Integrating Technology in Mathematics Learning: What Some Students Say

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We report on a study involving the integration of technology in the teaching and learning of senior secondary mathematics. Student responses were obtained before and after the second year of the two year program, with respect to attitudes to technology; alternative motivations within collaborative settings; preferences for technology use in mathematical activity; and choices involving strategic preferences for technology use. Some few substantial shifts in position were identified, while other positions were sustained. The students provided self-assessments of their confidence and competence in technology use.

As technology has been increasingly imported into educational settings, so the variety of pedagogies associated with its use might be expected to increase. Ramsden (1997) has acknowledged the impact of inherited teaching traditions on the introduction of technology by referring to an instinct for teachers to begin by looking for electronic ways of doing familiar jobs previously done by textbooks and lectures. Similarly, Thorpe (1998) in examining teaching behaviours and attitudes towards technology found that technology was being used essentially to enhance preferred teaching methods. That is, the technology was being utilised in a conservative way. In this paper we report on selected aspects of a study that investigated pedagogical issues in the integration of technologies such as graphical calculators into senior secondary school mathematics (see Goos, Galbraith, Renshaw & Geiger, 2000, for details). In particular we examine students' attitudes towards the use of technology in the context of a specific classroom learning environment.

Background to Study

In Dunham and Dick's (1994) review of research on the use of graphical calculators, a survey of studies linking calculator use with achievement yielded mixed results. Some studies found significant differences in favour of calculator groups, others found no differences, and at least one found in favour of a control group. In several cases it did not seem clear just what was being compared with what. Sometimes the mere presence of a calculator appeared to serve as an experimental condition, and this seems an impoverished approach to researching impact and effectiveness. A comprehensive review of research on graphical calculator use (in the decade to 1995) was provided in Penglase and Arnold (1996). Despite the plethora of studies reviewed, they noted a dearth of research addressing learning environments and teaching approaches designed to maximize learning benefits. In their review of Australasian research in the subsequent period 1996-1999, Asp and McCrae (2000) commented that this particular gap had not been seriously addressed here, although substantial work on other aspects of graphical calculator use was noted. In contrast to some of the more conservative approaches noted above (Ramsden, 1997;

Thorpe, 1998) Templer, Klug, and Gould (1998) express the conviction that technology should be used to encourage students to explore and investigate mathematical concepts. In doing so they raise problems perceived to emerge when students work with technology in a self-monitoring environment. Specifically they noted that having mastered the rudiments, the majority of students "began to hurtle through the work, hell bent on finishing everything in the shortest possible time". The following comment (or a close relative) was noted as occurring frequently: "I just don't understand what I'm learning here. I mean all I have to do is ask the machine to solve the problem and it's done. What have I learned?" So for many reasons the teaching-learning environment remains an important context for examining alternative ways in which technologies, teachers and students combine in the pursuit of mathematical goals.

A Sociocultural Perspective on Teaching and Learning with Technology

Sociocultural perspectives on learning emphasise the socially and culturally situated nature of mathematical activity, and view learning as a collective process of enculturation into the practices of mathematical communities. The classroom as a community of mathematical practice supports a culture of sense making, where students learn by immersion in the practices of the discipline. Rather than relying on the teacher as an unquestioned external authority, students in such classrooms are expected to defend and critique ideas by proposing justifications, explanations and alternatives. A central claim of sociocultural theory is that human action is mediated by cultural tools, and is fundamentally transformed in the process (Wertsch, 1985). The rapid development of computer and graphical calculator technology provides numerous examples of how such tools transform mathematical tasks and their cognitive requirements. Within particular knowledge communities, then, tools are cultural resources that re-organise, rather than amplify, cognitive processes through their integration into human practices. Following a Vygotskian framework adopted in previous studies (see Goos, Galbraith & Renshaw, 1999), we move beyond the most widely known definition of the ZPD (as the distance between what a child can achieve alone and what can be achieved with the assistance of a more advanced partner or mentor) to two other representations of particular relevance to our classroom context. These are firstly the conceptualisation of the *ZPD in egalitarian partnerships*. This view of the ZPD, involving equal status relationships, suggests that there is learning potential in peer groups, wherein students have incomplete but relatively equal expertise – each partner possessing some knowledge and skill but requiring the others' contribution in order to make progress. In our research context this feature becomes relevant through the collaborative activity of students in bringing technology to bear on mathematical tasks with varying levels of individual technological and mathematical expertise. A second extension of the ZPD concept is created by the *challenge of participating in a classroom* constituted as a community of practice. Through the establishment of a small number of repeated participation frameworks such as teacher-led lessons, peer tutoring, and individual and shared problem solving, students are challenged to move beyond their established competencies and adopt the language patterns, modes of inquiry, and values of the discipline. Such a classroom environment, representative of an active community of learners, is augmented by the availability of technology as another agent in the search for powerful and meaningful mathematical learning and application.

