DOES COMPUTER CONFIDENCE RELATE TO LEVELS OF ACHIEVEMENT IN ICT-ENRICHED LEARNING MODELS?

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ABSTRACT

Employer expectations have changed: university students are expected to graduate with computer competencies appropriate for their field. Educators are also harnessing technology as a medium for learning in the belief that information and communication technologies (ICT's) can enliven and motivate learning across a wide range of disciplines. Alongside developing students' computer skills and introducing them to the use of professional software, educators are also harnessing professional and scientific packages for learning in some disciplines.

As the educational use of information and communication technologies increases dramatically, questions arise about the effects on learners. While the use of computers for delivery, support, and communication, is generally easy and unthreatening, higher-level use may pose a barrier to learning for those who lack confidence or experience. Computer confidence may mediate in how well students perform in learning environments that require interaction with computers.

This paper examines the role played by computer confidence (or computer self-efficacy) in a technology-enriched science and engineering mathematics course in an Australian university. Findings revealed that careful and appropriate use of professional software did indeed enliven learning for the majority of students. However, computer confidence occupied a very different dimension to mathematics confidence: and was not a predictor of achievement in the mathematics tasks, not even those requiring use of technology. Moreover, despite careful and nurturing support for use of the software, students with low computer confidence levels felt threatened and disadvantaged by computer laboratory tasks. The educational implications of these findings are discussed with regard to teaching and assessment, in particular.

The TCAT scales used to measure technology attitudes, computer confidence/self-efficacy and mathematics confidence are included in an Appendix. Well-established, reliable, internally consistent, they may be useful to other researchers. The development of the computer confidence scale is outlined, and guidelines are offered for the design of other discipline-specific confidence/self-efficacy scales appropriate for use alongside the computer confidence scale.

1. INTRODUCTION

Undergraduate education is changing to accommodate new demands for technology skills. Graduate attributes that are now being demanded by employers include a range of computer competencies that vary from discipline to discipline. The explosion in the development and use of professional software is likely to increase the demand for such skills. Word-processing, spreadsheet and database skills are generally being addressed in foundation computing courses, but the development of skills using professional software that is peculiar to a discipline or profession must necessarily be done in context and by specialists in that discipline.

The demand for university education has led to great changes, and undergraduate classrooms now accommodate different levels of preparedness, attitudes and beliefs across a diverse range of cultural and learning backgrounds. Among the factors that may impact on students learning, are attitudes to the use of technology and learning preferences. Students come in fully aware of the role computers are likely to play in their professions and future studies; and most have grown up in an era of technology and computer games, are familiar users of email, word-processing, and web browsers. It seems reasonable to expect that are "turned on" by the computational and processing power of technology. Many educators seek to harness that technology enthusiasm for effective learning: see, for example, Goos and Cretchley (2004) for a review of research into the wide range educational uses of computers in the teaching of mathematics in Australasia at all levels over the period 2000 to 2003.

Nevertheless, some learners, and not exclusively the mature-aged, express anxieties about using computers for learning, and some feel disadvantaged by their lack of experience with technology. Are these students likely to under-achieve if they are forced to use computers early in their undergraduate studies? Certainly, much of the educational use of information and communication technologies (ICT's) includes relatively unthreatening use of computers as a medium for delivery, support, and communication. However, higher-level use of professional software in the learning environment may be more threatening and pose a barrier to learning. Not only must students master the technical skills necessary to use the software, but they must be experienced enough to know how to use it effectively. While it is clear that use of professional software, in particular, may be appropriate for learning, questions arise about how much students' levels of familiarity with computers, and their confidence in their ability to use computers, affect their motivation and progress in courses that integrate the use of technology into learning.

