

# Can graphics calculators change pedagogical practices in the secondary mathematics classroom?

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**Abstract.** Quality education is essential for the workforce and society and ICTs are claimed to contribute to quality education. In particular, graphics calculators (GCs) have gained widespread acceptance in secondary school mathematics classrooms. They provide a vastly cheaper vehicle, in comparison to computers. However, acceptance of ICT has not been uniform and it can be argued that there are five broad categories of ICT integration into the classroom. Teachers tend to view ICT as either: a demon; a servant; an idol; a partner; or, as a liberator. This has an influence upon student learning. The traditional classroom associated with teacher centred pedagogy and behaviourist learning principles can also impede quality learning. This paper will examine the claim that GCs act as a 'pedagogical Trojan Horse' moving teachers towards student centred classroom strategies. When unleashed within the classroom, handheld technologies can alter the very nature of the teaching and learning process. As teachers and students gain in confidence and experience in the use of the technologies, the speed of transformation increases.

## BACKGROUND

The world of the twenty-first century is characterized by the development of 'knowledge economies' wherein a nation's social cohesion and economic prosperity depend upon a skilled and knowledgeable citizenry. The world of the twenty-first century is also characterized by change and uncertainty. Those involved with education and research are concerned with the effects of this uncertainty and the types of knowledge and skills that are needed as a response. Poverty, political conflict, and a lack of teachers and infrastructure can hamper access to education. It is in this context that the role of the teacher and the place of technology needs to be considered. Most governments are keen to develop and grow and to do this they demand educational change. A portion of the budget is usually devoted to providing schools and institutions with the hardware requirements of information communication technologies (ICT), yet the issue is more complicated than the provision of resources. For example, Salomon (2000) points to a growing emphasis in society upon the access to information, and the processes of selection and integration that it implies. He highlights an important distinction between access to information and the knowledge that results from it, and argues that the information accessed is not the same as the knowledge constructed on its basis. Thus the information highway and the information age are not the same as the knowledge highway or the knowledge age.

The process of transforming information into knowledge is a demanding and purposeful process that requires both instruction and a community of learners. In this transformation process the role of the teacher is crucial. The context of a traditional classroom that is associated with teacher centred pedagogy and behaviourist learning principles can act as an impediment to this process. Across many countries, both politicians and educational administrators have argued that technology in schools, particularly Internet connectivity, is essential to prepare pupils for a future within a knowledge-based economy. Generally their response has been the provision of the physical resources, curriculum and policy documents, yet many have lagged in the area of teacher professional development and this has greatly influenced the manner of integration of ICT within schools.

## INTEGRATION OF ICT INTO THE CLASSROOM

Mathematics educators used ICT initially for drill and practice, based on behaviorist theories and outcomes and concentrating on mastery of skills. Later the tool and tutee models (Taylor, 1981) became popular because these promoted higher order thinking and were supported by psychological theories about information processing, constructivism, cooperative learning, and metacognition. This paradigm shift was also supported by advances in hardware (e.g., larger memory, faster processor, wireless technologies, down-sizing) and software (e.g., Dynamic Geometry Software such as Cabri and Geometer's Sketchpad, Computer Algebra System such as Maple, Mathematica, Derive, and Java applets). Accompanying this paradigm shift was pressure to change the objectives and topics of the mathematics curriculum with less focus on computational skills and more upon exploratory and investigative tasks. However not all of the teachers or systems have kept abreast of this directional shift. Schools and teachers have responded to this pressure to change and adapt in a variety of ways and have adopted different approaches in response to their beliefs about teaching and learning. An examination of the research literature, it could be argued, produces five broad categories or metaphors of teacher response when it comes to the integration of ICTs within their classroom (White, 2003, 2004 in press). These metaphors describe how teachers tend to view ICT as either: a demon; a servant; an idol; a partner; or, a liberator.

*ICT as demon:* The evidence for this approach is observable in the teachers who actively oppose and subvert any attempt to integrate ICT into the curriculum. They are either afraid or not willing to learn and so conduct an active or passive resistance campaign. If forced by authority, they will do the minimum and often the resulting surface knowledge leads to surface integration and sometimes to inappropriate use. For example the "Singapore Ministry of Education recommends that 30% of curriculum time should involve use of ICT. Some mathematics teachers try to satisfy this by using PowerPoint as a presentation tool, which is usually not effective to teach pupils how to solve problems" (Yang, Butler, Cnop, Isoda, Lee, Stacey, Wong, 2003, p.61). Another example could consist of "getting pupils to search for articles in mathematics as a research task is not likely to be beneficial to the pupils in terms of enhancing mathematical understanding" (Yang, et. al, 2003, p. 62). Some teachers resistance has resulted from being sent to a professional development program on the use of some software package only to return to school where the software is not available. Goos, Galbraith, Renshaw, and Geiger (2000) used the metaphor of technology as master to describe this stage.

