What Students Say: Analysis of Structured Survey Data in Relation to Technology and Mathematics Learning

Vince Geiger
Hillbrook Anglican School
<vincent@gil.com.au>

This paper continues a long term investigation into students' views about and attitudes toward the learning of mathematics within a technologically rich classroom environment. The data was sourced via a series of questionnaires that focused on the role of technology in student/student and teacher/student interactions within this environment and, in particular, the collaborative aspects of these interactions. The advantages/disadvantages of technology in investigating novel mathematical problems were also explored. Links are drawn between the results of this survey and earlier work which developed categories of students' use of technology.

Despite the wide-spread uptake of the use of graphing calculator and computer technology in Australian mathematics classrooms, at least in the final two years of schooling, there is still no clear view of what advantages technology enhanced approaches to instruction offer students and teachers. Further, it appears that reports in the literature about students' dispositions and preferences in relation to technology enhanced approaches to learning mathematics are limited. This paper reports on a series of surveys, conducted with students studying a specialist mathematics course over a two year period, aimed at providing insight into students' perceptions on the role of technology in learning mathematics. The questionnaire that forms the basis of these surveys explores students' views in relation to classroom interaction (student/student and student/teacher), strategic vs. procedural use of technological devices, and students' general dispositions toward the study of mathematics in a technologically rich environment.

The Literature

While there have been numerous studies on the effect of electronic technologies on students' understanding of mathematical ideas and concepts (e.g., Portafoglio, 1998; Weber, 1998), it is still a matter of conjecture as to what clear advantages are on offer when using these technologies (Penglase & Arnold, 1996).

Other studies have investigated the role of graphing calculator and computer technologies in student/student and student/teacher interaction (eg Goos, Galbraith, Renshaw & Geiger, 2000) and the effect of the teacher, as a role model user of technology, on students attitudes to its use (Goos et al., 1999). The first study categorises such interaction as: *master* (where the actions of teachers or students are constrained by a limited technological competence); *servant* (where users have developed a level of technical competence but have not internalised such facility to the point of incorporating the use of technology into strategic planning and decisions); *partner* (in which technology has become an integrated component of approaches to learning mathematics and solving mathematical problems); and *extension of self* (where the degree of integration of technology into the process of mathematical thinking has become almost seamless Both studies emphasise the effect of classroom interaction, both one on one and as a collective, on the way technology is used. The way technology is used must consequentially influence students' perceptions on the role of technology in knowing and doing mathematics, and also on themselves as learners. This view is consistent with the findings of Forster, Taylor and Davis (2002) in their study of students' feelings of empowerment when presenting mathematical ideas publicly using a graphing calculator and overhead projection panel.

The use of technological tools can influence the distribution of expertise, and so responsibility for learning, across individuals in a classroom (Goos, 1998). Geiger and Goos (1996) and Farrel (1996) have also indicated that the use of technology can help facilitate process or problem solving oriented approaches to learning. A classroom based study by Geiger (1998) argues that students can develop positive dispositions to this approach to learning over time.

This paper attempts to provide insight into students' preferences and predispositions in relation to learning mathematics in a technologically rich and highly collaborative environment. Specifically this investigation seeks to address the following research questions:

- What roles can be identified for technology in student-student and student-teacher interactions?
- How can technology be used to promote collaborative student/student and student/teacher interaction?
- What are students' perceptions of the role of technology to investigate and explore novel mathematical ideas and concepts?
- What are students' beliefs about the learning and teaching of mathematics within a collaborative, technologically rich teaching/learning environment?

