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Factors leading to the adoption of a learning technology: The case of graphics calculators

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This paper reports on a case study which examined factors leading to the adoption of graphics calculators (GCs) by secondary mathematics teachers in the state of New South Wales, Australia. In total, 587 teachers of the General Mathematics Course (Years 11 and 12) participated in the study. The median teachers' stage of adoption of GCs was found to be at the "Understanding and application of the process" level, the third lowest on a six point scale. The results also indicate that competence is the most important factor in explaining stages of adoption, training the second most important, followed by personal interest in GCs as well as faculty support. Teachers' gender, teaching experience, educational qualifications and the number of GCs in schools were not found to be statistically significant. Qualitative analysis of teachers' open ended comments also shed light on the nature of the explanatory variables. The findings are relevant to curriculum development policy and the design of professional development programs, and has implications for the introduction of other technologies.

Introduction

New technology offers significant potential for enhancing the learning and teaching of mathematics at all levels. However if there is resistance to the adoption of technology then the potential will not be realised. This study considers the example of the adoption of graphics calculators (GCs) in upper secondary schools of New South Wales (NSW) as an example of the implementation of new learning technologies.

The use of GCs is a relevant case study in mathematics education because this technology permits students to enhance their spatial-visualisation skills, connect mathematical concepts in a richer context, and create greater understanding in particular topics such as functions and graphing (Geiger & Goos, 1996). For nearly twenty-five years the implementation of GCs has been attempted by public and private education systems having large budgets spent for that purpose. These efforts include both the purchase of handheld class sets as well as professional development courses for mathematics educators. However, as Goos and Bennison (2008) indicate, "technology still plays a marginal role in mathematics classrooms and that educational policies, access to technology resources, and institutional support are insufficient conditions for ensuring effective integration of technology into teachers' everyday practice" (p. 103).

Much of the research has focused on measuring the magnitude of the impact of GCs on students' academic performance as well as on teachers' attitudes in regard to GCs using descriptive statistics, chi-square and correlation analysis (Routitsky & Tobin, 1998; Tobin, Routistsky & Jones, 1999; Goos & Bennison, 2008). However, there is a scarcity of literature on the possible explanatory effect of personal and environmental variables affecting the adoption of GCs using quantitative methods.

This study makes mainly use of multiple regression analysis as a tool for explaining and exploring relationships among variables (Osborne, 2000). Multiple regression is commonly used in the exploration of personal and environmental factors resulting in the adoption of technology (Atkin, Neuendorf, Jeffres & Skalski 2003; Bussey, Dormody & Van Leeuwen, 2000; Featherman & Pavlou, 2003; Ndubisi, 2004; Shah Azam, 2007). This study adds to the existing body of GCs literature by presenting findings for explaining and identifying the most important factors leading to technological adoption.

Background

Studies on the impact of GCs in secondary education have revealed positive effects in the teaching and learning of mathematics. A body of research has related this positive impact to GC's capacity to connect graphical, algebraic and tabular representations of data and concepts to one another creating consequently a richer association of mathematical ideas (Alguire & Forster, 1999, Hennessy, Fung & Scanlon, 2001; Kwon, 2002; Portafoglio, 1998; Vonder Embse, 1992; Weber, 1998). Similarly, GCs are beneficial in situations where mathematical modelling is necessary. This is so because GCs empower learners to simulate hypothetical or real-life situations for investigation purposes thus producing student-centred environments (Arnold, 2004; Simonsen & Dick, 1997). Studies conducted by Galbraith, Renshaw, Goos and Geiger (1999), and Cavanagh and Mitchelmore (2003) also reveal that these devices are able to generate richer communication among students and between students and teachers. When compared to desktop computers and other technologies, GCs stand out for their portability, compactness and low cost.

One important measure of the success of any educational reform is the extent to which it is adopted by teachers. Several schemes have been designed to evaluate the adoption of various technologies in educational settings (Cafolla & Knee, 1995; Evans-Andris, 1995; Hadley & Sheingold, 1993; Russell, 1995). Russell (1995) conceptualised six stages of adoption following a qualitative research project investigating how school teachers enrolled in a postgraduate course learned to use electronic email while interacting with students on a specific learning task. Russell suggested that in adopting technology, teachers or any other adult may start at any point and will develop at their own rate through the following six stages: (a) awareness, (b) learning the process, (c) understanding and application of the process, (d) familiarity and confidence, (e) adaptation to other contexts, and (f) creative applications to new contexts.

