IJITCE

ISSN 2347- 3657

International Journal of
Information Technology & Computer Engineering

Email : ijitce.editor@gmail.com or editor@ijitce.com

International Journal of Information Technology & Computer Engineering

ISSN 2347–3657
Volume 4, Issue 4, Nov 2016

DISENTANGLING THE NEXUS: ATTITUDES TO MATHEMATICS AND TECHNOLOGYIN A COMPUTER LEARNING ENVIRONMENT

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Abstract

Understanding how the advent of computers and other technology impacts the mathematics learning environment requires first gaining insight into students' attitudes and beliefs. Despite the dearth of rigorous assessments, we survey the literature on the effects of technology on mathematics education. We detail the findings of a comprehensive pilot research and talk about the connection between emotional characteristics and performance after developing suitable attitude measurements. The research finds crucial qualities where mathematics and computers interact by disentangling effects related to both fields. We present the results of administering six Galbraith-Haines scales to 156 students, talk about what it means for students' self-esteem, driving forces, involvement, and engagement with the technology in the classroom, and show that the computing and mathematics attitude scales measure unique aspects of students' behavior in this area.

1. **introduction**

Though several optimistic statements have been made on the beneficial effects of technology on mathematics education, rigorous assessments of these claims are more difficult to find. According to Fey (1989), who conducted a "state of the art" assessment of mathematics teaching technology at the time:The practical effects of these initiatives on math teachers' day-to-day work are hard to pin down, and the almost limitless optimism of technophiles in our profession is backed by few empirical data.In a similar vein, Kaput and Thompson (1994) caution against blindly embracing technological innovations made for other audiences, as this might cause uncomfortable synergies in the classroom or force teachers to alter their lessons to fit the new technology.These studies fail to differentiate between mathematically-specific performance and attitude issues and technology-related issues. Our goal in writing this study was to draw that line by separating mathematical attitudes from technological ones. by studying it. Mathematical applications in fields like engineering and actuarial science are the focus of this study,

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ISSN 2347–3657
Volume 4, Issue 4, Nov 2016

Computational mathematics workshops are at the heart of the curriculum; students learn to utilize a graph plotting tool, a symbolic algebra program, and spreadsheets to organize their work. Students acquire and retain information, as well as the ability to apply what they have learned, in real-world circumstances. Consequently, the curriculum incorporates not only connections between mathematical operations and application settings, but also between digital and analogue forms of knowledge representation. Given the prevalence of computers in everyday life, it is important to investigate whether or not the observed responses reflect a lack of interest in mathematics or a preference for the technical tools used in the program.

We set out to do two things specifically in this study: first, determine the mathematical performance-based "value added" impact of the computer-based teaching program, and second, develop a battery of focused "attitude" assessments that would make it easier to address the impact of computer-based teaching programs in relation to student characteristics. The method for achieving the latter goal is detailed in this article.

ATTITUDE MEASURES

The affective domain

As Hart (1989) has pointed out there is no clear agreement on the rela- tionship between affective variables and performance, nor even universal agreement on the meaning of terms used in discussing affect. Correlation- al studies have confirmed relationships between affective variables and achievement, and some claim to predict achievement (Fennema and Sher- man, 1976; Meyer, 1985). However, the research does not give a clear picture of the direction of causal relationships (Hart, 1989; Schoenfeld, 1989), with some, as above, arguing that positive attitudes will improve the ability to learn, while others argue that the best way to foster positive attitudes is to provide success (Tall and Razali, 1993).Given the loose and multi-faceted use of the term 'affect' Hart (1989), following Mandler (1989), replaces it with the three dimensions of *beliefs*, *attitudes*, and *emotions*. Here *belief* reflects a judgement about a certain set of concepts; *attitude* represents an emotional reaction to an object, to beliefs about an object, or to behaviour towards the object; *emotion* sig- nifies a hot agitated arousal created by some stimulus. McLeod (1989a)

summarizes the dimensions of *beliefs*, *attitudes* and *emotions* as repres- enting increasing affective involvement, decreasing cognitive involvement, increasing intensity, and decreasing stability.*Attitude* may be seen as the result of emotional reactions that have been internalised and automatized (McLeod, 1989a) to generate feelings of moderate intensity and reasonable stability. Marshall (1989) has hypo- thesized a cognitive mechanism for attitude development situated in the network concept of human memory (Anderson, 1983, 1995). Here atti- tude represents the evocation of stored affective memories, involving a dispassionate response.