Self-referent thought and belief is the focus of psychological research in many domains. Researchers generally distinguish between self-esteem, self-efficacy and self-confidence. Self-confidence is commonly viewed as a combination of self-esteem and self-efficacy. Commonly termed confidence, the construct of self-efficacy, in particular, was introduced by Bandura as a core aspect of his social-cognitive theory (see Bandura, 1977, 1997). Self-efficacy is an indicator of how people feel, think and act. General self-efficacy is associated with beliefs and feelings about one's ability to cope with and succeed at a wide range of tasks, including the demanding and novel. Research in a broad range of fields: clinical, educational, social, developmental, health, and personality psychology (Bandura, 1997; Maddux, 1995; Schwarzer, 1992) has revealed that a strong sense of general self-efficacy is related to better health, higher achievement, and more social integration. Low self-efficacy is associated with beliefs that one will not cope with tasks and challenges, anxiety, helplessness and pessimism about personal development.

Self-efficacy and confidence are also commonly accepted as being domain-specific: one may have strong self-beliefs in some domains, and lower self-beliefs in others. Self-efficacy levels can enhance or impede motivation: people with high self-efficacy in a domain will take on more challenging tasks in that domain (Bandura, 1995), and stick to them. The implication is that learners with high domain-specific self-efficacy are likely to engage effectively in course learning tasks in that domain and achieve academically.

But what of learning environments which transcend domains, and where self-efficacies vary across those domains?

The research reported here explored the role played by *computer self-efficacy*, or *computer confidence* as it is more commonly termed, in a learning environments in which students must interact with computers when learning mathematics. The study investigated whether computer confidence might relate to students' attitudes, learning behaviour and learning outcomes in a technology-enriched learning programme? Specific questions asked, when students interact with computers for learning, were the following:

- Does computer confidence (or self-efficacy) correlate with confidence (or self-efficacy) in the discipline domain (mathematics in this case)?
  (in this case, the discipline domain was tertiary level mathematics)
- Doe computer confidence/self-efficacy correlate with attitudes to using technology for learning?
- Does computer confidence/self-efficacy predict levels of engagement in course learning tasks?
- Does computer confidence/self-efficacy correlate with performance on course assessment tasks?

One further general question was investigated:

- Does the use of technology stimulate engagement in course learning tasks?

The development of pertinent scale instruments for research in a technology-enriched learning environment is outlined in the next section. They measure computer confidence, mathematics confidence, and attitudes to the use of technology for learning mathematics. Currently in use for research in a core course in an Australian university, and in technology-enriched courses in a number of countries, these Likert-style scales yield strong psychometric ratings for reliability and internal consistency.

2. CONSTRUCTION OF CONFIDENCE & ATTITUDE INSTRUMENTS

For research into learning in a technology-enriched undergraduate mathematics course, the University of Southern Queensland inter-disciplinary Project Team (Cretchley, Fogarty, Harman & Ellerton, comprising specialists in the area of Psychology, Education and Mathematics) developed Likert-style questionnaires to measure the following:

- computer confidence;
- mathematics confidence;
- attitudes to using technology when doing and learning mathematics.

It is not appropriate here to debate fine differences between the constructs termed self-*confidence*, *self efficacy and self-esteem.* Such efforts can be found in the work of researchers like Bandura (1977, 1997) and Tartre and Fennema (1995). Generally, the commonly understood notion of *self-confidence* is regarded as encompassing *self-efficacy* and *self-*

esteem. The *confidence* instruments developed by the USQ Project Team for this level of educational research are suitably broad. Items testing self-efficacy predominate, but the scales include items exploring aspects of self-concept and motivation. See Cretchley *et al*. (2000), and Fogarty *et al*. (2001) for a full description of their development. In short, a set of test items was devised for each of three desired constructs, and a questionnnaire comprising these items administered to a large cohort of students in a technology-enriched university mathematics course. Likert-style responses were invited on a scale from 1 to 5, 1 denoting strong disagreement, 2 disagreement, 3 neutral, 4 agreement, and 5 strong agreement. Factor analysis of the data confirmed the expected 3-factor structure: 13 items comprised a strong scale for measuring *computer confidence* (or *computer self-efficacy*); an 11-item scale measured *mathematics confidence* and a further 11-item scale measured inter-domain *attitudes to the use of technology for doing and learning mathematics*.