Christensen (1997a; 1997b) adapted Russell's (1985) conceptualisation into a self-report scale designed to characterise teachers' adoption of educational technology in general, such as computers, emails, software and multimedia. The revised six stages of adoption in the Christensen's (1997b) *Teachers' Attitudes toward Information Technology Questionnaire (TAT)* are as follows:

> *Awareness*: I am aware that technology exists, but have not used it – perhaps I'm even avoiding it. I am anxious about the prospect of using computers.
>
> *Learning*: I am currently trying to learn the basics. I am sometimes frustrated using computers. I lack confidence when using computers.
>
> *Understanding*: I am beginning to understand the process of using technology and can think of specific tasks in which it might be useful.
>
> *Familiarity*: I am gaining a sense of confidence in using the computer for specific tasks. I am starting to feel comfortable using the computer.
>
> *Adaptation*: I think about the computer as a tool to help me and am no longer concerned about it as technology. I can use it in many applications and as an instructional aid.
>
> *Creative Application*: I can apply what I know about technology in the classroom. I am able to use it as an instructional tool and integrate it into the curriculum. (Christensen, 1997b)

Fraze, Fraze, Baker and Kieth (2002) explored those stages of adoption among 310 agri-science teachers and found that the mean of stage adoption was between stage 4 (Familiarity/ confidence) and stage 5 (Adaptation). Other studies corroborated the findings of Fraze et al., such as Christensen and Knezek (2001) with 508 secondary teachers, and Christensen (1997b) with 25 elementary teachers. All these studies were carried out with United States samples.

As with the implementation of educational technology in schools, authors such as Knezek, Christensen, Hancock and Shoho (2000) and Hudson, Porter and Nelson (2008) are of the opinion that supporting teachers' beliefs in regard to the new technology are as important as curriculum resources and professional development. If teachers' beliefs correspond to the purposes of a particular innovation then it is apparent that change will be more likely follow. The converse is also true. When teachers resent the innovation, chances are that resistance will occur with subsequent lack of change (Handal & Herrington, 2003). Educational reform in the field of educational technology is a complex process transcending the purchase of equipment and the provision of technical support. For an innovation to be sustainable it is necessary to ensure that issues such as enough professional assistance and preparation time are available (Ertmer, Addison, Lane, Ross, & Woods, 1999; Handal, 2004; Pender, 2000).

Important advances in the teaching and learning of mathematics at the senior secondary school level have occurred in the last decade. Significant among these developments is the trend on fostering problem solving, modelling, use of technology and real life applications linked to central mathematical concepts and procedures. The increasing advocacy on those skills and on active construction of knowledge is exemplified in curriculum documents and examinations such as the Higher School Certificate Stage 6 (Years 11 and 12) Mathematics General Course which "provides a context within which to develop general competencies considered essential for the acquisition of effective, higher-order thinking skills necessary for further education, work and everyday life". (Board of Studies NSW, 1999, p. 12; Handal, Bobis & Grimison, 2001).

The Stage 6 General Mathematics course was introduced in 1999 to replace the former *Mathematics in Society* (Board of Secondary Education NSW, 1981) and the *Mathematics in Practice* (Board of Secondary Education NSW, 1989) courses. It is taught in Years 11 and 12 of the secondary curriculum. Nearly fifty percent of the students sitting the HSC are enrolled in the General Mathematics course.

The Stage 6 General Mathematics course (Board of Studies NSW, 1999) encourages the use of technologies in teaching and learning, particularly GCs and spreadsheets (Clarke, 2001; Grove, 2001), and technology is identified as a key competence. Throughout the syllabus document, there is advice for teachers on "the nature and suggested use of technology that is appropriate to the unit" (Board of Studies NSW, 1999, p. 13). GCs were also allowed for the first time in 2001 in a NSW Higher School Certificate examination formalising their adoption in the General Mathematics course which was introduced in 1999.