The Fennema-Sherman Mathematics Attitude Scales (Fennema and Sherman, 1976) or variations on them have been frequently used to measure affective variables particularly in relation to gender differences in achieve- ment and attitude. The Autonomous Learning Behaviour Model (Fennema and Peterson, 1985) set out to explain the relationship between affective variables in the students' internal belief system, and gender differences in mathematics participation and achievement. Autonomous learning beha- viours characterize the autonomous learner, such a student prefers to work independently, chooses to engage in high-level mathematical tasks and per- sists when a task proves difficult. In consequence the learner experiences success which strengthens the internal belief system leading to further suc- cess. The ALB model is therefore a feedback model. The internal belief system is hypothesized to consist of confidence, a perception that mathem- atics is useful, a facilitative attributional style, and a perception of sex-role congruency between self and mathematics.

Note that we are working within the beliefs-attitudes dimensions of the Mandler-Hart classification rather than the emotion dimension. 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 for gathering data.

The students have chosen to participate in further (tertiary) mathem- atics studies on a voluntary basis. Female students in so choosing would appear to be comfortable with mathematics in relation to their gender, and the usefulness of mathematics to the individual students has been acknow- ledged through their choice of course. Autonomous learning characteristics among this student group are assumed to be high, and the causal structure of the Fennema-Peterson (ALB) model is not an assumption of this study.However with respect to influences on mathematics learning, mathemat- ics confidence and mathematics motivation are deemed to be potentially important influences.

Mathematics attitude scales

Mathematics confidence and mathematics motivation scales were con- structed to parallel components of the Fennema–Sherman attitude scales but designed to be suitable for undergraduates. Each scale contained eight items, with four items worded positively and four items worded negatively, being randomly distributed within the scales. Characteristics of the scales are described below.

Mathematics confidence. Students with high mathematics confidence 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. Students with low confidence are nervous about learning new material, expect that all mathematics will be difficult, feel that they are naturally weak at mathematics, and worry more about mathematics than any other subject.

Mathematics motivation. Students with high mathematics motivation, enjoy doing mathematics, stick at problems until they are solved, con- tinue to think about puzzling ideas outside class, and become absorbed in their mathematical activities. Those with low motivation do not enjoy challenging mathematics, are frustrated by having to spend time on prob- lems, prefer to be given answers rather than left with a puzzle, and cannot understand people who are enthusiastic about mathematics.

Computer attitude scales

These scales were designed to parallel the corresponding mathematics scales.

Computer confidence. Students demonstrating high computer confidence 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. Students with low computer confidence feel disadvantaged at having to use computers, nervous about learning new

ISSN 2347–3657
Volume 4, Issue 4, Nov 2016

computer based procedures, do not trust computers to produce correct answers, and panic if errors occur when using a computer program.

Computer motivation. Students demonstrating high computer motiva- tion 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. Students with low computer motivation avoid using computers, believe their free- dom is eroded by program constraints, think that computers make them mentally lazy, and cannot understand how others become absorbed by computer activity.

