Student reactions to the use of graphics calculators

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Abstract:

A set of graphics calculators was used to supplement teaching and learning in an undergraduate mathematics course. Student attitudes to the innovation were collected, through Likert items and optional unstructured written responses. Attitudes were generally favourable, although time pressures and assessment in the course were sources of concern. Classification of written responses provided some legitimacy to a proposed series of metaphors for technology, and suggested an additional metaphor of technology as a nuisance might also be needed to understand student reactions.

The use of computers in mathematics education has been severely constrained so far, by practical, economic and social problems. The practical problems have included the difficulty of transporting students to laboratories when necessary, as well as the difficulties of acquiring educationally suitable software. Seymour Papert's observation in *Mindstorms* (1980) that the computer laboratory was invented by schools as a form of self-defence against the invasion of computers seems prophetic, and uncomfortably close to the experiences of many secondary and tertiary mathematics teachers. Since the popularisation of microcomputers nearly twenty years ago, mathematics teachers have lamented the lack of educationally suitable software, which has been a substantial disincentive to widespread use of computers in mathematics teaching. Economic problems have been mainly a consequence of the relatively high capital cost of computer purchase, so that individual student ownership has not been generally feasible. Social problems have been related to perceptions of teachers and students about the place of technology in mathematics, and the consequent construction of curricula on assumptions of limited availability. It has not been *necessary* for students to use computers in most mathematics courses, even if it has been advantageous. Many authors recently have suggested that the use of graphics calculators are more likely than computers to solve these problems (E.g. Andrews & Kissane 1994; Bradley, Kemp & Kissane 1994; Kennedy 1994; Kissane 1995.)

The main purpose of this paper is to provide a partial evaluation of an ongoing project at Murdoch University involving the use of graphics calculators in a first year undergraduate mathematics course. With a number of calculators that are shared between students and used in tutorials and out of hours in several campus locations, students have been provided with a limited form of access to computing technology.

Kissane (1995) has suggested that there are a number of metaphors for technology that might help to explain the reactions of people to the use of computers and calculators in mathematics. Such metaphors may well be subconscious and may allow for an explanation of the different kinds of reactions of different people to the same experiences. The six metaphors suggested are that of laboratory, tool, teaching aid, curriculum

influence, cheating device and status symbol. A second purpose of this paper is to see whether these speculations regarding metaphors for technology are adequate to understanding student reactions to the use of graphics calculators in this particular case.

The Course

Fundamentals of Mathematics is a first year mathematics course that revises basic concepts of algebra and trigonometry and introduces students to matrices and differential calculus. In many ways the course is similar in content to courses taken at the upper secondary school level. However the course is taught using mainly lectures and tutorials as opposed to typical secondary school class teaching. Many students taking the course are mature age students returning to study after some years break; most of the rest are students straight from secondary school but with limited mathematical backgrounds. Almost no students reported having used a graphics calculator before the course began.

To accommodate graphics calculators in this course, some reorganisation was necessary, especially in tutorials. Students were not expected to own graphics calculators, and very few did. Rather, a set of calculators was used by students in the weekly tutorials, with specific tasks suggested by activity sheets, while some calculators were available for short loan at three locations on campus. Further detailed information about organisation for the use of graphics calculators in the course is given in Bradley, Kemp & Kissane (1994)

Assessment components for the course comprised weekly assignments, three short tests and a final examination. Although assignments did not require the use of graphics calculators, students were not prevented from using them. One of the three tests specifically required the use of graphics calculators, but students were prevented from using graphics calculators on the other two tests and during the final standard three hour examination. Detailed information about course assessment and some evidence of student achievement is contained in Kissane, Bradley & Kemp (1994)

Methodology

As part of the official University evaluation of the course, students were given a Likert-style questionnaire concerned with various aspects of the course and its teaching. A number of questions related specifically to graphics calculators were included. In addition, students were also invited to comment in writing about any aspects of the course, including the use of graphics calculators. Students were not obliged to complete the questionnaire.

