Proceedings of the
2nd National Conference on Graphing Calculators
October 4–6, 2004 • 29–43

# MEASURING THE ADOPTION OF GRAPHIC CALCULATORS BY SECONDARY MATHEMATICS TEACHERS

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**ABSTRACT**

*The low level of use of graphic calculators by mathematics teachers is a major concern of curriculum developers and teacher educators. While several reasons have been advanced to explain this situation, recent developments have shown that there is a need to examine not only teachers' skills in the use of the calculators but more importantly the link between teachers' attitudes and beliefs about mathematics and the use of graphic calculators to support classroom instruction. In this paper we describe an instrument (Teachers' Attitudes Toward Information Technology Questionnaire, TAT) that would allow researchers to generate data about the above link and develop strategies for encouraging a higher and more effective use of graphic calculators by mathematics teachers.*

## 1 INTRODUCTION

Graphic calculators have been in the educational arena for nearly fifteen years. Both private and public educational systems have spent large amounts of money in the past two decades acquiring these hand-held devices and a massive number of professional development courses have been run to prepare teachers. Graphic calculators have the potential to become an integral part of school mathematics curriculum because they assist students in obtaining a better association among mathematical ideas, enhance spatial-visualisation skills and foster a deeper understanding of graphing and functions, among others [1]. Although much has been written about the students' cognitive and affective gains due to the use of graphic calculators, little research has been conducted on the actual take-up of these devices in schools. There is some evidence of teachers' negative attitudes towards technology, and in particular, to graphic calculators which can be inhibiting their implementation [2,3]. It is therefore important to examine teachers' actual levels of and barriers to adoption of graphic calculators in order to guide further implementation initiatives.

## 2 GRAPHIC CALCULATORS

Graphic calculators have been shown to be advantageous in teaching and learning mathematics for several reasons. Basic graphic calculators include the same capabilities as scientific calculators in allowing for graphical representation of data and algebraic equations. As the level of sophistication increases, these capabilities may include programming, large memory, data analysis, financial calculations, numerical equation solving, data analysis, fractals and binomial probability distribution tables. These capabilities also include graphing, matrix and complex number arithmetic, regression and elementary hypothesis testing, and simultaneous display of graphs. There is research showing gains in students' learning outcomes that may be attributable to the use of graphic calculators particularly in the learning of functions [4]. In general, it appears that the benefits gained from using graphic calculators may lie in their utility to represent and link data in algebraic, graphical, or tabular formats, thereby creating a more meaningful learning environment [5].

Graphic calculators also permit students to simulate or modify various mathematical situations for modelling and investigative purposes enabling student-centred learning and higher order thinking [6]. Studies conducted by Galbraith, Renshaw, Goos, and Geiger [7] also indicate that graphic calculators may foster a better interaction between students and teachers. Additionally, graphic calculators hold some logistical advantages over desktop computers. They are cheaper than desktop computers and more affordable when large numbers are required. Graphic calculators are also smaller in size and therefore more portable. For example, they can be taken to the classroom, home or to an excursion for field work. Unlike desktop computers, graphic calculators come with their own software without the need for extra purchasing. Graphic calculators can also be connected to other peripheral devices such as printers or desktop computers.

## 3 TECHNOLOGY EDUCATION IN SCHOOLS

Educational reform is a complex phenomenon where many innovations, particularly in mathematics education, have not been successful [8]. Teachers' adoption of a particular innovation is now seen as an equation consisting of several instructional, curricular and organisational factors. Knezek, Christensen, Hancock, and Shoho [9] have argued that effective educational change using technology requires more than just well-designed curricular packages or extensive professional development programs. According to these authors, for an innovation to succeed in educational technology the existence of supporting teachers' beliefs and attitudes accounts for approximately 40% of the total change necessary. In turn, skill competence accounts for the 30% of the total while a significant portion of the remaining sector relates to access to technological tools. Kissane [10] writes:

> Teachers are a crucial part of any process of curriculum change, and need to be supported in various ways. Through the lens of the implemented curriculum, the opinions and practices, beliefs and competencies of the teacher are a critical part of the curriculum. Curriculum developments that do not adequately provide for the legitimate needs of teachers do so at their peril (p. 70).