Attitudes to Technology

Our discussion of situational factors would be incomplete without acknowledgment of the role that disposition towards technology may play in impacting on learning settings. McLeod (1985) reminds us that unfamiliar technology can cause special difficulties, even when the tools are as primitive as ruler and compass. Hence the attitudes with which students approach technology supported learning is a matter of significant interest. The study of attitudes towards information technology (most frequently computers) has a shorter but more intensive history than its mathematical counterpart. Indeed the emphasis in research studies has been overwhelmingly towards interaction with technology as such, rather than on its use in particular learning contexts. This is despite Selwyn (1997) noting that an awareness of students' attitudes towards technology constitutes a "central criterion in the evaluation of computer concerns and in the development of computer based curricula". Similarly for graphical calculators! To the extent that factors such as confidence, anxiety, competence and liking have the potential to affect performance on learning tasks involving technology use, these attitudinal properties are important to bear in mind when designing learning sequences, and in monitoring involvement and interpreting performance characteristics.

The Study

Research Questions

Consistent with the issues visited in the preceding discussion, as part of our larger study we seek evidence that provides insight into the following:

1. Disposition of students towards using technology in learning mathematics.
2. Development of collaborative preferences (or not) by students as they work with technology in mathematics learning.
3. Choices of *specific* forms of calculator use favoured by students.
4. Choices of *general* strategic purposes for calculator use favoured by students.
5. Perceptions of students with respect to their global facility and confidence with graphical calculators as a personal resource.

Data gathering procedures appropriate to 1-4 are detailed below. For 5 we use a taxonomy describing different modes of working, within which categorisations have been formulated through observing the actions and talk of students working individually and collaboratively with graphical calculators. They were first described in (Galbraith, Renshaw, Goos, & Geiger, 1999) and are summarised for reference in the Appendix.

Classroom Context

This paper describes one aspect of a two-year (Years 11 & 12) study focused on a Mathematics C classroom in a co-educational independent school in Queensland. (Mathematics C is an advanced subject taken by students intending to pursue serious study of mathematics at tertiary level). In this classroom the pursuit of mathematical competence and understanding occurs within a framework consistent with the socio-cultural perspective described above. This involves mutual interactions between the teacher and individual students, the total group, and subgroups of students working together; interaction between individual students and peers involving both cognitive and interpersonal exchanges; individual action and reflection; and interaction between all human participants and artefacts such as text material, and in the context of our special interest, technology. Graphical calculators occupy a central integrated role throughout the course in both teaching and assessment, and this technology is augmented by computer activity e.g., spreadsheeting as deemed appropriate according to topic and purpose. Technologies are used to perform mathematical computations that would otherwise be conducted in more time consuming ways, or be beyond the capabilities of pen and paper methods (eg., calculations involving operations on large matrices). They are also used in the sense of *catalysts* (Willis & Kissane, 1989) as a means of provoking mathematical explorations and discussions, or to invoke the use of problem solving skills. And in their individual and collaborative activity, students are invited to utilise technology in any way that they see fit and are able to justify or defend.

Data Sources

On average a lesson was observed and videotaped every one to two weeks, with more frequent classroom visits scheduled if a technology intensive approach to a topic was planned. Audiotaped interviews with individuals and groups of students were conducted at regular intervals to examine factors such as the extent to which technology was contributing to the students' understanding of mathematics, and how technology was changing the teacher's role in the classroom. At the beginning of the course and at the end of each year students completed a questionnaire on their attitudes towards technology, its role in learning mathematics, and its perceived impact on the life of the classroom. A final class interview/discussion reviewing the two-year program was videotaped. Here we draw on data from questionnaires administered in the November of each of the two years of the program, with brief reference to interviews conducted with selected students during the second year (Year 12). The class of fifteen students completed questionnaires at the end of Year 12. Of these, twelve had also provided corresponding data at the end of Year 11, and our data source is substantially the responses from these students in successive years. Students enter Year 11 with a variety of backgrounds, and during this year the culture of the classroom is established (see Goos, Galbraith & Renshaw, 1999), the various technologies, teaching approaches, and learning formats are experienced, and the expectations of the teacher made clear. By the end of Year 11 students are able to respond in an informed way to the questionnaire items. However we are further interested in stability or change in student opinions and assessments during the Year 12 program, a time during which the implications of performance as a gateway to tertiary studies exert increasing pressures. The questionnaire contained structured Likert style items together with a section inviting open responses. Structured items designed to address the areas represented by research questions 1-4 are grouped respectively in sections A to D in Figure 1 below.

Structured Technology Questionnaire

The item format used SA (5) to SD (1) in sections A to C, and Always (5) to Never (1) in section D. In order that high scores reflect more of the property of interest asterisked items were reverse coded. For example in section B item 1 is such an item, for agreement represents preference for *non-collaborative* activity.