Computer and mathematics interaction

The interactive significance of the learning and instructional context has been emphasized in general by Lester, Garofalo and Kroll (1989) and McLeod (1989b). McLeod (1985) also points out that unfamiliar tech- nology can cause special difficulties even when the tools are primitive, e.g., ruler and compass. Given the significance of engagement for effective learning (Anderson, 1995; Reif, 1987; Chi et al., 1989) the extent to which students interact with learning materials is of central interest. In a com- puter environment students may simply respond to the screen or be active in note making and summarizing. The physical separation of the learn- ing components; pen and paper, computer screen, and human brain adds a further dimension to the co-ordinating processes required for effective learning strategies. We have designed a scale to assess the extent to which students' mathematical thinking interacts with the computer medium.*Computer and mathematics interaction.* Students indicating high com- puter and mathematics interaction believe that computers enhance math- ematics 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 algebra- ic and geometrical ideas. Students indicating low interaction find difficulty in transferring information from screen to self, gloss over mathematical details on screen, find keyboard instructions distracting, and do not make notes or review material when a computer session is finished.

Engagement in learning mathematics

There has been valuable research on the extent to which active engagement on the part of learners has contributed to effective outcomes. Reif (1987) found that experts used elaborations effectively in interpreting and applying concepts in mechanics while Reder et al. (1986), and LeFavre and Dixon (1986) found that examples provided a powerful framework for learning. In elaborating, good students generate more ideas and are more persistent

than weaker students (Chi et al., 1989). Other studies (Swing and Peterson, 1988) found that integrative and elaborative processes such as analysing, defining and comparing were related to better understanding and memory while Reder and Anderson (1980) demonstrated that summaries supported effective learning.

Anderson (1995) advises that when factors are frequently associated with concepts in learning the association is remembered better; information is remembered better when part of an inter-connected network of know- ledge; elaborating material with redundant information facilitates recall, studying material at spaced intervals aids long-term retention; memory for information can be improved by manipulations that increase the amount of elaboration performed by the learner. Engagement on the part of the learner is therefore an important factor in successful achievement, and is a construct of interest in the study. An eight item scale was designed to find the extent to which students used active strategies.*Mathematics*

International Journal of Information Technology & Computer Engineering
ISSN 2347–3657
Volume 4, Issue 4, Nov 2016

engagement. Students who score highly on this scale 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. Students scoring low on the scale prefer to learn material rather than work through examples, treat ideas in mathematics as

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

separate units to be remembered, do not make notes, do not usually check calculations, and like to revise material all at once.

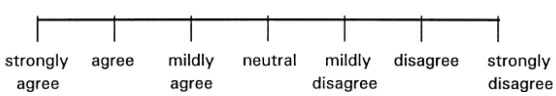
THE SIX SCALES AS AN EFFECTIVE MEASURE

Within the format of the instrument, the questionnaire items were presented on a Likert scale. In each question students were asked to express their agreement or disagreement with a statement to describe their own attitude or belief. Sample responses were provided by way of models, for example:

You might be in substantial agreement with the statement

I like mathematics because it is always right or wrong

and so place an X between *strongly agree* and *agree* on the



scale:

Respondents were given a further sample *neutral* response without intermediate scale descriptions. Within each scale the eight items were

TABLE 1

Items 1–8 which form the scale for Mathematics Confidence.

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

TABLE 2

The average observed attribute score is given for each item on each of the six scales. The expected average for each item is given under model average. This is derived from the logit measure of the FACETS analysis (Linacre, 1990). 156 students rated their own attributes, the lowest number rating any item was 146. The *scale reliability*, defined in Section 3, for each attribute continuum is indicated.

Mathematics confidence (mconf)			Mathematics motivation (mmotiv)			Mathematics (mengag)	
Item	Observed average	Model average	Item	Observed average	Model average	Item	Obser averag

International Journal of Information Technology & Computer Engineering

ISSN 2347–3657
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1	9.3	8.2	50	9.7	8.1	17	4.9	2.6
2	7.6	5.7	51	6.4	3.6	18	6.3	3.8
3	9.3	8.1	52	7.9	5.3	19	9.2	7.4
4	7.1	5.1	53	8.7	6.5	20	10.6	9.7
5	6.4	4.2	54	8.6	6.3	21	9.3	7.5
6	8.9	7.5	55	8.7	6.5	22	9.9	8.5
7	7.4	5.4	56	8.8	6.7	23	6.9	4.4
8	7.5	5.5	57	8.9	6.8	24	7.5	5.1
mean	7.9	6.2	mean	8.5	6.2	mean	8.1	6.1
std.dev	1.0	1.4	std.dev	0.9	1.2	std.dev	1.8	2.3
scale reliability		0.96	scale reliability		0.94	scale reliability		0.99