Several studies show that the use of technology may bring about a positive change in classroom interaction as well as in learning outcomes [11,12]. Although educational administrators have invested significant resources, literature suggests that technology has not been well implemented in schools [12,13]. Disappointing results in the implementation of educational technology initiatives in the last decades has led some critics to form the view that the so-called computer revolution is failing to rise [13,14]. The low take up of educational technology observed in the last twenty years indicates that the implementation process is very intricate indeed and more complex than the original model of simply purchasing and installing large numbers of computers [15]. Many explanations have been advanced for a lack of technological adoption by teachers including conservative beliefs about the nature of mathematics and the nature of teaching and learning mathematics. Other variables include: lack of professional assistance, insufficient preparation time, unavailability of proper educational software and hardware, among others [3,14].

## 4 TEACHERS' BELIEFS ABOUT USING EDUCATIONAL TECHNOLOGY

Research on teachers' pedagogical beliefs and their effect on curriculum implementation has gained prominence in the last twenty years. Teachers' beliefs, amongst a range of factors, appear to influence instructional behaviour as well as student achievement. These beliefs encompass a broad range of personal assumptions about what teaching and learning is and should ideally be, and therefore predict instructional practice (you teach the way you believe a subject-matter should be taught). Beliefs, in general, are propositions that, although not necessarily veritable, are seen as true by the person holding the belief. They include beliefs about the nature of knowledge, assessment, textbooks, self-efficacy, school culture, instructional strategies, among others. A teacher belief system is a sort of personal and private curriculum that acts as an interface between curriculum theory and practice. The literature reveals that if teachers' pedagogical beliefs are not congruent to the beliefs that sustain an educational reform, the outcome of such a mismatch can impinge on the success of the innovation [8].

Teachers' beliefs about the worth of technology in education have been discussed as partial predictors of the low take-up of information and communication technologies (ICT) in schools. Despite strong support from the literature showing the beneficial effects of ICT in education [11], there is evidence that a significant number of teachers are still unsure about the ability of these tools in enhancing students' learning outcomes. Research reports indicate that there are teachers who believe that computers are "an add-on", and "optional activity", "supplemental" and "a way to keep kids busy" [15, p. 62]. In one occasion, a teacher perceived "the classroom computer not as a teaching tool but kind of a rewards kind of thing, like when kids are done with their work". Mills and Ragan [16] surveyed 30 U.S. elementary teachers and found differences in their levels of adoption of ICT in teaching and learning which was ascribed to variations in teachers' beliefs about the worth of technology in education. In a study with 60 Australian teachers, Newhouse [12] found that even when teachers had the necessary ICT technical skills, some of them were still have the opinion that traditional teaching was the most useful pedagogical approach. Similar findings have been documented by Niederhauser and Stoddart [17] surveying 2170 school teachers and Becker [18] examining the pedagogical beliefs and practices of 4083 middle and high school teachers. In those studies, unfavourable teachers' beliefs about the worth of ICT in the classroom stand as one of the major barriers to successful implementation.

Research on teachers' beliefs about graphic calculators is limited. Related studies with four-function calculators reveal that a significant number of teachers consider these devices as an impediment to the development of numeracy skills rather than as a problem-solving tool. Many teachers still believe that using calculators inhibits students' acquisition of computation skills and therefore should not be used in class [19]. Similarly, Milou [2] surveyed 146 middle and high school U.S. about their use of graphics calculators in the classroom and found that many of the participants found the use of graphics calculators in the teaching of algebra to be problematic. Most of their concerns were associated with the possible loss in students' computational skills. These findings raise major implications for the use of graphics calculators in the mathematics curriculum as these negative beliefs could militate against future implementation.