While this was a significant change for NSW, the use of GCs in external examinations had already taken place in other Australian states, such as Victoria (1997), South Australia (2000) and Western Australia (1998). Tasmania followed suit in 2005. Although Queensland does not have external examinations, GCs are allowed in all school examinations. Despite many resources and much effort, there is evidence that a large number of teachers are not using GCs in their classrooms, often due to lack of expertise, negative attitudes to these devices, or just a lack of an environmental support at the workplace (Goos & Bennison, 2007, 2008; Thomas, Hong, Bosley & delos Santos, 2008; Hudson, Porter & Nelson, 2008).

Research questions

The present study investigated the impact of a number of educational variables which are traditionally examined in research dealing with implementing GCs and other digital learning technologies in the teaching and learning of mathematics. These include: geographical location, gender, educational qualifications, teaching experience, training, professional development modes, faculty support, perceptions of self competence, interest in using GCs in teaching and learning, and resources (Forgasz & Prince, 2001; Loong, 2003; Forgasz, Griffith & Tan, 2006; Routitsky & Tobin, 1998; Thomas, 2006; Griffith, 2007). More specifically, the study sought to address the following research questions:

1. At which stage of adoption of GCs do NSW secondary mathematics teachers perceive themselves?

2. How are these stages of adoption related to

   i. Teachers' gender?
   ii. Teachers' interests towards GCs?
   iii. Teachers' experience and academic qualifications?
   iv. Teachers' perception of collegial support in regard to GCs?
   v. Teachers' perception of self competence in using GCs?
   vi. The availability of GCs in school?
   vii. Teachers' previous professional development activities with GCs?

Methodology

Questionnaire

A questionnaire (see Appendix) was designed to measure teachers' stages of adoption and attitudes towards GCs. Specific details about questionnaire design were reported previously by Handal, Chinnappan & Herrington (2004). The questionnaire was adapted to the use of graphic calculators from the *Teachers' Attitudes toward Information Technology Questionnaire (TAT)* version 2.0 (Christensen, 1997b), which has been used in various studies related to the implementation of educational technology such as computers, email, software and multimedia. TAT includes two sub-scales: the *Stages of Adoption* and the *Teachers' Attitudes towards Technology* sub-scales. Studies using the *Stages of Adoption* sub-scale include Christensen (1997a), Christensen and Knezek (1999), Christensen and Knezek (2001), Fraze, Fraze, Baker and Kieth (2002), and Knezek, Christensen, Hancock and Shoho (2000). Knezek and Christensen (1997a; 1997b; 1998a; 1998b) have used the *Teachers' Attitudes Towards Technology* sub-scale in their studies.

The second TAT sub-scale follows Zaichkowsky's (1985) *Modified Personal Involvement Inventory* (PII) and measures teachers' perceptions towards a particular technology. It focuses on the concept of interest and involvement, defined as "a person's perceived relevance of the object based on inherent needs, values, and interests" (Zaichkowsky, 1985, p. 342; Bei & Simpson, 1995). Scores from this sub-scale are reversed before being averaged together to produce a single score. Research by Knezek, Christensen, Miyashita and Ropp (2000) has produced a high test-retest reliability estimate (0.91) for the *Stages of Adoption* sub-scale. In turn, work conducted by Knezek and Christensen (1998a) found a Cronbach's alpha internal reliability coefficient between 0.91 to 0.98 within items of the same sub-scale.

The questionnaire items were adapted to a GC context and subsequently piloted with four academic staff from the Faculties of Education at Macquarie and Wollongong Universities and ten school teachers. Respondents indicated their satisfaction with the semantic aspects of the items.

Sample

Six copies of the questionnaire were emailed to all 406 secondary schools administered by the NSW Department of Education and Training (DET), during September-October 2009. A pre-paid, self-addressed envelope accompanied the questionnaires along with a letter addressed to the school principal assuring anonymity and confidentiality. The letter requested school principals to pass on the questionnaires to the head teacher mathematics and the mathematics teachers in their schools who have taught or were currently teaching the Mathematics General Course, Years 11 or 12. Information for completing the form and details about the research study were also provided.

A total of 58% of schools returned the questionnaire and 587 teachers of the General Mathematics course participated in the study. Satisfactory return rates by DET region are shown on Table 1, adding strength to the data.

Data analysis

Descriptive statistics such as analysis of means and medians were used to characterise measures of central tendency among the variables. The dependent variable was *stages* *of adoption*. The independent variables were educational region, gender, educational qualifications, teaching experience, training, professional development modes, faculty support, perceptions of self competence, interest in using GCs in teaching and learning, and number of calculators. The relationship between variables and questionnaire items for the statistical analysis is shown Table 2.

