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Research Reports

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POTENTIAL FACTORS INFLUENCING SENIOR SECONDARY STUDENTS' USE OF CAS CALCULATORS IN MATHEMATICS

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The following paper reports on certain aspects of the quantitative analysis of data collected from 367 participants across six Victorian secondary schools in Australia. The data was collected using the Mathematics and Technology Attitudes Scale (MTAS) developed by Pierce, Stacey and Barkatsas (2007) which measures five affective variables examining students' learning with technology in mathematics. Using ANOVA techniques, statistically significant differences were found between the MTAS variables and gender, school, grade, year level and years of CAS experience.

INTRODUCTION

As we move deeper into the 21st century, the use of digital technologies have become such an integral part of the teaching and learning process they are now viewed more as "necessities rather than luxuries" (Bouck & Joshi, 2012, p. 115). As discussed by Hall (2010), there are a variety of technologies now accessible for teaching and learning within the classroom domain including electronic whiteboards, computers, laptops and calculators. Apart from their increased availability, research in the field of education has also "recognised the potential for mathematics learning to be transformed by the availability of digital technologies" (Goos & Bennison, 2008, p. 102). Guerrero, Walker and Dugdale (2004) noted:

> When technology is used well . . . it can have positive effects on students' attitudes towards learning, confidence in their ability to do mathematics, engagement with the subject matter, and mathematical achievement and conceptual understanding. (p. 5)

The potential benefits of technological resources in mathematics have also been acknowledged by educational organisations. In the 1996 'Statement on the use of Calculators and Computers for Mathematics in Australian Schools' by the Australian Association of Mathematics Teachers (AAMT, 1996), it was recommended that "all students have ready access to appropriate technology as a means both to support and extend their mathematics learning experiences" (p. 1). A publication by the Australian Curriculum, Assessment and Reporting Authority (ACARA, 2009), an educational body which shapes the writing of the National curriculum, also highlighted that "digital technologies allow new approaches to explaining and presenting mathematics, as well as assisting in connecting representations and . . . deepening understanding" (p. 12).

While the use of technologies have presented many advantages, Drijvers, Doorman, Boon, Reed and Gravemeijer (2010) expressed concern that the integration of technology within mathematics has fallen behind the promising expectations of the past two decades. In Australia, implementation of calculators equipped with computer

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algebra system technology (CAS) has faced various obstacles, despite becoming an important aspect of the senior secondary mathematics curriculum in the state of Victoria (VCAA, 2013). Factors such as student attitudes, teacher perceptions, time restrictions and the technical skill required to use the CAS have made integration difficult, and as such these technologies continue to play "a marginal role in mathematics classrooms" (Goos & Bennison, 2008, p. 103).

CONTEXT AND RATIONALE

In 2001, CAS calculators were introduced into Victorian secondary schools as part of a pilot study which aimed to investigate the effects that the use of 'supercalculators' would have on the senior mathematics curriculum (Stacey, McCrae, Chick, Asp & Leigh-Lancaster, 2000). Since then, the senior mathematics curriculum developed a new subject – Mathematical Methods (CAS) – which emphasised "the appropriate use of computer algebra system technology (CAS) to support and develop the teaching and learning of mathematics and in related assessments" (VCAA, 2013, p. 179). This technology is also expected to be used in the alternative subjects, Further Mathematics and Specialist Mathematics.

Geiger, Faragher and Goos (2010) highlight that CAS calculators hold many potential benefits to enhance the teaching and learning of mathematics:

> [They] not only have the capability to perform a wide range of mathematical procedures, such as function graphing, matrix manipulation and symbolic operations, but also the capacity to provide users with real time advice about errors as mathematics is done. (p. 48)

As a result, CAS calculators are not only a useful technological resource to complete mathematical work, but their time-saving capabilities also allow for a shift in the focus for learning to more conceptual understanding rather than the mastery of algebraic manipulations (Heid & Edwards, 2001). However, the advantages of CAS have been overshadowed by the polarised findings of educational research. As argued by Hall (2010), "development of a promising technology does not guarantee that it will achieve widespread use" (p. 232). While in some cases teachers and students have made use of CAS calculators successfully, others have encountered difficulties which have marginalised CAS use in the classroom. It is therefore important to examine the issue of implementation further with Hall (2010) proposing four essential questions in regards to the introduction of new technologies:

Is it being used?
How well is it being used?
What factors are affecting its use/non-use?
What are the outcomes?