The Study

Classroom Context

The study was situated in a specialist mathematics (Mathematics C) class, over a two-year (Years 11 & 12) period in a co-educational independent school in Queensland. As part of the study the teacher (and principal investigator) endeavoured to promote the acquisition of mathematical competence and understanding within a framework consistent with a socio-cultural perspective of learning/teaching (see Goos, Galbraith, & Renshaw, 1999). 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 particular, technological devices. Graphing calculators occupied a central integrated role throughout the course in both teaching and assessment, and this technology was augmented by computer activity e.g., use of spreadsheets, as deemed appropriate according to topic and purpose. The integration of technology into the learning of mathematics was also a foundational pillar on which the teacher's approach to instruction was based. This integration took the form of parallel development of both mathematical and technological skills rather than the more orthodox approach of learning of mathematics followed by associate technology skills. All students were provided with a TI-83 or TI-92 graphing calculator. These were available at all times during Mathematics C classes. Students were permitted and encouraged to take these devices home. Computer facilities were readily available upon request during the first year of the study and at all times during the second year. All students had access to computer facilities at home with, at least, word processing, spreadsheet software, and function graphing applications installed.

Both graphing calculator and computer technologies were used in a variety of settings and for a range of mathematical activity. These technologies were used as *Tools* (Taylor 1981) and as *Catalysts* (Willis & Kissane 1989). Technologies were used as *Tools* to perform mathematical activities they would have otherwise conducted in some other more time consuming way or to perform tasks that would have been beyond their capabilities without the assistance of computer or calculator technologies (e.g., calculations involving operations on large matrices). Calculators and computers were used as *Catalysts* to encourage mathematical explorations and discussion or to promote the use of problem solving skills (e.g., the search for conditions associated with population stability in an exploration of the logistic equation). Students were encouraged, in their individual and collaborative activity, to utilise technology in any way that they saw fit and were able to justify or defend.

Data Sources

Data collection was based around a series of surveys. The structure of the questionnaire on which these surveys were based was developed to be consistent with the research questions and sought to elicit students' responses in relation to the:

- disposition of students towards using technology in learning mathematics;
- development of collaborative preferences (or not) by students as they work with technology in mathematics learning;
- choices of specific forms of calculator use favoured by students;
- choices of general strategic purposes for calculator use favoured by students; and
- perceptions of students with respect to their global facility and confidence with graphical calculators as a personal resource.

The questionnaire was used in both pilot and main study components of a larger investigation. This paper refers principally, because of a restriction on space, to the students' responses first five aspects, listed above, of the questionnaire during the main study. Structured Likert items, designed to address the areas represented by research questions, were identical to those used in the pilot and main studies except for the addition of Question 6 in Section 2, which was added for the final survey. This allowed for valid comparison of responses across time both within the context of the main study itself, as well as between the pilot and main studies. Further, this approach provided opportunity to note the strength of support (or otherwise) for a position or construct as well as making it possible to mark noteworthy changes in opinion or attitude, again both within and between the two studies.

Structured items designed to address the areas represented by research questions are grouped respectively in sections 1 to 3 in Figure 1 below. The item format used strong agreement (SA) (5) to strong disagreement (SD) (1) in Sections 1 to 3, and Always (5) to Never (1) in Section 5. In order that high scores reflect more of the property of interest asterisked items were reverse coded. For example in section 2, question 1 is such an item, for agreement represents preference for *non-collaborative* activity.

The questionnaire also included a section that invited open-ended responses. This paper, again due to space restrictions, will refer to the Likert component of the questionnaire alone.

During the two years of the main study, questionnaires were distributed at the beginning of the course and at the end of each year. Of the 17 students who began the course in 1998, 15 continued until completion. Of these 15, 11 completed the questionnaire instrument on all three occasions. It is from these 11 students that the Likert data, analysed below, is sourced.

Results

Responses are recorded in Figure 1 below. Scores at the end of each item represent totals for that item recorded on February 1998, November 1998 and November 1999 respectively. Since, in this case 11 students completed all questionnaires the total score on any item can vary between 11 and 55. Thus totals of 41 (upper quartile of total) and above are taken as indicators of solid support or conversely for 14 (lower quartile of total) and below. A shift of 5 or more is taken as a noteworthy shift as this can be thought of as equivalent to the net effect of more than half the class changing their score by 1.