Section A. Motivation/Confidence (SA—SD)

1. I enjoy using technology during mathematics lessons. (50,50)
2. I will work with technology for long periods if I think it will help me solve problems. (48,51)
3. I feel confident I can use technology when faced with a new problem in maths class. (47,46)
4. If I make a mistake when using technology I am usually able to work it out for myself. (44,40)
5. Using technology makes me more confident about maths because I can check ideas as I go. (51,48)

Section B. Collaborative Preferences (SA—SD)

*1.I prefer to work with technology on my own when studying mathematics. (37,40)
2. I prefer to work with others when using tech because I feel I need help if something goes wrong. (41,45)
3. I prefer to work with others when using tech because I like to discuss what I see on the screen. (37,49)
4. I prefer to work with others when using tech because I really need to share what I find. (45,46)
5. I don't like others to see my work with technology in case they criticise what I've done. (51,44)

Section C. Interaction and Engagement with Technology (SA—SD)

*1.I prefer to just learn mathematics without the extra burden of technology. (48,47)
*2.Technology is only there to check what you do with pen and paper. (50,49)
3. Technology allows me to explore my own ideas about maths as well as those discussed in class. (41,44)
4. By looking after messy calculations technology makes it easier to learn essential ideas. (54,52)
*5.I prefer to learn maths first without technology, then learn the tech to do the maths more quickly. (27,32)
*6.I tend to use technology for basic calculating tasks but not much else. (45,46)
7. I find technology particularly useful when exploring unfamiliar problems. (42,49)
8. Technology helps to link ideas. e.g., shapes of graphs and their equations. (51,52).
*9.I can often solve a problem using technology, but think afterwards I don't really understand it. (41,38)

Section D. Choice of Strategy in School mathematics (Always—Never)

1. I use technology at school when I get stuck on a problem. (46,46)
2. I use technology at school to look at a problem in a different way e.g., picture or table. (39,44)
3. I use technology at school as a way of discussing a problem with others. (36,45)
4. I use technology at school when I feel pen and paper isn't helping. (42,44)
5. I use technology at school as a first resort when looking at a mathematical problem. (40,39)

Figure 1. Questionnaire items.

Open Ended Questions

A sample of these is provided below – abbreviated for convenience. They invite reflective comment on identified aspects of the program.

- Are there any advantages (disadvantages) in using technology instead of pen and paper? Use examples to illustrate how it helps (gets in the way) of learning.
- Are there ways in which you believe technology helps you to think differently e.g., ways of approaching unfamiliar problems or an investigation?
- Are there benefits in students presenting their calculator work to the class via a viewscreen and OHP? Benefits for presenter? For class? For teacher?
- Does using technology change the teacher's role in the classroom? In what way(s)?
- Which description best fits the way you use technology in the classroom? (See Appendix 1)

We shall be restricted by space to consider responses to only the last of these. The individual student interviews triangulated some of these open questions as they followed a question pattern similar to the above. Additionally views on the value of technology in learning particular topics (e.g., matrices and vectors) were pursued. The interviews were conducted by a researcher external to the school but well known to the students. The interview data are strongly consistent with corresponding questionnaire output.

Selected Findings & Reflections

Structured items

To conserve space, outcomes have been included with the questions in Figures 1 to 4. The elements in the ordered pairs denote the Year 11 and Year 12 responses respectively. Since 12 students completed both questionnaires the total score on any item can vary between 12 and 60. We have chosen to display totals rather than means because they are more informative. For example a shift of 6 can be thought of as equivalent to the net effect of half the class changing their score by 1 in the same direction, or more radical moves by fewer students and so on. On this basis shifts of more than 5 points might be considered worth looking into. In fact such shifts occur in 4 of 24 items (17%) indicating generally robust outcomes, but some issues that invite close scrutiny. The rating *magnitudes* are also important. We consider totals above 45 as indicative of solid to strong group support for the relevant construct, and conversely for very low scores. Examining the data leads us to the following observations. Section A ratings (question 1) maintain high values except for item 4 for which scores decrease slightly while remaining in the moderate range. This is consistent with a general wariness that any student might be expected to express when considering the challenge of finding and correcting errors. The first item in Section B (question 2) provided students with an opportunity to express displeasure with collaborative activity. On the Year 12 instrument two students answered this way (one strongly), six gave their positive support, and four remained neutral. Of the four items probing reasons why peer support was helpful a major positive shift is evident on item 3. This is a pleasing outcome for a classroom in which discussion and justification have been centre-pieces of the pedagogical model. The sensitivity suggested by the responses to item 5 is in fact substantially due to two students who clearly felt vulnerable to peer comment – they each recorded a negative shift of 3 points in their Year 12 response. This is a timely reminder that collaborative classrooms involve more risk taking, and associated sensitivities need to be recognised. Section C (question 3) canvassed specific preferences of students in relation to the use of technology for specific mathematical purposes. The sustaining of high ratings across items 1, 2, 4, 6, 8 indicates that the class group sees technology as a positive help in learning mathematics, values its power, does not relegate it to trivial tasks and values its assistance in problem solving. Two other matters of interest emerge from these data. Item 9 reflects an uncertainty that strikes a chord with the comments of other students cited earlier in this paper (Templer, Klug, & Gould, 1998). Item 5 addresses the major issue of how technology can best enhance mathematics learning in terms of its point of entry into a topic, among students positively disposed towards its general helpfulness. While there has been some movement in favour of its integration following the Year 12 experience there remain clear and distinct preferences that are disguised by the raw totals.