*ICT as servant:* Teachers may adopt a conservative position that uses integration in the sense of technologies being used by the teacher and students "yet the pedagogy remains much the same as in the past" (Downes, Fluck, Gibbons, Leonard, Matthews, Oliver, Vickers, & Williams, 2001, p. 26). ICT thus is a tool for enhancing students' learning outcomes within the existing curriculum and using existing learning processes (Russell & Finger, 2003). Salomon (2000) sees this as a "consistent tendency of the educational system to preserve itself and its practices by the assimilation of new technologies into existing instructional practices. It fits into the prevailing educational philosophy of cultural transmission, where there is a body of important knowledge that has to be mastered". Generally the focus is upon mastery with a consequent development of drill and practice programs, and a "most powerful and innovative technology is taken and is domesticated ... Emasculated tools cannot do any harm, but they do not do any good either" (Salomon, 2000, p. 2).

Baturo, Cooper, Kidman, and McRobbie (2000) conducted a study examining teacher perceptions in relation to their students completing a computer based learning system (ILS -

integrated learning system) with a mastery learning theoretical basis. ILS was designed to consolidate already introduced mathematics topics through a work-sheet mastery format and not to teach new material. The researchers concluded: "the future of integrated learning systems such as that in this study may be problematic as teacher knowledge of educational uses of computers increases, and student experience with computers proliferates. However, transmission models of teaching have been very resilient and resistant to change and so a future for this ILS may remain" (Baturu, et. al., 2000, p. 71).

*ICT as idol:* This approach promotes ICT as a tool for use across the curriculum where the emphasis is upon the development of ICT-related skills, knowledge, processes and attitudes (Russell & Finger, 2003, p. 3). It is more focused upon teaching about computers rather than with computers. Salomon is critical and refers to this as a technocentric approach where educators expect that ICTs on their own will bring about a change (Salomon, 2000). Thus teachers "promote the use of computers in the classroom as if using technology was an end in itself" (Downes, et al., 2001, p. 23). They are seduced by the 'dazzle effect' of these 'techno toys' and fail to consider the teaching and learning implications beyond a surface level. There are many examples of professional development programs that give teachers intensive experience of a software package but fail to assist teachers with the teaching and learning implications. These teachers then struggle to use what they have learnt when they return to their classroom. This information is quickly forgotten and lost because teachers have not constructed and integrated it with their existing pedagogical knowledge.

*ICT as partner:* There are teachers who have seriously attempted integrating ICT into their classroom and to "change the orientation from teaching *about* computers to teaching *with* computers" (Russell & Finger, 2003). These classrooms are where "students are actively engaged in gathering data, aggregating their data with those gathered by other students, and making meaning of their results" (Downes et. al., 2001, p. 26). Here ICTs are integral to the pedagogy that changes not only *how* students learn but *what* they learn. In terms of mathematics, it means the use of ICT moves beyond pointing to how ICT can support, improve, and provide new ways of teaching to how ICT changes the way mathematics is expected to be performed. The use of graphics calculators and the various probes allow data to be captured outside the classroom and to be transferred and analysed at a later time. Real data thus can be analysed with the use of a mathematical model, and conclusions and inferences produced.

*ICT as liberator:* This is a radical approach where integration is a component of the reforms that will alter the organisation and structure of schooling itself. "Among the diversity of school types will be virtual schools, where students spend part or all of their time working 'off-campus', for example, from home using an online computer" (Russell & Finger, 2003, p. 3). There is over one hundred virtual schools already existing in the U.S.A. as evidence of this trend. However there are unintended and unwelcome effects of virtual schools such as the example of high range internet users experiencing increased loneliness, depression, anxiety and poorer social relationships (Kraut, Patterson, Lundmark, Kiesler, Mukopadhyay, & Scherlis, 1998). Salomon (2000) states that "not many students have the self-discipline or the sustained motivation to be distance-, virtual learners" (p. 4). He regards this approach as another example of technocentrism that is in danger of yielding virtual results.

Yet there are alternatives where "more sophisticated understandings of the implications of ICTs for reforms in curriculum, pedagogy and assessment are required" (Russell and Finger (2003, p. 9). Goos et. al., (2000) used the metaphor of extension of self to best describe how teachers incorporated the technologies into prior teaching methods by reshaping pedagogy towards problem solving, investigations and where control was passed to students.

