girls* (32.37%).

- *Cluster 4* (12.12% of participants), consists of students with average mathematics achievement, average levels of mathematics confidence, negative levels of affective engagement and positive levels of behavioural engagement, with average levels of confidence in using computers, and a strongly positive attitude to learning mathematics with computers. Cluster 4 type students are *statistically significantly more likely to be girls* (63.78%) *than boys* (36.22%).
- *Cluster 5* (9.90% of participants), consists of students with high mathematics achievement, high levels of mathematics confidence, strongly positive levels of affective engagement and behavioural engagement, who are not confident in using computers and they have a positive attitude to learning mathematics with computers (boys, girls). Cluster 5 type students *are statistically significantly more likely to be girls* (59.22%) *than boys* (40.78%) and they are *statistically significantly more likely to be Year 10 students* (65.420%) *than Year 9* (34.58%) students.
- *Cluster 6* (12.67% of participants), consists of students with high mathematics achievement, very high levels of mathematics confidence, strongly positive levels of affective engagement and behavioural engagement, who are very confident in using computers, and a very negative attitude to learning mathematics with computers. Cluster 6 type students are *statistically significantly more likely to be boys* (60.15%) *than girls* (39.85%).
- *Cluster 7* (19.98% of participants), consists of students with very low mathematics achievement, very low levels of mathematics confidence, strongly negative levels of affective engagement and behavioural engagement, who are not confident in using computers, and a negative attitude to learning mathematics with computers. Cluster 7 type students *are statistically significantly more likely to be girls* (58.02%) *than boys* (41.98%) and they are *statistically significantly more likely to be Year 9 students* (53.24%) *than Year 10* (46.76%) students.

In the original MTAS study (Pierce, Stacey & Barkatsas. 2007) it was found that boys had statistically significantly higher scores than girls for each subscale except BE. The differences were greatest for TC and MC with MT and AE demonstrating less difference. While 50% of boys score 16+ on MC, this was true for only 25% of girls. TC scores are even more strongly higher for boys, with approximately 75% of boys scoring 16+ and only 25% of the girls. These results reflect the common finding that boys express greater confidence than girls. The variable MT is, with two exceptions, not significantly correlated with the others. However, it is correlated positively with TC for boys and negatively with MC for girls. The authors claimed however, that:

> It is important to note that not all the students with negative attitudes to learning mathematics with technology are girls. The distributions of MT have a long tail for both boys and girls and high inter-quartile ranges (the highest for the boys' scores). The high variability in MT is therefore not explained by gender differences: we need to look beyond learning environment and gender to explain the range of students' evaluations of the effectiveness of learning with technology (p. 296).

Conclusions

The results from both the statistical analyses indicate that:

Students with high mathematics achievement demonstrated high levels of mathematics confidence, strongly positive levels of affective engagement and behavioural engagement are not confident in using computers, appear to have a positive attitude to learning mathematics with computers. It could be argued that their objective is to improve their performance via the use of technology.

Students with excellent mathematics achievement demonstrated very high levels of mathematics confidence, strongly positive levels of affective and behavioural engagement, are very confident in using computers and they have a positive attitude to learning mathematics with computers. Students in this category appear to be overconfident and they do not believe that the use of technology will enable them to improve their performance. It could also be argued that they have not experienced the benefits of technology in learning mathematics.

Students with negative attitudes toward mathematics, low mathematics achievement, low levels of mathematics confidence and low levels of affective engagement and behavioural engagement, demonstrated confidence in using computers and positive attitude to learning mathematics with computers. Further research is required to identify the best teaching and learning environments for students in this category.

The two factors that seem to be associated with the development of a positive attitude to learning mathematics with computers are mathematics confidence and affective engagement. This finding is in agreement with the findings of the initial MTAS study (Pierce, Stacey & Barkatsas, 2007) which was conducted in Australia.

Overall, high-achieving boys appear to be more confident in mathematics, to demonstrate stronger behavioural and affective engagement, to be more confident in using computers and to have a more positive attitude to learning mathematics with computers, than girls do.

As a final concluding comment, we would agree with Weglinsky's (1998) argument that:

> Computers are neither cure-alls for the problems facing schools, not mere fads that have no impact on student learning. Rather, when they are properly used, computers may serve as important tools for improving student proficiency in mathematics, as well as the overall learning environment in the school" (p. 4).

As we work through the full spectrum of opportunities offered by information and communication technology (ICT) for enhancing the teaching and learning of mathematics, it is important that we invest in teaching innovations that will boost low or average-achieving students' – especially girls' – confidence in learning mathematics.

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