The course evaluation questionnaires were completed by a majority (58%) of the 126 enrolled students. Because of the anonymity associated with the data collection procedures, it was not possible to determine why some students decided not to complete the questionnaires, and hence not possible to determine what sources of bias are involved in the responses. The most plausible inference is that students with strong positive and strong negative views are more likely to make their views known, but there are no means of verifying this.

Student responses were collated and summarised and written responses were classified independently by two of the researchers.

Results

In this section, evaluation data from the two data sources are summarised, and a discussion of the implications of these is given in the following section.

Likert scales

Table 1 summarises the responses to the Likert-style items specifically concerned with attitudes towards graphics calculators. Students were asked to indicate whether they strongly agreed, agreed, disagreed, or strongly disagreed with the statements; the mean scores in the table were calculated by assigning

weights of 4, 3, 2 and 1 respectively to these four responses. For each item, a small number of students indicated that they were unable to judge or left the item blank; such responses are not represented below. The mean scores are thus constrained to fall between 1 and 4, with a higher mean score associated with a more positive attitude, and a score of 2.5 representing ambivalence. The items are reported in the table in order of mean score.

Table 1 Mean scores on selected Likert items	Mean
Using the graphics calculators helped me to understand graphs of polynomial and rational functions.	3.15
Using the graphics calculators helped me to understand graphs of trigonometric functions.	3.10
Eventually I enjoyed using the graphics calculators.	3.05
It was a good idea to be able to use the graphics calculators in the test.	3.01
Using the graphics calculator helped me to understand the relationship between graphs and solutions to equations and inequalities.	2.96
Using the graphics calculators helped me to understand matrices and their uses to solve systems of equations.	2.88
Overall I enjoyed using the graphics calculators.	2.83
Some assignment questions should require the use of graphics calculators.	2.76
I think that we should be allowed to use graphics calculators in the final examination.	2.71

Free-response items

Not all students who completed the questionnaires availed themselves of the opportunity to provide unstructured feedback on the course, and in particular on the use of graphics calculators. Consequently, the data are unlikely to be a representative sample of student opinions, as they have a clear element of self-selection and volitional bias. Of the 73 students completing the questionnaires, only 59 (81%) provided written comments. Further, of those students who commented, only 39 of the 59 opted to comment on graphics calculators. A consequence of this data attrition is that inferences about the attitudes of the entire group of enrolled students regarding graphics calculators from the volitional comments of about one third of the enrolled students are fragile. Nonetheless, patterns in the responses might be used to examine potentially fruitful lines of enquiry for a more rigorous evaluation study, and to determine whether the suggested metaphors are recognisable and comprehensive.

Overall disposition

Of the 39 written responses that referred in some way to graphics calculators, 23 reflected a positive view of the use of the calculators, 11 reflected a negative view, and 5 appeared to be ambivalent. These classifications were inferred from the data and made independently by two of the research team, with a high degree of inter-rater agreement. Unfortunately, the data collection process did not permit written responses to be associated directly with the Likert responses, since students were assured by the University of complete anonymity through a process of physically separating the two forms of feedback, one of which consisted of handwriting which might be identifiable. Hence, it is not possible to determine the extent to which students projected a congruent view of graphics calculators in these two different response formats.

Implicit metaphors

Responses were further read with a view to determining the extent to which they seemed to reflect various metaphors for technology postulated by Kissane (1995). Each response was read independently by two researchers, and classified according to which of the metaphors seemed to underpin the comments. A comparison of classifications revealed a strong degree of inter-rater agreement, and the few differences were discussed and resolved. In 30 of the 39 cases, a single metaphor characterised a student's response, but in

six cases, there appeared to be two relevant metaphors. The remaining three comments were not classifiable in this way:

The graphics calculators were a good idea.