## A TROJAN HORSE

What is a Trojan horse? To a digital child it is a virus that enters as a simple message and sometimes harms your computer. To others it is the huge wooden horse left behind by the Greeks who for over ten years had laid siege to the city of Troy. The inhabitants of Troy overjoyed at the end of the siege, took the horse inside their city. Once inside the defensive walls, the Greeks hidden inside the horse were able to open the gates and the city fell. In many countries, there are a sizeable number of teachers at the Demon or Servant stage of integration. These teachers use mainly teacher centred teaching strategies and have been holding out for a lot longer than ten years against the forces of constructivism and the proponents of student centred learning. What is needed is a pedagogical Trojan horse for not only the integration of ICT but also for the change to student centred teaching and learning strategies. Hand held technologies can be that Trojan horse to help educational authorities gain entry inside the defensive walls of these teachers. Once inside the walls, the process of change cannot be stopped.

The cost, size and portability of the graphics calculator (GC) enables it to overcome a number of presenting problems associated with computers. The cost of computers, of site licenses for software, of the extra security required and their relatively fixed status are reasons often given by the resistant teacher. You would not take a laptop computer to places where you can take a GC connected to a probe such as a swamp or a beach. The ideal world would have every school possessing an abundance of secure computer laboratories with the relevant software. The real world requires interim effective strategies. A teacher using GC technology every day even though the strategies may be teacher centred is still preferable to a teacher with none who is waiting because conditions are not ideal. Waiting for an ideal world is a waste of time.

Yet, like the spy Sinon who convinced the Trojans to move the horse inside the city as a war trophy, so teachers can be persuaded that using a GC will not be a great imposition. To do this they need to be shown ways that GCs can support their usual ways of teaching mathematics. This means integrating the GC into their current practice. For example, teacher centred approaches lend themselves to a GC connected to a display panel for teacher demonstration purposes. The teacher retains absolute control of the technology and its use. Until teachers are confident and comfortable at this stage, they will resist further prodding. The GC can be taken home by the teacher in order to increase proficiency of use. This stage is the same as taking the Trojan horse into Troy as the teacher must get used to it being in the classroom. It is the beginning of the movement to unleash what is inside this technological horse, a movement from mainly teacher centred strategies to student centred strategies and of increasing student use of graphics calculators from limited to unrestricted (see table 1).

Once the teacher has achieved a degree of proficiency with the GC, then they can be shown how GCs can improve the usual ways of teaching mathematics. For example, by making use of the GCs ability to instantly provide multiple representations of a function or through the revitalising of geometry from mainly description to a dynamic environment. Dynamic geometry software offers older students opportunities to investigate spatial phenomena by modelling mechanical linkages to gain insights into geometric relationships and proofs (Vincent & McCrae, 2000). While the teachers still retain control of the technology, they can begin to use the power of the technology to focus upon the concept rather than just faster reproduction of the skill. Equations such as ' $y = a \sin(bx+c) + d$ ' can be entered and 'what if' questions can be directed by the teacher to the students with the aim of investigating the changes to the graph as the variables a, b, c, and d change. Through providing the teacher with a number of suitable activities and strategies the level of student participation and engagement is increased. The walls are falling and the movement has

begun.

Table 1

*The Movement from Mainly Teacher Centred Strategies to Student Centred Strategies and the Increasing Student Use of Graphics Calculators, from Limited to Unrestricted. .*

	Focus on teacher centred strategies	→	Focus on student centred strategies
Limited use of graphics calculators	<ul style="list-style-type: none"> <li>• Teacher uses GC and panel (and/or probes) for a demonstration.</li> <li>• Teacher directs the process and the class.</li> </ul>	<ul style="list-style-type: none"> <li>• Teacher uses GC and panel for a demonstration.</li> <li>• Realistic problem that students attempt to solve by asking 'what if' questions which the teacher demonstrates on the GC</li> </ul>	<ul style="list-style-type: none"> <li>• Teacher uses GC and panel (and probes) for a demonstration.</li> <li>• Realistic problem and data collected by teacher on the GC.</li> <li>• Teacher uses the GC as directed by the students.</li> </ul>
↓	<ul style="list-style-type: none"> <li>• Teacher uses GC and panel (and probes). Students have 1 GC between 2-3 students</li> <li>• Teacher directs the process and the class.</li> <li>• Strong classroom management strategies used.</li> </ul>	<ul style="list-style-type: none"> <li>• Teacher uses GC and panel (and probes). Students have 1 GC between 2-3 students.</li> <li>• Realistic problem that students attempt to solve by asking 'what if' questions which the teacher responds to on the GC</li> </ul>	<ul style="list-style-type: none"> <li>• Teacher uses GC and panel. Students have 1 GC between 2-3 students.</li> <li>• Realistic problem and data collected by teacher and down loaded to student GCs.</li> <li>• Students work on problem with teacher allowing students limited direction of the process.</li> </ul>
Widespread use of graphics calculators	Teacher uses GC and panel (and probes). Every student has a GC.	<ul style="list-style-type: none"> <li>• Teacher uses GC and panel (and probes). Every student has a GC.</li> <li>• Realistic problem and 'what if' questions.</li> <li>• Students share teacher's data.</li> </ul>	<ul style="list-style-type: none"> <li>• Teacher and students use GC and probes to collect and analyse data to solve realistic problems</li> <li>• Students work as mathematicians using modelling.</li> </ul>