While Hall (2010) refined these questions with respect to the change required to implement new digital resources, the student and teacher perspective in relation to these questions is also valuable as they are ultimately the users of these new technological innovations. Without understanding the obstacles faced by each within the mathematics classroom, the benefits of using CAS calculators are essentially lost. As summarised by Guerrero, et al. (2004):

> Technology has shown potential for positive effects on student engagement and achievement, on teaching techniques, and on the learning environment overall. [However], the extent to which this potential is realised relates to *how* [emphasis added] the technology is used within the mathematics curriculum. (p. 16)

The data analysis reported in this paper is part of a broader study which aims to explore students' use of CAS calculators in senior secondary mathematics and the possible factors which may influence their use. The purpose of the quantitative dimension of the study was to aid in the identification of potential factors (to guide subsequent interviews and classroom observations) and to determine any differences that may exist between the MTAS variables and gender, school, grade, year level and years of CAS experience.

METHODOLOGY

The questionnaire used in this study is the Mathematics and Technology Attitudes Scale (MTAS) designed by Pierce, Stacey and Barkatsas (2007). The questionnaire consists of 20 items divided into five subscales measuring the affective variables technology confidence (TC), mathematics confidence (MC), affective engagement (AE), attitude to learning mathematics with technology (MT) and behavioural engagement (BE). Four statements are allocated to each subscale and for each statement students indicate their extent of agreement on a five-point scale ranging from strongly agree to strongly disagree, or from nearly always to hardly ever (for behavioural engagement). Additional items relating to gender, school, grade, year level and years of CAS use were also added to the questionnaire.

To analyse the MTAS responses, each participant's overall score for each subscale was determined. This was achieved by adding together the scores for the four individual items in each subscale with values ranging from 5 (strongly agree/nearly always) to 1 (strongly disagree/hardly ever). Each participant can obtain a maximum score of 20 and a minimum score of 4 for each subscale. According to Pierce et al. (2007), subscale scores of 17 or above are considered to be high scores, indicating a positive response to the examined factor. Scores of 13-16 are considered to be moderately high, and scores of 12 of below are considered to be low scores indicating a neutral or negative attitude.

The 367 participants came from six secondary schools across Victoria, Australia. Three were government schools (two co-educational and one all girls'), two were independent co-educational schools and one was a catholic co-educational school. The questionnaire was administered to mathematics students in Years 11 and 12 (the final two years of secondary schooling) as these are the years in which the CAS calculator is used most extensively. A number of schools had less mathematics subjects on offer due to lack of student participation and other schools only had certain classes participate in the questionnaire based on teacher interest. Findings with respect to these schools have been made with caution as the responses provided may not be representative of the schools' senior mathematics student population.

RESULTS

Principal Component Analysis

Prior to conducting 'between groups' analyses, the 20 items of the MTAS were subjected to a Principal Components Analysis (PCA) in order to validate the scale and show that the items continue to load on the same component as seen in prior studies (Barkatsas, 2011; Barkatsas, Kasimatis & Gialamas, 2009; Pierce, et al., 2007). The PCA results revealed that the five components (all with eigenvalues greater than 1) explained 66.5% of the variance with the first component (mathematics confidence) contributing to 30.37% and the second component (attitudes to learning mathematics with technology) contributing to 13.97%.

To establish the factorability of the data, Bartlett's test of Sphericity (BTS) and Kaiser-Mayer-Olkin (KMO) measure of sampling adequacy were examined. According to Tabachnick and Fidell (2007), BTS should be significant ($p < 0.05$) and KMO values should be greater than 0.6. Analysis of the questionnaire revealed that both conditions were satisfied with BTS = 0.000 and KMO = 0.853. Additionally, each subscale was subjected to a reliability analysis. The Cronbach alpha values obtained were 0.912 (MC), 0.850 (MT), 0.784 (BE), 0.755 (TC) and 0.754 (AE) which indicated a strong to acceptable degree of internal consistency (Field, 2013).

Analysis of MTAS subscales

Analysis of variance (ANOVA) techniques were used to compare the means of each subscale against different variables (e.g. gender). In addition, post hoc analyses were also conducted to determine where the significant differences between each of the groups lie. Tukey's test was selected as it is considered one of the most commonly used post-hoc tests as it controls well for the Type I error and has reasonable statistical power (Field, 2013). Table 1 summarises the main findings from the ANOVA (p-values), highlighting where statistically significant differences were identified.

Post hoc analyses determined the following results:

- Boys achieved a higher average score on the technology confidence and mathematics confidence subscales compared to girls. (Note: data from the all girls' school was not included to remove the influence of a different learning environment).
- Significant differences between schools were evident for the mathematics confidence, affective engagement and attitude to learning mathematics with technology subscales.

Variable	**MTAS Subscales**				
	TC	MC	AE	MT	BE

Gender	0.001*	0.000*	0.442	0.638	0.189
School	0.122	0.000*	0.000*	0.001*	0.048*
Grade	0.923	0.000*	0.009*	0.137	0.000*
Year Level	0.027*	0.211	0.234	0.573	0.067
Years of CAS experience	0.003*	0.894	0.418	0.888	0.965

Table 1: ANOVA results for each subscale.