Computer confidence (cconf)			Computer motivation (cmotiv)			Computer interaction (cmint)		
Item	Observed average	Model average	Item	Observed average	Model average	Item	Observed average	Model average
33	9.1	8.6	25	7.0	5.8	41	7.2	6.0
34	6.2	4.8	26	7.0	5.9	42	7.6	6.5
35	7.1	6.0	27	7.6	6.7	43	7.2	6.1
36	6.6	5.3	28	7.1	6.0	44	5.5	4.2
37	7.2	6.1	29	7.7	6.8	45	8.6	7.8
38	7.5	6.5	30	8.1	7.3	46	6.3	5.1
39	7.6	6.6	31	6.6	5.3	47	6.9	5.7
40	6.9	5.7	32	7.1	5.9	48	8.9	8.2
mean	7.3	6.2	mean	7.3	6.2	mean	7.3	6.1
std.dev	0.8	1.1	std.dev	0.5	0.6	std.dev	1.0	1.2
scale reliability		0.94	scale reliability		0.78	scale reliability		0.95

TABLE 3

Correlations between the six attitude scales. The descriptors used in the headings for each scale are defined in Table 2.

is predicted to do this since their attribute level on this item is relatively low (4.2). Additionally, they seldom study the content shortly after a computer session is ended (mean 5.1), and they rarely reflect about their session with an admittance item (46). The majority of students will acknowledge the significance of using writing implements throughout a session (item 45, mean 7.8) and will comprehend the following (item 48): I am able to better understand the relationship between, say, the forms of graphs and the equations that describe them thanks to the computer. The answers to open question 70, "How do you feel about utilizing computers to study mathematics?" provide some useful information. Typical opinions like: incredibly useful, excellent concept, and highly successful contrast with: it doesn't teach me arithmetic at all, but it would help me verify my answers and... books would be simpler.

5. Dissimilarities in How People Feel About Mathematics and COMPUTING

The focus of this study is on the role that students' computer usage and mathematical attitudes play as distinct factors in mathematics education that makes use of technology. To go more into this matter, we examine the student replies in this part.Take a look at Table 3 for the six scales' relationships. According to Table 3, there is a substantial correlation between the

ISSN 2347–3657
Volume 4, Issue 4, Nov 2016

confidence and motivation scales in mathematics (r=0.47) and computers (r=0.71), but a less correlation when the subjects are taken out of context. The modest association between, say, mathematics confidence and computing confidence (mconf versus cconf 0.29, Table 3) demonstrates this. A substantial correlation (r=0.46) exists between mathematics engagement and motivation.

TABLE 4

Factor pattern matrix. The left-hand row definitions are given in Table 2.

Percentage of variance 67.2

The computing-mathematics interaction scale is more strongly associ- ated with the computer confidence (0.61) and computer motivation (0.68) scales than with the mathematical scales, suggesting that computer atti- tudes are more influential than mathematical attitudes in facilitating the active engagement of computer related activities in mathematical learning. These results suggest that Factor Analysis using the six scales as input variables with a two-factor solution as goal is appropriate. Using oblimin rotation (SPSS) following a principal components analysis the loadings shown in Table 4 were obtained. the two factor solution confirms that the computer and mathematics related scales define different dimensions with

computer properties dominant in the interaction scale.