Table 1: Survey return rate

DET region	%	DET region	%
New England	50	South Western Sydney	51
North Coast	55	Sydney	58
North Sydney	49	Western NSW	57
Riverina	76	Western Sydney	58
South East Illawara	68	Hunters Central Coast	65

Table 2: Questionnaire items and variables

Variable	Item	Question
Gender	Q1	Gender
Educational qualifications	Q2	Highest completed educational qualifications
Teaching experience	Q3	Years of teaching experience
Training	Q4	Have you ever received any training on GCs?
Professional development modes	Q5	Check the option that best describe your training on GCs
Support	Q6	What level of support exists in your faculty for using GCs?
Competence	Q7	How would you rate your competence using GCs?
Number of graphics calculators	Q8	How many GCs does your school own?
Interest	Q9	Choose one location between each adjective to indicate how you feel about teaching and learning using GCs
Stages of adoption	Q10	Please read the description of each of the six stages related to the adoption of graphics calculators. Choose the stage that best describes where you are at.

Through multiple regression analysis, the study looked at the degree of univariate correlation between the dependent variable (teachers' stages of adoption) and the set of independent variables as outlined above. The level of significance for all statistical tests was set at 0.01 (two-sided tests). The model was used for explaining and identifying the most important factors that correspond to higher stages of adoption. The qualitative analysis of teachers' responses to the open section of the questionnaire focused on the variables found to explain stages of adoption. Forty-three percent of the teachers contributed with their comments, suggesting a reasonable interest on the topic.

Quantitative analysis results

To facilitate the statistical analysis, scores were reversed to indicate a positive progression in responses to questionnaire items 6, 7 and 9. The median *educational qualification* range was a Diploma of Education plus a Bachelor Degree in any discipline. The median *teaching experience* range was 16-20 years. Around half (49%) of the participants were female. The median faculty *support* range fell into the "Low" category range on a scale ranging from "None" to "Low", "Medium", and "High". Median perception of self-competence was "Satisfactory" on a scale ranging from "Incompetent" to "Satisfactory", "More competent than other", and "Very competent".

The median range on the *number of graphics calculators* in school was 21-30 per school, which suggests about one class set of GCs for the whole school. Two-thirds of the participants reported having attended some professional development on using GCs and in response to the question, "What best describe your training on graphics calculators?", the following frequencies were obtained (Table 3).

Table 3: Professional development options

Option	Frequency
Teacher journal/magazine	4
College or university	40
Peer/colleague	76
School district office	18
NSW or AAMT conferences	35
Private GC company	145
Teacher self-taught	6

Means of teachers' responses to the ten items of the *interest* sub-scale are shown in Table 4. The scale ranged from 1 to 7, with 7 being the highest possible positive score, and 4 representing a perception lying midway between strongly disagree and strongly agree. The data in Table 4 indicate opinions on the personal *interest* with GCs ranging between "somewhat disagree" and "somewhat agree".

Table 4: Teachers' interest on using graphics calculators

Opinions	Mean	S.D.
Important	3.92	1.817
Interesting	4.71	1.525
Relevant	4.28	1.723
Exciting	4.06	1.521
Means a lot	4.23	1.494
Appealing	4.20	1.677
Fascinating	4.01	1.498
Valuable	4.55	1.533
Involving	4.51	1.499
Needed	3.94	1.869

The median *stage of adoption* of GCs was 3 ("Understanding and application of the process") with Stages 1 and 2 containing 48.5% of the responses while the modal stage was 1 ("awareness"). Responses to the *stage of adoption* item are shown in Figure 1 which shows up the frequency in the lower stages.

Multiple regression was used to investigate the explanatory effect of each independent variable upon the dependent variable *stages of adoption* on the basis of their combined scores. The ten items of the *interest* sub-scale measuring opinions about the personal *interest* towards GCs were also included as independent variables, as in Table 4.

A stepwise multiple regression analysis was conducted to identify explanatory variables based on their contribution to the model. Beta coefficients measure how strongly each independent variable explains the dependent variable. Results in Table 5 show multiple regression beta coefficients for five independent variables that were found to significantly relate to the dependent variable, namely, *competence* ($p < .001$), *important* ($p = .001$), *appealing* ($p = .011$), *support* ($p = .011$) and *training* ($p = .003$).