Students with grades in the A+/A range (80-100%) scored higher in the mathematics confidence, affective engagement and behavioural engagement subscales than students with grades in the B+/B range (70-79%) or C+/C range (60-69%).

Students in Year 12 scored higher on the technology confidence subscale than students in Year 11.

Higher technology confidence scores were evident if a student had used CAS calculators for 2 or 3 years compared to a student who had used CAS calculators for only one year.

DISCUSSION

Gender Differences

As the CAS calculator has become a more integral part of the senior mathematics curriculum in Victoria, Australia, there has been concern regarding gender equity and whether technology is accentuating gender differences in mathematics (Forgasz & Griffiths, 2006). The results obtained from the MTAS determined that there were statistically significant differences between male and female students in the technology confidence and mathematics confidence subscales. Males achieved a higher average score than females on both affective variables, which is consistent with prior large-scale studies conducted by Pierce et al. (2007) and Barkatsas (2011). Schmidt (2010) also discovered gender differences after surveying upper secondary school students in Thuringia, Germany. With respect to CAS calculators, the study found that male students experienced fewer difficulties and made more use of this technology in other lessons as opposed to female students. It is possible that the greater difficulties encountered by girls when using CAS calculators may make it more difficult to develop confidence with this technology. Alternatively, the obstacles faced by girls may be the result of lower technology confidence. It is anticipated that subsequent observations and interviews with students will provide greater insights into these differences and how they affect students' use of CAS calculators as part of their mathematics learning.

Differences between Schools

Figure 1 summarises the main findings from the ANOVA and post hoc analyses. Statistically significant differences were found for the mathematics confidence, affective engagement and attitude to learning mathematics with technology subscales and these have been shown in the box plots below. It can be seen that there were variations between schools for each of these variables.

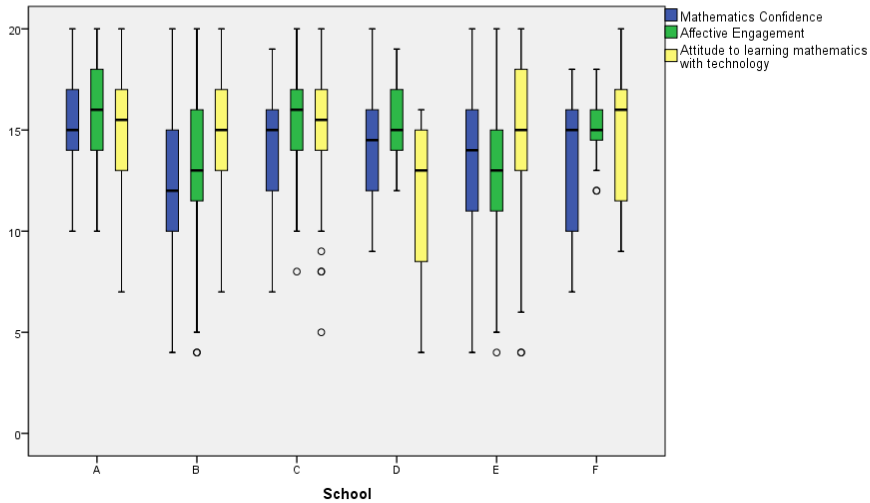

Figure 1: Mathematics confidence, affective engagement and attitude to learning mathematics with technology subscales by School

The key findings obtained from the MTAS data were that students in School B (Catholic, co-educational) obtained lower mathematics confidence scores than all other schools, students in School B and E (Government, all girls') obtained lower affective engagement scores, and students in School D (Government, co-educational) obtained a lower score on the attitude to learning mathematics with technology subscale. As the subscale on attitudes relates specifically to the CAS calculator, it is a point of interest to determine how negative attitudes may affect students' use of this technology in mathematics. It was also noted that School D had various students from low socio-economic families, which created issues of accessibility to the CAS. The difficulty in obtaining this technology, which is essential for 'technology-rich' assessments, may also have led to the development of negative attitudes in students.

Differences between Grades

Findings from the data analysis revealed statistically significant differences between student grades and the MTAS subscales mathematics confidence, affective engagement and behavioural engagement. Students who obtained grades within the A+/A range (80-100%) scored higher, on average, on the mathematics confidence, affective engagement and behavioural engagement subscales than students with other grades. These results are in agreement with the study by Barkatsas et al. (2009) who performed a cluster analysis to explore the interrelationship between student attitudes, gender, engagement and achievement. The authors concluded that "students with excellent mathematics achievement demonstrated very high levels of mathematics confidence [and] strongly positive levels of affective and behavioural engagement" (p. 569). However, Barkatsas et al. (2009) also noted that these students may be overconfident and may not consider technology to be beneficial to their mathematics learning - a point which has been explored further in the subsequent qualitative sections of this study (but are not reported here).