Teachers' mathematical beliefs can be explained as an outcome of past personal experiences (you teach mathematics the way you were taught mathematics). There are many avenues leading to the formation of a teacher's belief system. Richardson [20] stated that many teachers' beliefs on how to teach mathematics derive from years sitting and listening to a variety of teachers in school. Once in the teaching career, teachers enact the same beliefs and consequently reproduce instructional behaviors. Pajares [21] suggested that this process resembles an apprenticeship style in learning how to teach. Mayers [22] adds that:

> Many prospective teachers believe that subject matter such as mathematics at the elementary level is "simple" … and that already [they] know enough to start teaching before they even begin their professional studies. They believe some more methods and a little classroom management would be helpful, but they believe they know enough about what they are going to teach and how. What they do not know, they believe they will learn in school classrooms. Veteran teachers who tell them that the primary benefit of teacher education is the opportunity to do field work, especially student teaching, reinforce this belief (p.13).

There is some evidence that in some cases, teacher education programs are too busy concentrating on imparting pedagogical knowledge with little consideration given to modifying beliefs. Consequently, some teacher education programs might have little effect in producing teachers with beliefs consistent with curriculum innovation and research [23]. For example, Marland [24] found that reasons given by inservice teachers on their use of classroom strategies, were not related to what they were taught in their college training. There is also some evidence confirming that teachers' decision making does not rely solely on their pedagogical knowledge but also on what they believe the subject-matter is and how it should be taught [25,26]. These beliefs are hard to change and very often conflict with educational innovations threatening educational change [7,27].

The literature shows that teachers also develop their own beliefs (or teachers' implicit theories) in the course of their careers. In Marland's [24] words, "Teachers' implicit theories of teaching are thus the products of teachers' efforts to make sense of their experiences and to generate a basis for effective action in the classroom". These beliefs are acquired in a "clinically way of looking at the world" which is similar to the methods experienced by medical doctors [28]. Nespor [29] adds that given the unpredictability and uniqueness of classroom events, teachers have to resort to their own beliefs particularly in pedagogical situations when formal knowledge is not available, it is disconnected, or cannot be retrieved**.** Richardson [20] also points to personal experiences as factors shaping teachers' beliefs. By personal experiences, Richardson [20] includes aspects of life that go into the formation of world view; intellectual and virtuous dispositions; beliefs about self in relation to others; understandings of the relationship of schooling to society; and other forms of personal, familial, and cultural understandings. Ethnic and socio-economic background, gender, geographic location, religious upbringing, and life decisions may all affect an individuals' beliefs that, in turn, affect learning to teach and teaching" (p.105). In particular, it seems that culture makes a differential effect on teachers' beliefs [30]. Laurenson [25] adds other factors that influence formation of beliefs and teaching practices. Laurenson claims that because of the influence of behaviourism, there has been great pressure on teachers to align to a strict and rigid set of instructional objectives which has restricted teachers' creativity. Also, administrative constraints like enforcing lesson plans, are accountable for the development of negative beliefs about teaching. Likewise, Laurenson suggests that teachers sometimes choose easier academic tasks that result in smooth learning environments rather than planning lessons where students are challenged with difficult work. Laurenson is also of the opinion that limited knowledge of the subject matter, such as knowledge of technology, inhibits teachers' ability to organize a lesson effectively. Finally, many teachers come from an education background where the only technology was the blackboard. In NSW, for example, the average teachers' age is 47.

## 5 TEACHERS' LEVELS OF ADOPTION OF TECHNOLOGY

Teachers' adoption of innovations is an important measure of successful educational reform. Several schemes have been designed to evaluate degrees of adoption in technology education. Christensen [31,32], presented six stages through which teachers go through in their process of adopting technology in their instructional practice. According to Christensen [31], teachers can start at any point and develop at their own rate. The stages comprise: (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.