Finally we consider the extent to which the students are responding differently within different scales. We have previously noted that there is variation among the observed mean item scores shown in Table 2. Since the observed students' responses reflect substantial differences between con- fidence and motivation levels associated with mathematics and computing, we anticipate significant differences in attitude measures betweencomputer confidence (cconf) and mathematics confidence (mconf)computer motivation (cmotiv) and mathematics motivation (mmotiv)We have noted that computer influence is dominant in relation to the computer-mathematics interaction, we therefore further anticipate signi- ficant differences to occur betweencomputer-mathematics interaction (cmint) and mathematics confidence (mconf)computer-mathematics interaction (cmint) and mathematics motivation (mmotiv)but not significant differences to occur between

TABLE 5

t-test results for pairs of scale scores. These means are obtained by summing the means of the eight items in the respective columns of Table 2. Two decimal place accuracy as provided in the printout of the results has been retained. Variables in column 2 are defined in Table 2.

Test No. Variables No of pairs Means Difference Standard *t*-value signif

of means error (2-tail)

computer-mathematics interaction (cmint) and computer confidence (cconf)computer-mathematics interaction (cmint) and computer motivation (cmotiv)These six predictions were examined through a series of t-tests and the results are contained in Table 5. The number of students in the respect- ive analyses comprised those who had provided complete uestionnaire responses to the corresponding scale items. The number varied from 135 to 142 over the six tests. The statistic used as the basis for the tests was the summed score over the eight items on each scale. The omission of mathem- atics engagement from this analysis does not affect the outcomes as with respect to the computer variables its effect parallels that of mathematics motivation with which it correlates strongly.As can be seen from Table 5, the results on the analyses (1)–(6) are as predicted and we therefore argue that the evidence summarised in Tables 3– 5 provides support for our contention that the *computing* and *mathematics* attitude scales capture distinctive properties that impact on instructional contexts involving computer technology in the learning of mathematics.

REFLECTIONS

We set out to devise a set of targeted ‘attitude’ measures that would more precisely enable the impact of computer based teaching programmes to be addressed in terms of student characteristics. This was in response to issues such as the very real criticisms of Fey (1989), reports of studies in which causal aspects of positive outcomes are difficult to target (e.g., Mackie, 1992), and the uncritical acceptance of technology encapsulated by Kaput (1992). We have grasped the nettle to try to understand some aspects of what it is that technology brings to teaching and learning mathematics. We have shown how the six Galbraith–Haines scales were conceived and developed and how they may be used to identify distinctive features associated with attitudes to mathematics and to computing within a particular cohort of students. For these students, we have established that computer influence is dominant in determining attitudes to computer-mathematics interactions which will be expected to have significant impact when integrating the use of computers and graphic calculators in the undergraduate curriculum.

Symbolic manipulator software (such as Derive, Maple, Mathematica) is being incorporated increasingly into undergraduate teaching (Pember- ton, 1995, 1996; Galbraith and Haines, 1996), with laboratory sessions replacing traditional tutorials and practice classes. Pedagogies for such instructional sessions are still in the process of development or refine- ment, and within this enterprise the interaction between mathematics and technology is of significant importance.

When students provide responses in relation to computing and math- ematics that are substantially different on attributes such as motivation and attitude there are consequent implications for instructional practice and research. Laboratory based individual case-study research is needed to develop a full picture of the way that different students approach their mathematics learning when assisted by technology, and how effective this learning is. The means to print out a complete record of a computer ses- sion means that stimulated recall provides an appropriate research tool for this purpose. In assisting students to re-construct both the cognitive and the affective aspects of their laboratory experiences, interview frameworks need to include (on the basis of this research) specific elements related to respective mathematical and computer based attributes, together with the interaction between the two. Some of the questionnaire items, suit- ably paraphrased, may be used to probe affective responses within specific settings.

In pursuing goals of more effective teaching another issue for future monitoring arises from the current work. This is whether, with increased exposure, differences between mathematics and computer based affectiveresponses to parallel attributes will diminish with time, or whether they represent distinctive sets of characteristics with a permanent presence in computer assisted mathmatics learning.

ACKNOWLEDGEMENTS

We would like to thank the editor and the referees for their valuable and helpful comments on this paper.

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