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Integrating technology into undergraduate mathematics

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This paper describes the importance of integrating technology into a mathematics course, in contrast to using items of technology as occasional pieces of support for students learning or teachers teaching. The integrated use of microcomputers in mathematics courses is problematic for practical reasons of access and cost, and we will argue that hand-held graphics calculators provide a more viable alternative. We describe our experiences to date with the use of graphics calculators in a first year mathematics course. During 1994, with access to a limited quantity of calculators, we began a process of integrating technology into the course; we will continue this process into 1995, with some support from a CAUT grant to do so. Particular focus will be placed on the design and administration of appropriate assessment tasks, but we will also describe some of the changes to pedagogy involved, as well as some practical issues of organisation in the context of limited resources.

Introduction

The context of undergraduate mathematics has undergone considerable change recently, with the development of various electronic technologies. Students arriving from secondary school almost certainly own a scientific calculator, which they have been using for some years. Computers are widely available wherever serious use of mathematics is undertaken, whether in educational institutions or in workplaces. Many students who take service courses in mathematics will need to make use of their learning in contexts in which technological help is taken advantage of. The main focus of this paper is the appropriate kind of response to such an environment.

It is inappropriate to regard technology as an add-on to a mathematics course, since this will inevitably lead to it being regarded as a frill, to be readily neglected by many. Indeed, this is the experience of many students with respect to computers and mathematics courses, both in secondary schools and in the early years of tertiary study. Institutions rarely have sufficient computer resources available when and where the students need them for the use of computers to be regarded as germane to mathematics and learning mathematics. Without such resourcing, mathematics courses are organised on minimalist assumptions of technological access, and are likely to be little different from those of a decade ago.

Adequate integration of technology into undergraduate mathematics courses includes a consideration of all aspects of a course: the mathematical content, lectures, tutorials, workshops, assignments, tests and examinations. Without a measure of coherence among the use of technology in all of these course components, there is a risk that the lowest common denominator position will be adopted, and the impact of technology will be minimal. For example, if technology is used for teaching and learning in lectures, but examinations are unaffected by its introduction, it seems quite likely that students will recognise its use as merely optional. If it is expected that students themselves will develop some expertise at using technology in mathematics, then this should be reflected in the style of tutorials and workshops.

It is difficult to integrate microcomputer technology into mathematics courses, for reasons of practicality and economics. Even when computer laboratories are available, the levels of student access for learning mathematics are necessarily limited, and it is physically cumbersome to provide access to the technology in assessment situations. As a consequence, it is unreasonable to expect that students will come to regard the microcomputer as a valuable mathematical tool.

The situation is rather different with graphics calculators however. Although microcomputers are much more powerful and flexible, since it is relatively easy to use a variety of software with them, graphics calculators have the substantial advantages of portability and cost. It is likely soon that students will have their own graphics calculators, which will be available at home as well as at university, and that they can be used in formal assessment situations such as examinations. Integration of technology is much more feasible in such circumstances, where reliance is not placed on microcomputers. More detailed discussions of the particular advantages of graphics calculators for learning mathematics are given in Andrews & Kissane (1994), Kissane (1994) and Kissane (1995). A description of the general nature and mathematical capacities of graphics calculators is given in Kissane (1993).

Experience to date

This paper is based on our experience with *Fundamentals of Mathematics*, a first year undergraduate course which reviews basic concepts of algebra and trigonometry and introduces students to matrices and the concepts of calculus. It is a service course, offered in both internal and external modes, intended for non-mathematics specialists who will go on to study a variety of courses at Murdoch University. In this paper we describe how graphics calculators have been integrated into the internal mode of the course. Successful completion of this course can provide an entrance to other mathematics courses but more generally students take the course to learn the mathematics that they will need to apply in other subject areas. Through the course students are exposed to a range of applications from a variety of discipline areas some of which illustrate the potential use of graphics calculators in these other subject areas.