In fact very few ratings of 3 were given. On the first occasion 8/12 students gave definite preferences (1,2) or (4,5) and on the second occasion the proportion was 9/12. The totals indicate that the majority retained a preference for mathematics first, then technology. In Section D (question 4) the striking change occurred in item 3. We observe the consistency with item 3 in Section B (see above) and note how this outcome is indicative that goals of encouraging peer collaboration are being fulfilled.

Open Response

For question 5 we leave the structured questionnaire and refer to the final open-ended question included on the Year 12 instrument and listed in the previous section: “Which description best fits the way you use technology in the classroom?” (See Appendix.) Sample responses are included in Figure 2 below. A representative of each category is given together with one example deemed to represent an intermediate position.

- *Master (M):* because I often don’t understand how to use every specific function of the technology, thereby limiting my use of such technology. I often don’t know if I’ve used it correctly and as a consequence I can’t be sure if my answer is correct or not.
- I think I’m between *master* and *servant*. I tell the calculator what to do sometimes but only stick to what I know usually. I don’t know exactly what it allows me to do, and if I haven’t been taught, I won’t look for it.
- *Servant (S):* because I do not have enough knowledge of technology to be able to investigate new concepts. However I do regularly use it for *familiar* tasks purely as a time saver and to verify and check my answers.
- *Partner (P):* Because my calculator has become my best friend. His name is Wilbur. Me and Wilbur go on fantastical adventures together through Maths land. I don’t know what I’d do without him. I love you Wilbur.
- *Extension of Self (ES):* Because my calculator is practically a part of myself. It’s like my 3rd brain. I use it whenever it can help me do anything faster.

Figure 2. Student self-perceptions of calculator expertise.

Students had no problem reaching a personal decision and justifying it. The 15 responses from the Year 12 students produced the following distribution. M (1), M-S (1), S (7), P (2), ES (4). Furthermore they were conscious about their assessments sometimes adding comments that eliminated other choices: “It is a lesser being, it is a machine – I am above such things”.

Conclusion

The findings reported here come from a larger study investigating the integration of technology into the mathematical practice of specific secondary school classrooms. Student attitudes towards technology provide important insights into such learning environments. In particular, we can interpret responses concerning the nature of technology facilitated mathematical discussion between peers from a sociocultural perspective that highlights the tool mediated and socially situated nature of learning. We note both commonly shared values and individual differences within student preferences for technology use and classroom procedures. Additionally, student self-assessments of their own use of technology in the classroom indicate that, for many, technology enters into their collaborative *partnerships* with peers (technology as partner) and *extends* their existing competencies (technology as extension of self), as well as providing *routine support* as a reliable servant. Such variability between students in their learning style preferences, and in their abilities and choices to access the power of technology available to them, reminds us again of dangers of placing undue reliance on oversimplified experimental studies, that regard a technology as some form of standard treatment condition.

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Appendix

Technology as Master. The student is subservient to the technology-a relationship induced by technological or mathematical dependence. If the complexity of usage is high, student activity will be confined to those limited operations over which they have competence. If mathematical understanding is absent, the student is reduced to blind consumption of whatever output is generated, irrespective of its accuracy or worth.

Technology as Servant. Here technology is used as a reliable timesaving replacement for mental, or pen and paper computations. The tasks of the mathematics classroom remain essentially the same—but now they are facilitated by a fast mechanical aid. The user 'instructs' the technology as an obedient but 'dumb' assistant.

Technology as Partner. A 'rapport' has developed between the user and the technological device. A graphics calculator, for example, becomes a friend to go exploring with, rather than merely a producer of results. The user is still in control, but there is appreciation that outcomes need to be judged against criteria other than simply that a result has been achieved – it is possible for the calculator to be 'wrong'.

Technology as an Extension of Self. This is the highest level of functioning, in which users incorporate technological expertise as an integral part of their mathematical repertoire, so that the partnership between student and technology merges to a single identity. Rather than existing as a third party a calculator may be used to share and support mathematical argumentation on behalf of the individual.