Ongoing research over a number of years has revealed that these three attitude scales, henceforth called the TCAT Scales (for Technology Confidences and Attitudes), demonstrate consistently high Cronbach internal consistency alphas (around 0.9) and high test/re-test reliability: see Fogarty et al (2001), and Cretchley & Galbraith (2002). The original 13-item computer confidence scale has been reduced by the author to a more efficient set of 11 items that yield similarly strong psychometric properties. The TCAT scale now used for establishing levels of computer confidence (including some self-efficacy) is offered below:

TCAT scale instrument for measuring Computer Confidence (CC)

I have less trouble learning how to use a computer than I do learning other things.
When I have difficulties using a computer, I know I can handle them.
I am not what I would call a computer person. R
I enjoy trying new things on a computer.
It takes me longer to understand computers than the average person. R
I have never felt myself able to learn how to use computers. R
I find having to use computers frightening. R
I find many aspects of using computers interesting and challenging.
I don't understand how some people seem to enjoy so much time at a computer. R
I have never been very excited about computers. R
I find using computers confusing. R

Appendix A gives the other two TCAT scales: one for mathematics confidence, the other for attitudes to technology when doing and learning mathematics. Researchers are welcome to use and modify them as required. The author would appreciate email notice of their use, and their source should be acknowledged, of course.

Likert-style responses were invited on a scale of 1 to 5, with 5 the highest, 3 neutral, and 1 lowest. Note that the computer confidence scale has 4 items phrased positively and 7 phrased negatively (marked R above). A student's computer confidence level was calculated as the mean of his responses after reverse scoring of the negative items.

Note that an equal balance of positively and negatively phrased items reduces the effect of unreliable responses: a string of same-level responses yields a mean close to neutral. Such a balance also reduces the effect of responses biased towards favouring (even unconsciously) the direction suggested by the wording. If desired, more items can be re-worded positively with care.

Because the mathematics and computer confidence instruments (MC and CC) were designed for parallel use and to facilitate comparison, their scale items were devised and worded very similarly, to reduce the effects of different interpretation. For comparison, given below are the first few items of the mathematics confidence scale, to show how closely the wording corresponds to that on the computer confidence scale:

I have less trouble learning mathematics than other subjects.
When I have difficulties with maths, I know I can handle them.
I do not have a mathematical mind. R
I enjoy trying to solve new mathematics problems.

The validity of these two scales as measures of domain-specific "confidence" is supported by both theory and testing. Theoretically their items were devised from the shared standpoints of an inter-disciplinary team that included an experienced research psychologist. Moreover, the scales share strong similarities and high correlations with scales devised independently by another research team (see Galbraith and Haines, 2000). Despite substantial differences, the USQ Project Team and Galbraith-Haines computer confidence data yielded Pearson correlation coefficients of 0.87 (significant at the 0.01 level, 2-tailed), when administered in parallel to 196 respondents in 2000 (see Cretchley & Galbraith, 2002). Similar high correlations were found for the two mathematics confidence scales.

The consistently strong psychometric properties of these three TCAT instruments may make them useful for educational research in other disciplines. Careful adaptation of their items may make them appropriate for a different subject without greatly disturbing their validity, internal reliability, and test-retest reliability.

3. THE STUDY QUESTIONS AND FINDINGS

When students are required to use computer software for learning, the burden of learning to use the technology effectively must be outweighed by the benefits gained from using the technology. Potential benefits include the stimulation of a novel or additional learning environment, the power and scope of the technology tool, and the technical and professional skills gained.

Clearly the technology burden and the levels of these benefits vary from student to student, and it seems likely that students who like using computers may be most advantaged in a technology-enriched learning environment. Hence an obvious question is whether a liking for computers plays a role in influencing the attitudes, learning behaviour, and levels of performance in a course in which students interact with computers for learning.