Year Level and Years of CAS experience

In a study by Barkatsas (2011), it was conjectured that "it may take at least two or three years for students to get accustomed to the complex functionality of CAS calculators" (p. 7). Results from the ANOVA supported these findings with statistically significant differences found in the technology confidence subscales for both Year Level and Years of CAS experience. Students in Year 12 scored higher, on average, for technology confidence than students in Year 11. Further, students who had used the CAS calculator for two or three years scored significantly higher, on average, for this subscale compared to students who had used this technology for only one year. It could be argued that the more time students have to familiarise themselves with the CAS calculator, the more confident they become with this technology. Although this subscale is not specific to CAS calculators, it still provides an avenue for investigation in the subsequent interviews and observations in this study. As different schools introduce CAS calculators at varying points in time (e.g. Year 9 or Year 11), it will be intriguing to determine how the years of experience have affected students' use of this technology in senior secondary mathematics.

References

Australian Association of Mathematics Teachers. (1996). *Statement on the use of calculators and computers for mathematics in Australian schools.* Retrieved from: http://www.aamt.edu.au/Publications-and-statements/Position-statements/Calculators-and-computers.

Australian Curriculum, Assessment and Reporting Authority (2009). *Shape of the Australian curriculum: Mathematics.* Retrieved from: http://www.acara.edu.au/verve/_resources/Australian_Curriculum_-_Maths.pdf

Barkatsas, A. (2011). Learning Mathematics with Computer Algebra Systems (CAS): middle and senior secondary students' achievement, CAS experience and gender differences. *Mathematics and Technology: Fifteenth Asian Technology Conference in Mathematics Electronic Conference Proceedings* (pp. 1-9). Blacksburg, VA: USA.

Barkatsas, A., Kasimatis, K., & Gialamas, V. (2009). Learning secondary mathematics with technology: exploring the complex interrelationship between students' attitudes, engagement, gender and achievement. *Computers and Education, 52(2),* 562-570.

Bouck, E. C., & Joshi, G. S. (2012). Assistive technology and mathematics education: reports from the field. *Journal of Computers in Mathematics and Science Teaching, 31(2),* 115-138.

Drijvers, P., Doorman, M., Boon, P., Reed, H., & Gravemeijer, K. (2010). The teacher and the tool: instrumental orchestrations in the technology-rich mathematics classroom. *Educational Studies in Mathematics, 75(2),* 213-234.

Field, A. (2013). *Discovering statistics using IBM SPSS statistics (4th Ed.).* London: Sage Publications.

Forgasz, H., & Griffiths, S. (2006). Computer algebra system calculators: gender issues and teachers' expectations. *Australian Senior Mathematics Journal, 20(2),* 18-29.

Geiger, V., Faragher, R., &Goos, M. (2010). CAS-enabled technologies as 'agent provocateurs' in teaching and learning mathematical modelling in secondary school classrooms. *Mathematics Education Research Journal, 22(2)*, 48-68.

Goos, M., & Bennison, A. (2008). Surveying the technology landscape: teachers' use of technology in secondary mathematics classrooms. *Mathematics Education Research Journal, 20(3),* 102-130.

Guerrero, S., Walker, N., & Dugdale, S. (2004). Technology support of middle grade mathematics: what have we learned? *Journal of Computers in Mathematics and Science Teaching, 23(1),* 5-20.

Hall, G. E., (2010). Technology's Achilles heel: achieving high-quality implementation. *Journal of Research on Technology in Education, 42(3),* 231-253.

Heid, M. K., & Edwards, M. T. (2001). Computer algebra systems: revolution or retrofit for today's mathematics classrooms? *Theory into Practice, 40(2)*, 128-136.

Pierce, R., Stacey, K., & Barkatsas, A. (2007). A scale for monitoring students' attitudes to learning mathematics with technology. *Computers and Education, 48(2),* 285-300.

Schmidt, K. (2010). Mathematics education with handheld CAS – the students' perspective. *The International Journal for Technology in Mathematics Education, 17(2),* 105-110.

Stacey, K., McCrae, B., Chick, H., Asp, G., & Leigh-Lancaster, D. (2000).Research-led policy change for technologically-active senior mathematics assessment. In J. Bana& A. Chapman (Eds.), *Mathematics education beyond 2000: Proceedings of the 23rd annual conference of the Mathematical Educational Research Group of Australasia* (pp. 572-579). Fremantle, W. A.: MERGA

Tabachnick, B. G., & Fidell, L. S. (2007). *Using Multivariate Statistics (5th ed.)*. Boston, MA: Allyn and Bacon.

Victorian Curriculum and Assessment Authority. (2013). *Mathematics: Victorian Certificate of Education study design.* Retrieved from: http://www.vcaa.edu.au/vce/studies/mathematics/mathsstd.pdf.