Section 1	
1	I enjoy using technology during mathematics classes (43,46,46,)
2	I will work with technology for long periods of time if I think it will help me solve a problem (43,44,47)
3	I feel confident I can use technology when faced with a new problem in maths class (43,42,43)
4	If I make a mistake when using technology I am usually able to work it out for myself (41,39,37)
5	Using technology makes me feel more confident about learning mathematics because I can check answers and ideas as I go (41,46,43)
Section 2	
1*	I prefer to work with technology on my own when studying mathematics (28,32,37)
2	I prefer to work with others when using technology because I feel I need help if something goes wrong (35,36,40)
3	I prefer to work with others when using technology because I like to discuss what I see on the screen (38,36,44)
4*	I don’t like others to see the work I do with technology in case they criticise what I’ve done (46,46,38)
5	When I use technology to study mathematics I really feel I need to share with others what I find (35,40,41)
6	I prefer to work with others when using technology because I often get good ideas from them (0,0,45)
Section 3	
1*	I prefer to just learn the mathematics and find the need to learn technology as well

	a burden (42,43,42)
2*	Good students don't need the assistance of technology to understand mathematics (41.5,40,40)
3*	Technology is only there to check what you do with pen and paper (37,47,47)
4	Technology allows me to explore my own ideas about mathematics as well as those discussed in class (42,38,39)
5	I am sometimes forced to use new mathematics when exploring the use of technological tools (38,39,39)
6	By looking after messy calculations technology makes it easier to learn essential ideas (40,49,47)
7*	I prefer to learn the mathematics first, without technology, and then learn the technology to do the mathematics more quickly (27,26,31)
8*	I tend to use technology to do calculating basic tasks but not much else (39,40,41)
9	I find technology particularly useful when exploring unfamiliar problems (43,40,44)
10	Technology allows me to learn mathematics more easily because I can work through a greater number of examples more quickly (39,37,46)
11	Technology helps me to link knowledge, e.g., the shapes of graphs and their equations (48,46,47)
12*	I can often solve problems using technology in the classroom but when thinking about the same mathematics latter I feel I don't really understand it (40,37.5,33)

Figure 1. Student responses across the time of the research.

The following observations are noted in relation to this data.

Attitudes. Responses to Section 1 indicated strong support for the use of technology in tandem with studying mathematics. The total scores on items from Section 1 ranged between 43 to 41, 46 to 39 and 46 to 37 on each run of the questionnaire respectively. There was no noteworthy shift in attitudes for any of the items. This was consistent with the results returned in the pilot study and demonstrated a high level of acceptance for the use of technology within this mathematics classroom. All ratings maintained high values except for item 4 in which scores decrease slightly while remaining in the moderate range. This is betrays a general wariness that any student might be expected to express when considering the challenge of finding and correcting errors.

Working Together with Technology. Students' responses in Section 2 (related to collaborative activity) move from being initially neutral (between 15 and 40 in four out of five items) toward being more strongly positive (41 and above on three out of six items). Of perhaps great interest, though, is the noteworthy positive shifts (Qs 1, 2, 6, 5) that take place in four out of the five items included on each of the questionnaires. A particularly large shift was evident on Q1 (+9) which provided students with an opportunity to express displeasure with collaborative activity. While the final rating (37) was still within a zone of moderation there was still a clear positive change in attitude toward working within a culture of collaboration.

The remaining items in this section aim to probe reasons for support (or otherwise) of collaborative activity. Items 2, 3 and 5 all return strong positive or near positive ratings by the end of Year 12 and each have been subject to a noteworthy shift of positive support (+5, +6, +6 respectively). This result is confirmation of the culture of teaching/learning favoured by the teacher of this class, though, it should be noted, that this support would not be as strong if judgements did not include responses to the questionnaire recorded at the beginning of Year 11. Clearly the positive changes in noted in the data from the main study have taken place over a longer period of time than in the pilot study.

The noteworthy drop in the rating of item 4 between Year 11 and Year 12 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.