A typical teacher in the first stage would admit that either he or she was not aware of a particular technology, has not used it or avoids using it. In the second stage, a teacher would admit that he or she is in the process of learning technology but is still not confident in using it. Stage 3 characterises teachers that have begun to understand the process of using technology and are able to identify specific tasks that can be relevant to them. Teachers situated in the next stage have a growing sense of confidence and feel comfortable in using technology. At stage 5, teachers are no longer worried about the technology itself but are more concerned about a broader range of applications and use as an instructional tool. In the final stage teachers are not only confident but feel willing enough to creatively integrate technology in the classroom. Fraze, Fraze, Baker and Kieth [33] studied 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). Similar findings were corroborated by Christensen and Knezek [34] investigating 508 school teachers and Christensen [32] working with 25 elementary teachers. All these studies were carried out with samples from the USA. In those studies, the terms *technology adoption* were taken to represent electronic e-mail skills, using the Internet, classroom use of integrated applications, and incorporating methods of teaching with technology tools.

Stages of adoption of technology can be measured through instruments such as the *Teachers' Attitudes Toward Information Technology Questionnaire* (TAT) (Appendix). TAT has been successfully used in a number of studies aimed at identifying various types of technology in education such as e-mail, computer, and multimedia, among others. The questionnaire was developed by Ronda Christensen [32] at the Texas Center for Educational Technology and consists of two sub-scales: the Stages of Adoption and the Teachers' Attitudes Toward Technology sub-scales. The Stages of Adoption sub-scale has yielded a high test-retest reliability estimate (0.91) from research conducted by Knezek, Christensen, Miyashita, and Ropp [35] while the semantic items of the Teachers' Attitudes Towards Technology sub-scale have yielded a Cronbach's Alpha internal reliability coefficient between 0.91 to 0.98 [36]. The semantic items from the Teachers' Attitudes Towards Technology sub-scale are originally taken from Zaichkowsky's [37] Modified Personal Involvement Inventory (PII), an instrument that focuses on the concept of involvement that is defined as "a person's perceived relevance of the object based on inherent needs, values, and interests" (p. 342). Scores from this sub-scale need to be reversed before being averaged together to produce a single score.

Survey studies in the form of questionnaires have the power to obtain information from large samples. They also permit the measurement of educational variables as well as the relationship among them [23,38,39]. Research has extensively used questionnaires to identify and characterise teachers' mathematical beliefs and espoused instructional practices. Semantic items are usually written to offer the participant a number of pre-established statements. The diversity of semantic items in a questionnaire offers the participants a wide range of standardised opinions from which to select those which most closely describe their own. The responses are subsequently analysed by statistical methods. Examples of large scale studies on teachers' beliefs and espoused practices conducted using semantic scales include the International Association of Educational Achievement (IEA) [30], the National Assessment of Educational Progress (NAEP) [40] and the Third International Mathematics and Science Study (TIMSS) [41]. These questionnaires collected a broad range of information such as attitudes, beliefs, teaching methodologies, resources and achievement. A large number of questionnaire studies on teachers' beliefs and espoused practices base their analyses on statistical comparison of mean scores from scale items in order to determine the magnitude and direction of these beliefs and practices. This approach is also used to identify the effect that traditional differential variables in education such as teachers' gender, faculty position, academic qualifications, years of teaching experience and teaching socio-economic area have on teachers' beliefs and espoused instructional practices. Examples of these include Eisenhower National Clearinghouse for Mathematics and Science Education [41], Frank [42], Howard, Perry, and Lindsay [43], Kifer and Robitaille [30], Perry, Howard, and Tracey [44], and Southwell and Khamis [45].