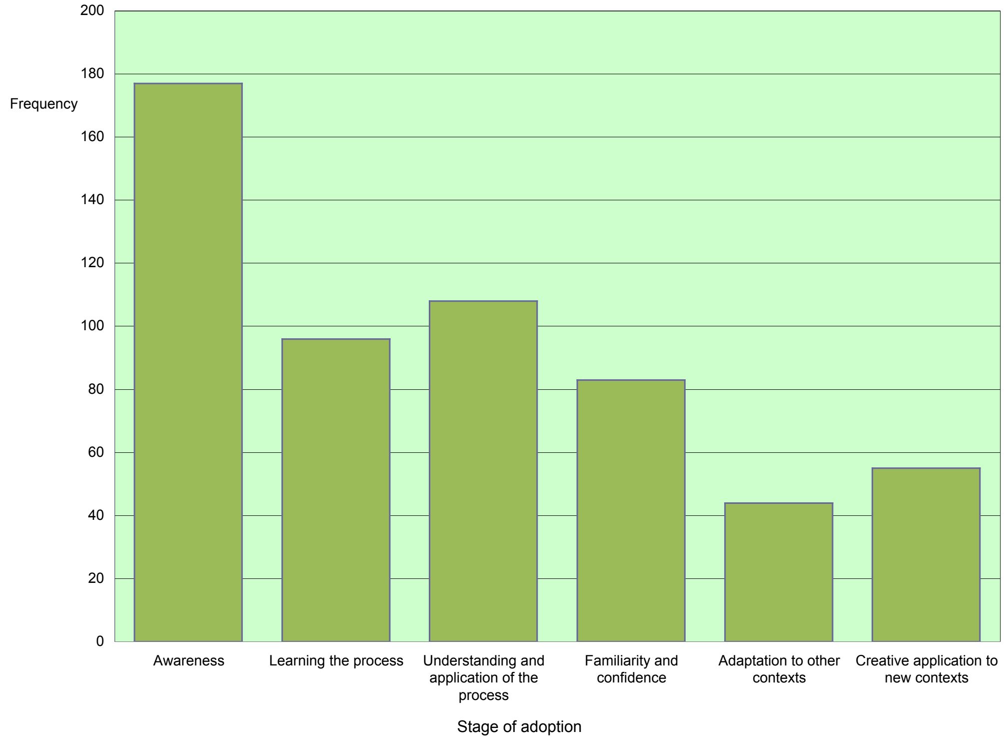

Figure 1: Stages of adoption frequencies

The results also reveal that the model is useful and a good fit for the data (R = .811; R^2 = .658, adjusted R^2 = .655, $p < .001$). Here, R = .811 stands for the multiple correlation coefficient while R^2 = .658 indicates that 65.8% of the variability in stage of adoption can be explained by the combinations of all variables. The multiple regression beta coefficients indicate the average change on the dependent variable when all the other independent variables remain constant.

Table 5: Multiple regression coefficients (first model)
Dependent variable: Stages of adoption

Variables	Beta	Std. error	t	Sig.
(Constant)	-.645	.136	-4.739	.000
Competence	1.237	.059	20.823	.000
Important	.101	.031	3.263	.001
Appealing	.086	.034	2.549	.011
Support	.134	.052	2.560	.011
Training	286	.095	3.017	.003

A factor analysis was conducted among the ten items of the *interest* sub-scale to determine whether or not they measured the same construct. For semantic purposes, the construct is referred to as *interest* following Zaichkowsky's conceptualisation (Zaichkowsky, 1985, p. 342; Bei & Simpson, 1995) as quoted in the Methodology section of this paper. The component matrix extracted a single factor which was corroborated by the eigenvalues plotted against the factor numbers on a scree plot. In general, a scree plot shows the number of factors suitable for a certain analysis before the plotted line turns abruptly to the right. Knezek and Christensen (1998a) also found a Cronbach's alpha internal coefficient of reliability between .91 and .98 for the combined ten items of the *interest* sub-scale. The factor extracted was used in further analysis.

A subsequent multiple regression analysis using the variable *interest* with the previously selected variables (*competenc*e, *support*, *training*) resulted in R = .808, R^2= .653, adjusted R^2 = .651; p = .000. Such results were consistent with the previous stepwise analysis and therefore the four variables (*competence*, *support*, *training* and *interest*), were taken as the basis for explaining the statistical model for this study. Multiple regression coefficients are shown in Table 6.