Apart from the general question of whether the use of technology stimulates engagement in course learning tasks**,** the specific questions discussed here are as follows: In a learning environment in which students interact with computers, does computer confidence/self-efficacy correlate with the following:

- students' levels of confidence in the discipline being studied;
- their attitudes to using technology for learning and engagement in the learning tasks;
- their performance on course tasks?

The findings report here are from data captured in an investigation of a technology-enriched Australian learning environment in which early undergraduate students were introduced to the use of powerful software package for learning and doing mathematics. The investigation began in 1998; however most of the data reported here was captured over the period 2000 to 2004.

The cohort comprised mainly Engineering, Science, and IT students in a core mathematics subject. Computer confidence and mathematics confidence were measured in parallel using the TCAT instruments at different points of time in the technology intervention: prior to the start, at mid-semester, and late in the semester. Further testing was done towards the end of a follow-on mathematics course, to test how robust the attitudes found in the first semester course were some time afterwards.

Attitudes to the use of technology when doing and learning mathematics were measured similarly, and via open questions and face-to-face interviews. Levels of engagement in the course learning tasks were assessed in the weekly 2-hour workshops where students worked on tutorial and computer laboratory tasks supported by their tutor. Performance was assessed by the grades achieved on a range of different types of course activities: assignments, examinations, computer-laboratory tests and computer workshop tasks.

3.1 How closely does computer confidence correlate with mathematics confidence?

It was hypothesised that students who are confident with computers may be generally confident personalities who also demonstrate high levels of confidence in their disciplines of study. Confidence as a general personality trait may influence specific levels of confidence: highly confident individuals may feel and report high levels of confidence and generally high self-efficacy in many domains, while others may report low levels of confidence in many areas. Given that computer studies and mathematics are often regarded as related disciplines, it was hypothesised that there may be high levels of correlation between, mathematics and computer confidence, in particular.

This study revealed, perhaps surprisingly, that mathematics and computer confidence correlate very poorly. MC and CC scale data yielded a Pearson correlation coefficient of 0.089 (significant at the 0.05 level) for 513 students tested on entry to the early undergraduate mathematics course. Moreover, despite the effects of course filtering, findings for 192 continuing students tested close to the end of the second semester course, revealed a similarly low Pearson rho: 0.135.

These findings add evidence to a growing body of data that computer confidence is a very different construct to mathematics confidence. Similar low correlations were found in earlier work by the USQ Project Team (see Cretchley et al, 2000) and in similar studies in other technology initiatives in Australia and the UK: see Galbraith, Pemberton & Cretchley (2002).

3.2 Does computer confidence relate to attitudes to the use of technology for learning?

The study revealed consistently moderate correlations between computer confidence and attitudes to the use of technology for learning mathematics. Data captured from 513 students on entry to the first semester course yielded a Pearson's correlation coefficient of 0.40, significant at the 0.01 level (2-tailed). Similar correlations (around 0.45, significant at the 0.01 level) were found for 192 students surveyed late in the follow-on second semester course, confirming the robustness of this finding in this sequence of mathematics courses.

Perhaps it is unsurprising that *computer* confidence and attitudes towards technology in learning mathematics were moderately related. But it was surprising that *mathematics* confidence correlated so weakly with those technology attitudes: Pearson's correlation coefficient, rho < 0.20.

3.3 Does computer confidence relate to levels of performance in a technology-enriched learning environment?

This study revealed no evidence at all that computer confidence related to achievement on a wide range of course tasks, not even those that specifically required the use of technology. Correlations between computer confidence and marks obtained on 2 course assignments and 2 examinations yielded Pearson coefficients close to 0. Most surprising is that computer confidence did not correlate positively with levels of performance on mathematical tasks in the mid-semester computer laboratory test.

Nor did analysis of variance reveal any differences in group mean levels of computer confidence between those groups of students who used technology more or less frequently in the test. Similarly, statistical tests performed on groups of students who used technology at different levels of technical difficulty revealed no substantial differences in computer confidence or attitudes to the use of technology. Observations of students working on workshop tasks in their weekly computer laboratory session also revealed no relationship between their levels of computer confidence and their ability to use technology effectively. Even highly computer confident IT students demonstrated mixed levels of use of the software when doing mathematics tasks: some used the software to get around doing handwork wherever possible, others seemed to cling to past habits and do what they could by hand. Interviews revealed that their behaviour was governed by perceptions of what is "correct" or "better", rather than their natural aptitude and liking for computers.