It is not uncommon for technology in the form of computers, slides, videos and so on to be used by teachers for demonstration purposes for teaching. In this case, however, technology in the form of graphics calculators has been integrated into other aspects of the course including tutorials and assessment, where it is used by students themselves. This was made possible through funding from various sources across the university which enabled us to purchase a set of 35 Texas Instruments TI-82 calculators for use with internal students in 1994. This particular calculator was chosen for use with the internal students partly because its predecessor, the TI-81, had proved to be successful with external students in 1993 and partly because the staff were familiar with them. (Bradley & Kemp, 1993) A detailed description of the main mathematical features of this particular calculator is given in Kissane (1994). The relatively modest investment enabled a class set of 20 of these portable computers to be used in tutorials and the rest to be put on reserve in libraries across the campus. The tutorials are scheduled at different times so that a brief case containing the calculators can be passed between tutors (Bradley, Kemp & Kissane, 1994a).

As is customary in most undergraduate courses there are weekly tutorials of fifty minutes. In 1994 about twenty minutes of each tutorial was allocated to student use of the graphics calculators. These sessions were directed by a series of detailed worksheets designed to reinforce the concepts presented in the lectures in the previous week, and to extend the students' understanding of the material. Students were expected to complete these in their own time if necessary, using the calculators on reserve or borrowing them on overnight loan.

Since the aim was to integrate the graphics calculators as much as possible, it was decided to allow the use of the graphics calculators in the third of the short tests taken during semester. The students were given the test during their tutorial time so that all students sitting the test at one time had individual access to a graphics calculator. The questions were designed to be more efficiently answered with the use of a calculator, including situations where solutions were difficult if not impossible to find by other means, although calculator use was not compulsory. Several versions of the test were prepared, to be used in each tutorial, and the results indicated that students taking the test in a tutorial at the end of the week had no advantage over students taking it earlier, a reassuring observation about test security. Due to practical constraints it was not possible to use the calculators in the final examination, however a part of the examination required students to interpret a graph drawn by a computer, a task similar to that needed for successful calulator use. This section of the examination helped to provide evidence of students' ability to understand the relationships between graphs of functions, equations, roots and inequalities.

As the introduction of the calculators into tutorials and assessment was new to this course we were particularly interested in how students perceived this innovation. An independent course evaluation showed that student responses to the use of the graphics calculators was varied, but on the whole was more positive than negative. 88% of the students eventually enjoyed using the calculators and over 80% felt that their use had helped them to understand graphs of polynomial, rational and trigonometric functions. However 76% thought it was a good idea to use the calculators in the test indicating some reservation on the part of the other 24%. A more complete description of student reactions is given in Bradley, Kemp & Kissane (1994a).

The content of *Fundamentals of Mathematics*, has much in common with upper secondary school courses so there are text books containing appropriate content. However the development of suitable graphics calculator activities and assessment tasks is a major undertaking due to a lack of appropriate published resources. During 1995, the improvement of existing tasks and development of new tasks will be helped by the use of a graphics calculator emulator and a computer link to the TI-82 so that actual calculator screens can be printed out. Nevertheless the integration of the graphics calculators into the course involves far more than the practicalities of production; it involves serious consideration of how the use of such technology can enhance student learning.

Assessment issues

The most critical aspect of integration for a mathematics course involves formal assessment, for several reasons. In the first place, the emphases on different aspects of mathematical learning are likely to change when students have graphics calculators available to them, and assessment situations demand that we understand these changes of direction. In the case of the TI-82 graphics calculator and the *Fundamentals of Mathematics* course, a number of calculator capacities need to be taken into account. These include a facility with graphing, with tabular representations (and thus evaluation) of functions, the numerical solution of equations, matrix manipulations and elementary calculus (differentiation and integration), as described in some detail in Bradley, Kemp & Kissane (1994b). When students have access to graphics calculators, some standard and traditional kinds of assessment items are rendered inappropriate, while other aspects of student thinking and activity need to be addressed instead.

Secondly, integration of technology into a mathematics course implies that the content of the course, and not just its assessment, is likely to change to some extent. For example, a different emphasis on the solution of equations seems important if students have access to a calculator that solves some equations directly with a 'solve' command, or allows for a graphical solution as well as an analytic solution, as the TI-82 does.

A different kind of change to such a course may be that an important new course outcome that might be expected is the extent to which students can use technology well. In the present case, this involves deciding when to use a graphics calculator and when not to do so, using it efficiently, interpreting the results obtained and describing them in appropriate mathematical language. Such an important course outcome needs to be assessed involving changes to the traditional style of assessment.