Table 6: Multiple regression coefficients (refined model)
Dependent variable: Stages of adoption

Variables	Beta	Std. error	t	Sig.
(Constant)	-.743	.152	-4.872	.000
Competence	1.255	.060	21.026	.000
Support	.126	.052	2.408	.016
Training	.242	.095	2.565	.011
Interest	.202	.035	5.235	.000

To corroborate the above results, an ordinal regression treating all exploratory variables as quantitative found the same four variables significant (though *support* has p = 0.048, so marginal). Again, *competence* was the most important predictor, with an odds ratio of 9.67, while *support*, *training* and *interest* have ordinal regressions of 1.22, 1.69 and 1.52 respectively. When *support* and *competence* were treated as ordinal (for consistency), the coefficients were consistent with the above, and with similar distances between them (indicating that the variables could be treated as numeric).

In general, the most important explanatory variable in the model is *competence* - one step up corresponds to 1.26 steps up on the adoption scale, linear regression, or an odds ratio of nearly 10, ordinal regression.

Finally, a univariate analysis of variance was used to investigate the possible differences in stage of adoption between different DET regions - a categorical independent variable not included in the multiple regression; this was carried out with the four previously identified explanatory variables (*competence*, *support*, *training* and *interest*) as covariates. Since region had a non-significant p-value (0.39), it did not seem to be required in the model.

Qualitative analysis results

The quantitative results in Table 6 are important because they identify four variables that explain around two-thirds of the variability in stages of adoption. These variables are: perceptions of *self competence* (or *competence*, for the sake of brevity), faculty *support*, *training* and personal *interest* towards GCs. Furthermore, perception of *self competence* is identified as the most important factor, suggesting that one more step on the competence scale yields an increment of 1.26 on the stage of adoption scale. Similarly, increments by a quarter on the stages of adoption scale can possibly be attributed to *training*. Minor increments occurred due to personal *interest* and faculty *support* effects.

A subsequent qualitative analysis examined teachers' responses to the open ended section of the questionnaire in regard to the four aforementioned explanatory variables.

Competence and training

It seems logical to relate perceptions of *self competence* to *training* because one naturally follows the other, provided that professional development is systematic, contextualised and sustainable. As some teachers stated:

> I would be keen and confident enough to use the graphics calculators, but haven't been exposed to them yet. It is a positive move forward and would help relate to my current use and increasing knowledge of smart board technology.
>
> Unless I can use something proficiently, I am not comfortable teaching it. I have had a couple of inservices, but they only skim the surface. They don't prepare you for classroom use.
>
> We need ongoing support if we are to use the calculators. One-off training sessions are not good enough.

The average age of a public school teacher in NSW is 47 years (Handal, Chinnappan & Herrington, 2004), so most teachers have left their teaching training long ago. In addition, the median teaching experience in this study ranges between 16-20 years, so it is likely that many teachers have not been sufficiently exposed to learning technologies such as GCs. The lack of teacher professional development is exacerbated by the fact that most teachers in the study undertook training through private companies, where sessions are typically not more than two hours in duration.

In fact, teachers' comments in the open section of the questionnaire indicate a demand for more integrated professional development programs on GCs:

> Teacher education on how to use graphics calculators properly for specific tasks is lacking. Most of us are expected to use graphics without any real instruction on how to use them. We are learning after the fact - this is not good enough - the same is true for the new laptop introduction - EDUCATE TEACHERS FIRST, many of us are willing we just need help.
>
> The inservice I had was nine years ago and due to that and lack of practice I've forgotten how to use them. A brush up would be good, but teachers do get little time to do things like that without a fair bit of pushing (especially older ones like me!).

Faculty support

Lack of faculty *support* for using GCs in the classrooms is illustrated by the following comments:

> The implementation of GC in secondary schools is completely dependent upon the executive's attitude towards the expense and effort.
>
> School based support/excitement for using these calculators is nil. I use them at uni, and can see how they would be exciting and very enriching for advanced/extension students. Our class set of graphics calculators is sitting underneath the computer table in our staffroom gathering dust. Sad.
>
> There hasn't been enough push for using graphics calculators from above.