These findings must be interpreted bearing in mind that none of the assessment tasks were designed specifically to test mastery of the computer software, and students were aware that this would be the case. All assessment tasks required essential knowledge of the mathematical processes and concepts of the course; technology use was an appropriate aid for graphing and computation, and in that sense, knowledge of the core mathematical concepts and processes were a gatekeeper to the use of technology. Even the tasks designed for the mid-semester computer laboratory test were mathematical in nature. For equity reasons, examination tasks were designed so that computer technology was not needed (hough it was permitted). However, appropriate and effective use of the computer for computation and graphing was a clear advantage in the assignments and in the mid-semester test where a number of tasks had to be completed within an hour.

3.4 Does the use of technology stimulate engagement in course learning tasks?

Responses to open questions on the threshold of the technology intervention revealed that most students (around 80%) were stimulated by the prospect of using computers in their mathematics studies; many highly so. Most students engaged willingly in the weekly technology exercises, and mastered enough software skills to support their problem-solving and complete the mathematical tasks, and many remained very positive about the use of computers throughout the technology intervention. Data captured later in their studies revealed that perceptions of the learning value of the technology tasks and the opportunity to build professional skills motivated most students very strongly. Around two thirds of those surveyed remained strongly positive about the opportunities afforded by the software, and some were clearly stimulated by the inclusion of technology tasks.

Many reported feeling that they had gained satisfaction and confidence from the experience. Reasons they gave for these positive responses were pride in harnessing the power of technology, enjoyment when using computers, and perceptions of the long-term benefits of computer skills and experience, especially with professional software. These perceptions seemed to be major motivating factors behind some students' very high levels of engagement in technology tasks.

Only a few students volunteered the view that course and assessment expectations played a role in raising their levels of engagement in the technology tasks. The reasonably high levels of engagement in the weekly computer laboratory tasks may have been stimulated to some degree by the fact that the mid-semester test was held in a computer laboratory. However, technology work in the course was not enforced, and students were fully aware that the end-of-semester examination tasks would not require use of the software.

Despite their willingness to give it a try, however, some students clearly felt vulnerable and disadvantaged by the technology component of the course. A minority felt computers did not aid their learning: at most 16% of these cohorts. Many first year students have difficulty adapting to their new lives and learning environments, and the affective burden of additional factors which may cause them additional stress must be balanced against potential educational gains. Nevertheless computer confidence, per se, did not seem to play a major role in their levels of engagement generally in course learning tasks. Only a handful of students declined to engage in the technology experience.

4. SUMMARY AND DISCUSSION

The role of computer confidence was investigated within a technology-enriched learning environment in which early undergraduate students were introduced to the use powerful scientific software for doing and learning mathematics in an Australian university. Research findings indicate that computer confidence may be a poor predictor of students' performance on course tasks, even those that invite or require the use of computers.

In the technology enriched model investigated, computer confidence did not relate to levels of performance on course tasks generally, nor to technical level or frequency of use of technology. However, it did correlate moderately with attitudes to the use of technology for learning mathematics. Moreover there were indications that computer confidence and technology attitudes are strongly motivational for learning in technology-enriched environments. Many students had highly positive attitudes towards the use of technology for learning and high levels of computer confidence: some who did not were nevertheless motivated to learn to use software that they perceived would be of value professionally. Relatively few expressed strong qualms initially, and by the end of the semester, the vast majority expressed perceptions that their software experience aided and enlivened their learning.