Research in progress at the University of Wollongong involves the use of a modified version of the TAT instrument that will be used in a major survey study in the state of New South Wales (NSW), Australia. The purpose of the study is to characterise the degree of adoption of graphic calculators in the NSW General Mathematics Course (Year 11 and 12). It also seeks to evaluate the impact of traditional differential variables in the implementation of educational technology. Whereas the original TAT refers to technological adoption in general, i.e, electronic mail, computers and multimedia, the modified version specifically addresses the adoption of graphic calculators issues as it relates to mathematics teaching and learning. As such, the modified version accommodates a number of independent and dependent variables for statistical analysis. The independent variables are: teachers' gender, teaching experience, academic qualifications, location, perception of collegial support, teachers' professional development, perception of self-competence and teachers' attitude towards graphic calculators. The dependent variable will be teachers' stages of adoption.

It is expected that the instrument will be available online through the intranet of the NSW Department of Education and Training to be completed by all secondary mathematics teachers of the General Mathematics Course. The General Mathematics Course is the only one of the four Higher School Certificate (HSC) courses that allows graphics calculators in its end-of-school final external examination. Nearly half of the students sitting for the HSC are enrolled in the General Mathematics course. Teachers are encouraged in the General Mathematics Course syllabus to use graphics calculators in the classroom.

The TAT modified version will also enable us to collect information on teachers' perceptions of self-competence and collegial support with regard to graphic calculators. Teachers' beliefs of self-competence as well as of collegial support in innovation initiatives have been documented by several authors although there is a lack of research in the field of graphic calculators. A major obstacle to implementing innovations in mathematics education is teachers' perceptions and reaction to peer pressure to resist innovations [46]. For example, Wilcox, Schram, Lapan, and Lanier [47] found this resistance and lack of collegial support with respect to small group learning and large group learning experiences, and Rogers [48] observed this resistance in introducing calculators as instructional tools. On the other hand, there is evidence that some school administrators maintain subtle policies that enforce traditional teaching and are doubtful and suspicious of innovations in mathematics education [46]. Perception of self competence, as outlined in this research, will provide an indicator of teachers' own assessment of graphic calculators skills. Such an indicator is necessary to relate the degree of teachers' expertise to levels of adoption and therefore recommend appropriate courses of action to curriculum policy-makers. Perception of self-competence is also linked to teachers' beliefs of their own efficacy. Bandura [49] defines self-efficacy as "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p. 2). Self-efficacy is a construct worth examining in the implementation of graphics calculators because such a perception affects both instructional behaviour and students' performance particularly in computing studies courses [50].

In addition the modified TAT version will generate information about the level of teachers' professional development in using graphics calculators as well as the number of graphic calculators provided by their schools. The modified TAT version will also contain an invitation to respondents to participate in a subsequent interview study. The collection and subsequent statistical analysis of such a broad range of data will characterise and quantify factors that appear to mediate the implementation of graphics calculators in NSW as well as extend the existing body of literature on implementing graphic calculators in teaching and learning mathematics. The modified TAT version has been trialled with secondary mathematics teachers in NSW.

## 6 SUMMARY

Despite the considerable resources that are made available to schools, there is evidence of a significant number of teachers who have not taken up the use of graphic calculators in their classrooms for lack of expertise, negative attitudes to these devices or just lack of support at the workplace. Levels of adoption of graphic calculators are worth measuring because they provide an indicator of the success of implementation initiatives, point to future policy recommendations, and allow for comparison across different samples. Such measures can also give us an indicator as to how other traditional differential variables have an effect on those levels. These variables might include teaching experience, teachers' instructional beliefs on technology, gender, academic qualifications, teaching socio-economic area, collegial support, perception of self-competence, among others. Given its capacity to relate data on teachers' personal characteristics to their instructional beliefs and adoption levels, the modified *Teachers' Attitudes Toward Information Technology Questionnaire* (TAT) stands out as a promising tool to examine potential pitfalls in the implementation of graphics calculators.