Finally, since our assessment practices make clear to both teachers and learners what is ultimately valued most in a course, student responses to the use of technology are notably different when it is clear to them that they will be expected to formally demonstrate a level of competence. In the case of the graphics calculator, our experience so far has persuaded us that some students need the extra incentive provided by the knowledge that at some point they will be expected to demonstrate that they can make intelligent decisions about when and how to use the technology.

An assessment issue of some importance concerns the varying capacities of different graphics calculator models. Care needs to be exercised that some students are not unduly advantaged by having access to more powerful models, or disadvantaged by being restricted to less powerful models. As noted by Kissane, Bradley & Kemp (1994), many uses of graphics calculators at the early undergraduate level do not rely on the most sophisticated capabilities of modern graphics calculators, so that, in effect the problems of differential capacity evaporate. In the particular case of *Fundamentals of Mathematics*, too, the problems are avoided since all students are using the same model calculator, although this phenomenon is not expected to last for many more years. In the USA, the College Board has addressed potential problems of differential capacity in the Advanced Placement examinations, by providing students with calculator programs to use, to ensure that each student taking an examination has at least a minimal set of calculator capabilities at their disposal.

In 1995, our integration of the graphics calculators will include the use of a calculator test (conducted in tutorial groups, as described above) as for 1994. In addition, student weekly assignments will include items for which calculator use is necessary, and arrangements will be made to allow students to use calculators in the formal final examination at the end of the semester. The design, trialling and implementation of these modifications to the assessment programme to incorporate the graphics calculators are supported in part by a grant from the Committee for the Advancement of University Teaching (CAUT). Among the issues to be addressed in this project are what needs to be written down by students in examinations when calculators are used to support their thinking, the effects of calculator access on examination questions that have not been specifically designed to probe student use of calculators, and the administration of examinations when there are not sufficient resources to provide each student with a calculator for the duration of the examination. Two possible solutions to the latter problem are to conduct more than one session for an examination, or to restrict the period for which students have calculator access, so that they can be shared around the whole class. There are advantages and disadvantages associated with each of these solutions. In time, as most students will be expected to own their own calculator, issues of this kind can be expected to diminish in significance.

Conclusions

Integration is the key to finding the appropriate response to technological change in undergraduate mathematics. A suitable balance needs to be struck between the enthusiastic and uncritical acceptance of new technologies on the one hand and the uncritical rejection of technological influences on curriculum on the other hand. Integration demands a careful consideration of all aspects of a curriculum, from both the perspectives of the learner and those of the teacher. It seems that the most important elements of integration, and probably the most difficult, are those related to assessment. Our experience to date suggests that graphics calculators are better candidates for integrating technology into mathematics courses than are other kinds of computers, and that both student and teacher reaction to their use is favourable.

References

Andrews, T. & Kissane, B. (Eds.) (1994). *Graphics calculators in the classroom*. Adelaide: The Australian Association of Mathematics Teachers.

Bradley, Jen, Marian Kemp & Barry Kissane (1994a). Graphics calculators: A (brief) case of technology. *Australian Senior Mathematics Journal*, 8(2), 23-30.

Bradley, Jen, Marian Kemp & Barry Kissane (1994b). Graphics calculators: Learning from experience. *Proceedings of the 4th Annual Australian Bridging Mathematics Network Conference*, Sydney University, 29-36.

Bradley, Jen & Marian Kemp (1993). Different strategies for teaching the same course to internal and external students. *Proceedings of the 3rd Annual Australian Bridging Mathematics Network Conference*, Queensland University of Technology, Brisbane, 51-58.

Kissane, Barry, Jen Bradley & Marian Kemp (1994). Graphics calculators, equity and assessment. *Australian Senior Mathematics Journal*, 8(2), 31-43.

Kissane, Barry (1994). Graphics calculators: What's new? *Cross Section* , 6(3), 16-20.

Kissane, Barry. (1995). Technology in secondary school mathematics - the graphics calculator as personal mathematical assistant. In Robert Hunting, Gail Fitzsimmons, Philip Clarkson & Alan Bishop (Eds.), *Proceedings of the International Commission on Mathematics Instruction Conference on Regional Collaboration*. (pp 383-392) Melbourne, Monash University.

Kissane, B. (1993). Sophisticated calculators: mathematics for a new age. In Tony Herrington (Ed.), *New horizons, new challenges*. The Australian Association of Mathematics Teachers, Perth, 227-240.