Like the Trojan horse, once unleashed within the classroom, handheld technologies alter the very nature of the teaching and learning process. For example, Sparrow and Swan (2002) noted a change of teaching style after the simple four function calculators were introduced into Year 6 Australian classrooms, with teachers adopting a more open, learner-centred approach. Textbooks were given a reduced importance within the curriculum as tasks became more problem-based and involved more student-initiated dialogue. Teachers commented that the presence of the calculators highlighted

differences in students' mathematics achievement that necessitated planning to better accommodate differences.

The final stages are about providing teachers with new ways of teaching mathematics using the GC. Where greater use is made of the dynamic, visual, and interactive capabilities of the GC and where students have greater access to the GC by having their own (see Table 1). The teacher continually works on achieving an acceptable balance between mastery of fundamental skills and the active construction and exploration of knowledge. The teacher learns to cede a degree of control to the students by allowing them to investigate and report back. If a simple four operations calculator can do this imagine what a powerful graphics calculator can do.

Table 2

*Summary of the Developmental Stages of Teacher Growth in Graphics Calculator Integration and Teaching/Learning Orientation Compared to Levels of Use of an Innovation (Hall & Hord, 1984, p. 84).*

Stage	Major Teacher Strategy	Technology Needed	Predominant Student Participation Style	Levels of Use of the Innovation	Description of Levels of Use of the Innovation
1	Teacher centred with total control	1 GC and 1 display panel	Students observe	Mechanical Use	Focus on short-term day-day use. stepwise mastery of innovation
2	Teacher centred but some sharing of control by directing 'what if' questions	1 GC and 1 display panel	Students answer questions and observe.	Routine	Use stabilised. Few if any changes.
3	Teacher centred and student centred approaches used	Class set of GCs and 1 display panel	Students question explore, observe, postulate and answer	Refinement	User varies the use of innovation to increase impact.
4	Learning community approach	Teacher and students own personal GC. Use of schools' display panels and probes	Students initiate and participate in explorations and investigations	Integration  Renewal	User varies to increase collective impact - both short and long term goals  Re-evaluates use and examines new developments

The teacher gives the students a learning BOOST (By Out Of School Time) by setting investigations to be done at home. As teachers and students gain in confidence and experience in the use of the GCs, the speed increases for the transformation of teachers from regarding handheld technology as a demon or servant to regarding handheld technology as a partner, and in some cases a liberator. To reach the last metaphor of integration, a teacher would have to be accomplished with

student centred teaching and learning strategies.

The speed of a teacher's development will depend upon a number of factors but the tale of the Trojan Horse should not be forgotten. The Greeks tried to speed things up by attacking with great force only to be stopped for ten years, so the process must begin in the top left hand side of Table 1 before it will ever move to the bottom right position. The approach that is being advocated in this paper is not without research support. In the literature of change that researchers have articulated there appears to be a hierarchy of levels in the use of any innovation. "There is a typical progression in a person's movements through the levels of Use. The progression is not locked in step by step, however, in general people move in sequence... This progression assumes, of course, that the innovation is appropriate, the principal and other change facilitators do their job, and time is provided" (Hall & Hord, 1984, p. 83). In Table 2, the developmental stage proposed in this paper is juxtaposed with that from earlier research and shows considerable resonance if we compare the major teaching strategy (distilled from Table 1) and the description of levels of use of the innovation. While not a perfect match, it is significant to note that stage 1 and 2 of the levels of use correspond closely with the ICT as demon and servant stages of integration and stage 3 and 4 correspond very well with ICT as partner and liberator.

## CONCLUSION

I have used a number of analogies in this paper to illustrate and highlight the key issues facing attempts to integrate ICT into mathematics classrooms and to transform teaching methods. Those who continue to advocate the use of blunt force to change teachers have had their day. They are like the generals outside the walls of Troy pleading for one more attack. Enough resources and time have been spent on these methods. It is time to respect teachers' knowledge and the teachers' voice and the transformative power of the graphics calculator over the integration of technology into the classroom and the pedagogy. The GC Trojan horse, once unleashed within the classroom can alter the very nature of the teaching and learning process where the gains are measured in student learning outcomes. It can provide an interim step in transforming teachers to influence their students to attain new goals

" ... such as the ability to ask smart questions, to work in teams, to acquire life-long-learning skills, to construct higher order knowledge and perhaps above all, to be able to tackle new, complex problems in intelligent and creative ways" (Salomon, 2000, p. 6).

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