The graphics calculators were very good and should be left as a component of the course.

We should have more time to use graphics calculators.

In each case, too little information was given for a confident inference to be made.

Examples of the agreed inferences about underlying metaphoric thinking are given below. In all cases, student responses have been reported *verbatim*, without any corrections to spelling or grammar.

Laboratory

The metaphor of graphics calculator as laboratory is associated with its use as a device for exploration of mathematical ideas, to help them learn better, and thus is essentially concerned with understanding mathematics. Nine of the responses seemed to project this view. Three examples are given below.

It was easy to understand functions with the use of the graphics calculator.

The graphics calculators are an invaluable aid to the learning of concepts.

The graphics calculators were helpful to associate the affects different parts of equations had on graphs.

Tool

The graphics calculator as a tool refers to the view that particular mathematical tasks might be handled by the calculator, rather than by conventional analytic methods. The focus is not so much on learning mathematics, but on completing an otherwise troublesome mathematical task. Eight of the responses seemed to make use of this metaphor, including the following examples.

The matrix function of the graphic calculator saves a lot of hard when finding the inverse of a matric or its discriminant. It is also helpful in solving equations.

By using the graphics calculator it was made easier to draw graphs of functions.

Calculators were excellent for doing equations etc but do not help in explaining the fundamental principles behind these equations/graphs.

Teaching aid

The metaphor of graphics calculator as teaching aid involves a shift of focus from the learner to the teacher, and thus might be expected to be more evident in the minds of teachers than of their students. The only two examples from the student responses were the following:

Use of graphics calculator and the maths package used in the lectures helped to understand, and also give more meaning to what we were doing.

I found the graphics calculators very helpful. The key to this were the step by step explanations on the exercise sheets.

Curriculum influence

The metaphor of curriculum influence acknowledges the pressure on various aspects of the curriculum of introducing a new element of technology. The term 'curriculum' is here used in its broadest sense of referring to the spectrum of teaching, learning and assessment experiences, planned and unplanned, associated with a course of study. Five of the nine student responses that seemed to reflect this orientation to the graphics calculator are given below.

The use of graphics calculators seemed to be secondary to the course proper, yet perhaps the benefit of including them into the course as an integral part may help overall understanding of the content. Their use may have been understated. Their full potential as a learning

aid could be used if directly associated with the course.

I thought the graphics calculators didn't give me as much as I could get from them. We should be allowed to use the calculators (graphic) and normal ones in a test together.

Use calculator in the exam, so that, get full use of calculator, if not, there is no point of using it in the test.

The use of the graphics calculator needs to be incorporated more into the assessment breakdown. The tutorials were often cut short in order to spend time on calculators that will aid little in the final exam. The calculators should be used in the exam to aid the mentally incapacitated.

I don't believe that the students should be assessed on using the graphics calculators. These appear to be used in the course to help people to see what graphs look like and other relationships. Therefore, they are an aid, NOT an assessable part of the course.

Cheating device

This metaphor concerns the view, often expressed regarding less sophisticated calculators, that the use of calculators is a form of cheating, and sometimes underpins a view that students should be prevented from using them because of the negative consequences. There were only two student responses that seemed to reflect this metaphor:

I believe it should be available in the exam. With the clause that all working must be shown. ... It should NOT be used and allowed as other calculators are as this will encourage students to rely on calculator & not be able to devise answers without it.

I don't think they should be used in the exam because maths is about using your understanding & perception and perhaps this ability will become obseliete if the calculator takes over, just as I'm unable to do simple sums without the calculator now.

Status symbol

This metaphor refers to an inclination to focus on technological devices and their features, rather than on their actual use, and often reflects a view that the latest model is better than earlier models *because* it is the latest. In a situation where only one graphics calculator was being used, and in which it was unlikely that students were even aware of other models, it is not surprising that this metaphor was not evident, with the possible exception of the following:

The graphics calculators are useful, however they can be difficult to use because of their poor resolution and poor keyboard. Why not do a deal with the Computer Services Unit and have some real computers with a useful graphing program available.