Perceived personal interest with GCs

A diversity of controversial and conflictive opinions about the role of GCs in instruction is revealed in teachers' responses to the open section of the questionnaire. Such contradictions are also reflected in the quantitative results of the *interest* sub-scale in Table 4 where two of the items yielded scores less than 4 (out of a maximum five points) such as *important* (mean score = 3.92) and *needed* (mean score = 3.94). Also the statistical analysis in Table 5 shows that *importance* and *appealing* were found as the least influential factors in explaining stages of adoption.

Firstly, some teachers are interested in GCs because they bring the visual and modelling dimensions into the teaching and learning of secondary mathematics.

> 2009 is the first year our school has purchased and used graphics calculators for our General students. I can see the benefits of using these calculators, allowing band 3 students to access and attempt some band 5 and 6 questions.
>
> Graphics calculators provide an opportunity for students to explore mathematical understanding with less teacher direction.
>
> Graphics calculators are a great tool to reinforce/support most concepts.

Other teachers feel that GCs are not relevant to instruction but rather inhibit the development of problem solving, computational and graphing skills.

> Graphics calculator use means students are not using their brains to think and problem solve. The technology is doing all the thinking and solving for them. It is another piece of technology that is aiding in the 'dumbing down' of teaching and learning.
>
> I firmly believe that they encourage poor learning with regard to certain skills due to a loss of hand-written graphing abilities. These are good for demonstrating after these basic skills have been learnt – not before.

Yet, there is another group of teachers who believe that GCs are relevant only to more advanced students:

> I feel that graphics calculators are far more useful for more academic students. Using graphics calculators without basic understanding of concepts I believe is useless!
>
> I am competent using graphics calculators BUT I do not believe they have a place in the General Maths Course. I do believe they have a role which could be played in the more "Pure" mathematics course assuming that questions are written which require working to be shown. As an introduction tool I find other graphics programs & data projector more useful.

Perceived *interest* with GCs is also expressed in terms of students' ownership and affordability:

> Our students don't own graphics calculators, so they won't use them in HSC. Hence used in very limited way by faculty.
>
> Until they are made freely available to all students then I do not believe they should be allowed.

Another group of teachers feels that GCs are not relevant because their use is not permitted in the examinations for the other three NSW HSC mathematics courses.

Among all Australian states and territories, NSW is the only one which does not allow all students to use GCs in their end of school examinations. In this regard, teachers' comments illustrate that opinion:

> Graphics calculators are not allowed in HSC examination (and consequently trial and assessment tasks) so the importance given to them and their use in classrooms is low. Students are still required, in examinations, to work without this tool. To me this presents a conflict between teaching and preparation for the HSC examination.
>
> As the HSC for gen[eral] maths still requires candidates to show working into a specific formula, the need for graphics calculators in exams is minimal (if at all).

The advent of the National Curriculum and the nationwide standardisation of those examinations and technology and teaching requirements might make the implementation of GCs a priority for the NSW Department of Education and has put some faculties on hold. As a teacher put it:

> We are now looking to the National curriculum and what calculators will be specified.

Nevertheless, teachers from other states illustrate their feelings about their instructional skills with GCs and what they came to experience in NSW:

> We do not have any graphics calculators at our school. I have used them when I taught in Qld and found them very valuable.
>
> I have come from Victoria where we have used GCs for at least 15 yrs across all HSC courses, including in exams. I am shocked at the lack of use of technology in the NSW Maths curriculum, certainly at my school.

Finally, the *interest* towards using GCs in teaching and learning mathematics is being challenged by the arrival of laptops and free web applications which appear to render the same functions, although with obvious restrictions in portability and compactness. Some teachers stated:

> There are better computer based software like *Geogebra* which can interface with other softwares like Microsoft *Word* and web browsers. This provides wider applications than graphics calculators. Graphics calculators are good for its compactness.
>
> Computer software/IRW more relevant. With many schools having access to technology such as computers and ever developing software, combined with the expense and lack of students ownership, the use of these is becoming less relevant to students and teaching.
>
> Prefer to use computer graphing. Find calculators screen too pixelated. They're not used in work so don't feel they're too important. The menu system is not intuitive – too time consuming to learn.