Technology as Mathematical Assistant and Collaborator. Section 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, 3, 6, 8, 9, 10, 11 (7 out of 12 items), by the end of Year 12, indicates that the class group views technology as a beneficial adjunct while learning mathematics. In particular it offers advantages over mere checking strategies, values its power, does not relegate it to trivial tasks, values its assistance in problem solving and the capability to link different types of mathematical knowledge. Also, noteworthy positive shifts occur for items 3, 6 and 10 (positive shifts of 10, 7 and 7 respectively), indicating that students have developed a clear appreciation of the advantages offered by technology in terms of efficiency when handling large calculations and developing competency with new ideas and concepts.

All other items receive a high/neutral rating with the exception of Question 12 (30), that is also subject to a negative shift of 7, and Question 7 (31). Further, this decrease has occurred steadily over the two years (ratings of 40, 37.5, 33) and so does not appear to be related to "one-off" negative experience. The opinion expressed here strikes at the heart of what it means to know and do mathematics and is directly related to the issues of deep, genuine understanding as well as the retention of skills. These are issues for mathematics classrooms in general and so it would be unwise to infer too strongly that this is specifically related to the use of technology alone. Nonetheless, the students' views expressed on both surveys indicated that this becomes an issue of greater concern as they progress through the course and is perhaps triggered when the relevance of understanding to performance on assessment takes on greater importance as students move into the summative assessment regime that exists in Year 12. The view expressed here is also consistent with that of Templer, Klug, and Gould (1998) who, although convinced that technology should be used to encourage students to explore and investigate mathematical concepts, also raised 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?" This serves to highlight the importance of teacher/student interaction that must include the monitoring of students' progress at relational rather than simply instrumental levels of understanding (Skemp, 1971).

Item 7 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 (a positive shift of 5) 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 9 out of 11 students gave definite preferences of 1or 2 (7 students) or 4 or 5 (2 students) followed, on the second occasion, by 7 out of 11 (1 or 2 – 6 students; 4 or 5 – 1 student), and finally 8 out of 11 (1 or 2 – 5 students; 4 or 5 – 3 students). The totals indicate that the majority retained a preference for mathematics first, then technology, which is supported by the proportion of students on each survey who recorded ratings of 1 or 2. It should be noted, however, that by the end of Year 12, neutral to strong positive ratings were in the majority (6 out of 11). This indicates that students entered the course and maintained a strong preference for mathematics first and then technology throughout Year 11. It would seem, though, that this preference is less strong by the end of Year 12. Here a relatively even distribution of preferences is evident, indicating that while the approach taken by the teacher has been more generally accepted over time, students initial preferences, that are more than likely rooted in their previous experience of learning mathematics, are strong and persistent.

Summary of Observations

The results of these questionnaires, in general, indicate positive support from students for the integration of technology into the process of learning/teaching mathematics. Students have recorded positive attitudes towards working collaboratively with peers when using technology although some sensitivity was expressed in relation to criticism of work, completed in this medium, by others. By facilitating discussion of mathematics between peers the tool mediated and socially situated the nature of learning from a sociocultural perspective.

Students acknowledge there are advantages when using technology in terms of efficiency when attempting to solve problems that carried a high computational load and when working through a sufficient number of examples in order to acquire competence in the use of a mathematical skill, which is consistent with the *technology as servant* metaphor for calculator use. Further, students saw the technology as a powerful tool in the investigation and exploration of problems including those set in unfamiliar contexts, which has resonance with *technology as partner* or *extension of self* descriptors. This positive statement needs to be tempered, however, with a strong expression of concern, by students, about the quality of their own understanding of some mathematical ideas and concepts even when they have demonstrated a capacity to make use of associated mathematical knowledge or skills, at least at an operational level, when using technology. This view could be related to a very reasonable fear allowing technology to become the *master* in terms of their mathematical competence.

These responses therefore reinforce earlier work on the identification of modes of students' calculator usage. These categories might thus be a useful informant to the design of teaching approaches that make strong use of technology. This said it, must also be born in mind that these categories represent vastly different modes of operation that exist within one classroom and that this variability must be recognised in any instructional design.

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