Nuisance

Eleven student responses did not fit the classification scheme suggested by Kissane's (1995) metaphors for technology, but nonetheless seemed to reflect a consistent underlying metaphor for the graphics calculator, which the researchers agreed could best be characterised as a *nuisance*. The sample below elaborates this metaphoric inference of unwelcome intrusion.

I find that graphic calculator is very time-consuming to learn because I don't take any valuable lesson from it. The graphic calculator is inaccurate and inefficient for measurement.

The graphics calculators took up too much tutorial time and I didn't get the opportunity to ask questions about the other subject matter.

The calculators were a waste of time. Just one more hassle in the course.

I thought the graphics calculators just added to the amount we already had to learn.

The graphics was confusing to me because I have no real maths background so I struggle with basic concepts the long way let alone on calculator. I'm not comfortable enough with the shapes of graphs to be able to see patterns to using the graphics calculator didn't help my understanding.

Each of the responses classified generally as negatively disposed towards the use of the calculator also reflected a metaphor of calculator as nuisance.

Discussion

Student response to the Likert items indicated a very positive attitude among respondents not only towards the use of the graphics calculators but also towards all aspects of the teaching of the course. It is noteworthy that the mean score on each of the graphics calculator items is above 2.5 (the score associated with ambivalence), suggesting that, on balance the students regarded the use of graphics calculators as appropriate for them. The nature of the group of students needs to be borne in mind when interpreting the data: many were taking the course because of their previous limited success with mathematics, and many students openly and informally expressed fears and reservations about their prospects for success in a mathematics course. Almost none of the students were enrolled in the course because of an expressed preference for mathematics; rather they were obliged to complete the course as a prerequisite for later study. In such circumstances, a positive response is particularly encouraging towards the continued use of graphics calculators.

Student unstructured comments suggest that there are a range of ways in which students thought about the use of graphics calculators in this course. Despite limitations in representativeness of the data, the responses suggest that Kissane's (1995) metaphors for technology are discernible and that they account for a substantial proportion of attitudes towards the use of graphics calculators. The additional metaphor of the graphics calculator as a nuisance provides a further insight into the orientations towards technology that might be expected, and which need to be accommodated in curriculum design and development. While it would be quite inappropriate to use the data reported here to make inferences about the relative prevalence of particular metaphors among the students enrolled in this course, they provide empirical evidence of the existence of the metaphors, and suggest that further, better controlled, investigation may be of value.

Rather than a single way of thinking about graphics calculators, it is likely that students will develop a number of ways, as they become more experienced. The amount of use of graphics calculators in this course was relatively small, and for some students would have been restricted (by personal choice) to a total for the semester of a few hours during tutorials. Personal calculator ownership, and more substantial integration of graphics calculators into a course are likely to develop a richer range of ways of thinking about technology in students, as argued by Kemp & Kissane (1995).

The sources of student attitudes are also of interest, and it seems likely that the views of lecturing and tutorial staff as well as the actual course activities would have a powerful influence. During 1995, the research team have further modified *Fundamentals of Mathematics* to integrate graphics calculators into course assessment, including weekly assignments and the final examination, with the assistance of a Committee for the Advancement of University Teaching (CAUT) grant. The metaphors of graphics calculator as a laboratory, a tool, a teaching aid and an influence on the curriculum may well be highlighted in students' minds by such activities, but

further research is needed to determine if this is actually the case.

The existence of metaphors for technology raises some intriguing questions. Not the least of these is the possibility of a mismatch between the orientations towards the graphics calculator of a student and a lecturer, or a student and a tutor, reminiscent of the mismatches of orientation to understanding first described by Richard Skemp (1976). Again, further research is needed to ascertain the nature, extent and consequences of such mismatches.

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