# APPENDIX

## Modified Version of the Teachers' Attitudes Toward Information Technology Questionnaire (TAT)

## USING GRAPHIC CALCULATORS IN THE GENERAL MATHS COURSE

The current Year 11 and 12 General Maths course recommends the use of graphic calculators in the teaching and learning of mathematics. This questionnaire is designed to assess your perceptions of the use of graphic calculators in your current General Maths classes. It should require about 5 minutes of your time. Usually it is best to respond with your first impression, without giving a question much thought. Your answers will remain confidential.

Thank you for your cooperation!

| | | |
|---|---|---|
| **Gender**: choose one | **Code:** Enter any set of four letters (For example: PKYL) | **School:** Choose a school |
| **Highest *completed* educational qualifications:** select | | **Years of teaching experience:** select |

## Section 1

| **Have you ever received any training on graphic calculators?** | Yes | ○ | No | ○ |
|---|---|---|---|---|

If **Yes**, check the option that *best* describes your training on **graphic calculators.**

| | | | |
|---|---|---|---|
| Teacher Journal/Magazine | ○ | College or University | ○ |
| Peer/Colleague | ○ | School District Office | ○ |
| NSW Mathematics Association Conference or AAMT Conference | | | ○ |
| Private Company (*Casio, Hewlett-Packard, Sharp, Texas Instruments*) | | | ○ |
| Other | ○ | | |

| What level of support exists in your faculty for using graphic calculators? | How would you rate your competence using graphic calculators? |
|---|---|
| select | select |
| How many graphic calculators does your school own? select | |

## Section 2

Choose one location between each adjective pair to indicate how you feel about teaching and learning using **graphic calculators**.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1. | important | ● | ● | ● | ● | ● | ● | ● | unimportant |
| 2. | boring | ● | ● | ● | ● | ● | ● | ● | interesting |
| 3. | relevant | ● | ● | ● | ● | ● | ● | ● | irrelevant |
| 4. | exciting | ● | ● | ● | ● | ● | ● | ● | unexciting |
| 5. | means nothing | ● | ● | ● | ● | ● | ● | ● | means a lot |
| 6. | appealing | ● | ● | ● | ● | ● | ● | ● | unappealing |
| 7. | fascinating | ● | ● | ● | ● | ● | ● | ● | mundane |
| 8. | worthless | ● | ● | ● | ● | ● | ● | ● | valuable |
| 9. | involving | ● | ● | ● | ● | ● | ● | ● | uninvolving |
| 10. | not needed | ● | ● | ● | ● | ● | ● | ● | needed |

## Section 3

**Instructions:** Please read the description of each of the six stages related to the adoption of **graphic calculators.** Choose the stage that best describes where you are at.

| | |
|---|---|
| ● | **Stage 1: Awareness**<br>I am aware that graphic calculators exist but I have not used them - perhaps I'm even avoiding it. I am anxious about the prospect of using graphic calculators. |

| | |
|---|---|
| ● | **Stage 2: Learning the process**<br>I am currently trying to learn the basics. I am sometimes frustrated using graphic calculators. I lack confidence when using graphic calculators. |
| ● | **Stage 3: Understanding and application of the process**<br>I am beginning to understand the process of using graphic calculators and can think of specific tasks in which it might be useful. |
| ● | **Stage 4: Familiarity and confidence**<br>I am gaining a sense of confidence in using graphic calculators for specific tasks. I am starting to feel comfortable using graphic calculators. |
| ● | **Stage 5: Adaptation to other contexts**<br>I think about graphic calculators 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. |
| ● | **Stage 6: Creative application to new contexts**<br>I can apply what I know about graphic calculators in the classroom.<br>I am able to use it as an instructional tool and integrate it into the curriculum |

**Would you like to participate in a follow-up of your ideas about graphics calculators?**

If **Yes**, my contact details are:

Name:

Home Phone number:

School Phone number:

Email:

Thank you for your time

Submit Query    Reset

Please click the button only once.

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