Discussion and conclusions

This study has shown that personal expertise, positive attitudes and faculty support in using GCs are vital to adoption. Furthermore, it has revealed that traditional differential effects in education such as gender, educational qualifications, geographical location and availability of technology did not play an important role in increasing adoption of GCs, as some may have expected.

It is noteworthy that the four explanatory variables (*competence*, *support*, *training* and *interest*) seem to be related to the concept of personal expertise, as opposed to the other variables that were found statistically non-significant, such as educational region, gender, qualifications, teaching experience, and number of calculators in the school. One might argue that these last five variables appear more system related and therefore more difficult for an individual teacher to change, at least in the short term.

The results of the study are discouraging. After ten years of the General Mathematics course in NSW, the teachers are still in the "Understanding and application of the process" stage, the third lowest on a six-point scale. This is much lower than the adoption levels reported by Fraze, Fraze, Baker and Kieth (2002) researching Internet technologies usage, and Christensen and Knezek (2001) investigating a broader range of educational technologies. In addition, in the present study the average number of GCs was 21-30 which makes only one class set per school, while the average level of faculty support is reported as "Low". Most of the professional development reported by teachers was sporadic and left in the hands of commercial firms and professional associations.

Teachers seem to be caught in an official contradiction: they believe that GCs are good for learning and teaching in the General Mathematics course but are not acceptable in the other three Calculus courses (Mathematics "2-Unit", Extension 1 and Extension 2), probably because either they are seen to be detrimental to learning or because of the disalignment between assessment and classroom practice. These dilemmas, a form of hidden curriculum, influence teachers' opinions on getting interested and involved with Gcs, causing a conflict as revealed in some of the teachers' comments. This also might be reason why most teachers' opinions about their *interest,* defined as "a person's perceived relevance of the object based on inherent needs, values and interests" (Zaichkowsky, 1985, p. 342), with GCs ranged between "somewhat disagree" and "somewhat agree".

Many reservations about GCs appear to be centred on de-skilling students, a common complaint against the use of technologies, corroborating results reported by Goos and Bennison (2008) and Thomas, Hong, Bosley and delos Santos (2008). It follows that teachers need to be reassured that technology can be useful for developing higher order learning skills Professional development activities should be pitched at the highest level of adoption where teachers can creatively use GCs as an instructional tool and integrate it into the curriculum. As one teacher commented, "Knowing how to use a wheelbarrow does not make you a good gardener."

Other issues emerging from the research are equity and the advent of other learning technologies. Will GCs survive alongside free web applications, laptops and touch and mobile devices? *Excel* spreadsheets, software like *Winplot* and GCs have coexisted in schools for many years as modelling and graphing tools, although GCs have the advantage of compactness, particularly for examination purposes. On the another hand, teachers' demands for GCs with more intuitive navigation, affordability, online connections and better compatibility with other interfaces are valid and need to be addressed by manufacturers, particularly since the NSW DET has announced that from 2010 each Year 9 student will receive a laptop under the *Laptops4Learning* (L4L) program (NSW DET, 2009).

It is interesting to note that the number of GCs in a school did not come up as an explanatory factor in the adoption model, although a previous study on computers

(Thomas, 2006), making use of descriptive statistics, indicated the importance that teachers ascribe to resourcing. In fact, many teachers' comments in the open section of the questionnaire complained about the small number of GCs owned by the school, as well as the prohibitive cost of a GC for students from disadvantaged backgrounds. The lack of student personal ownership of GCs is certainly an issue. Yet, at the school resourcing level, there is evidence from the responses that even when GCs are made available, they are not being utilised. Furthermore, it can be argued that a productive and vibrant mathematics lesson can be run with only one GC, so long as it is operated by a resourceful teacher in interaction with the class.

An important point is that simply stocking schools with new technologies will not necessarily lead to their automatic adoption or most effective adoption. In general, building teachers' competence with the technology is vital (Forgasz, 2002; Thomas, 2006). As corroborated in this study, the most explanatory factor in the adoption model was perception of self competence. In general, competence is best achieved through systematic, sustained and accessible professional development. Such training endeavours must focus not only on GCs navigational aspects but also on using the technology productively and creatively, so that teachers are assured of its instructional value.

Appendix: Questionnaire

Appendix: Questionnaire is contained in the accompanying file 'handal-appendix.pdf', URL http://www.ascilite.org.au/ajet/ajet27/handal-appendix.pdf

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