It is important to note, however, that students with low levels of computer confidence/self-efficacy reported strong feelings of anxiety and disadvantage at the prospect of using software for learning. Most of these entered the course with little prior experience of the use of computers, and some gained confidence over the technology initiative, but a few still felt disadvantaged after a full semester of use of the software, despite the well-resourced supportive classroom and laboratory learning environment. Inevitably, some reluctant technology users were not conscientious students: they demonstrated low levels of engagement in the course tasks generally.

The research findings confirm that computer confidence is a very different construct to mathematics confidence. Mathematics confidence was more closely related to students' performance than was computer confidence, on all types of course tasks, including those that required or invited the use of technology. This finding supports Tartre and Fennema's (1995) claim that mathematics confidence is the affective factor most closely related to mathematics performance. It also supports the notion that domain-specific self-efficacies are better predictors of achievement than computer self-efficacies and attitudes, even on tasks that require the use of computers.

The results generally support the notion of domain-specific self-efficacies: see Bandura (1997). However, research in other fields is needed to establish whether computer confidence is as different to other domain confidences and self-efficacies: that seems likely.

There are clear implications for computer-based learning initiatives, and for assessment in particular. For early undergraduate students who are finding the pressures of tertiary level study and changes in their learning environment difficult to manage, the effects of an additional perhaps unnecessary technology load are clearly serious. Those who have low levels of computer confidence are particularly vulnerable. Enforced use of software and assessment thereof may be more appropriate in later undergraduate courses. Students in this study clearly welcomed having some degree of choice over how much technology they used. A few learners (some of them industrious and conscientious) felt disadvantaged by a mid-semester computer laboratory test experience. Clearly educators need to balance the motivating role of assessment with the negative effects of enforcing an unwelcome and possibly ill-timed learning medium.

The development of instruments by a USQ Project team, to measure computer confidence alongside mathematics confidence, and to measure attitudes to technology when doing and learning mathematics (a cross-domain self-efficacy) is outlined. These scales are included in an Appendix. Tested in a range of technology initiatives over some years, these three TCAT scales yield high levels of reliability and internal consistency. The nature of the scales and their strong psychometric properties may make them valuable for educational research in other areas. Hence guidelines for adapting them for use in research into educational use of technology in other discipline domains are offered in this report.

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APPENDIX: TCAT Technology Confidence and Attitude Scales

TCAT instrument for measuring Mathematics Confidence:

I have less trouble learning mathematics than other subjects.
When I have difficulties with maths, I know I can handle them.
I do not have a mathematical mind. R
It takes me longer to understand maths than the average person. R
I have never felt myself able to learn mathematics. R
I enjoy trying to solve new mathematics problems.
I find mathematics frightening. R
I find many mathematics problems interesting and challenging.
I don't understand how some people seem to enjoy spending so much time on maths problems. R
I have never been very excited about mathematics. R
I find mathematics confusing. R

TCAT Instrument for measuring Computer Confidence:

I have less trouble learning how to use a computer than I do learning other things.
When I have difficulties using a computer, I know I can handle them.
I am not what I would call a computer person.
It takes me longer to understand computers than the average person.
I have never felt myself able to learn how to use computers.
I enjoy trying new things on a computer.
I find having to use computers frightening.
I find many aspects of using computers interesting and challenging.
I don't understand how some people seem to enjoy so much time at a computer.
I have never been very excited about computers.
I find using computers confusing.

TCAT instrument for measuring Attitudes to using Technology when doing and learning mathematics:

Computing power makes it easier to explore mathematical ideas.
I know computers are important but I don't feel I need to use them to learn mathematics.
Computers and graphics calculators are good tools for calculation, but not for my learning of mathematics.
Using technology is too new and strange to make it worthwhile for learning mathematics.
Using technology wastes too much time in the learning of maths.
I prefer to do all the calculations & graphing myself, without using a computer or graphics calculator.
Using technology for the calculations makes it easier for me to do more realistic applications.
I like the idea of exploring mathematical methods and ideas using technology.
I want to get better at using computers to help me with mathematics.
The symbols and language of mathematics are bad enough already without the addition of technology.
Having technology to do routine work makes me more likely to try different methods and approaches.