The implementation of graphics calculators in a large first year university unit

Pender Pedler, Ute Mueller, Malcolm Anderson and Lyn Bloom
School of Engineering and Mathematics
Edith Cowan University
p.pedler@cowan.edu.au

Abstract

In this paper we describe the implementation of graphics calculators as teaching and learning aids in a large first year university mathematics unit. This unit is a core unit in the Computer Science and Engineering programmes. The content of the unit includes vectors, matrix and complex number arithmetic, analytical geometry and systems of linear equations. Graphics calculators provide the best means of a student performing the required calculations quickly and efficiently, permitting the consideration of more realistic problems without a large computational burden. In 1999 for the first time students in this unit are expected to use a graphics calculator for all their calculations. However students have a wide range of calculator skills, from school leavers with a minimum of two year's experience with a graphics calculator to mature age entrants with little or no calculator experience. With such a diverse student background and permitting student use of a range of makes and models of graphics calculators, there are problems of equity of student access to the technology, practical problems of instruction in a large tutorial class and problems of ensuring examination fairness. A pilot programme in 1998 with a small number of students using Hewlett Packard HP 38G graphics calculators enabled resources to be developed and tested. This paper describes the development of a calculator policy and a set of non-model specific graphics calculator notes and exercises used to address these problems. The usefulness of these resources and the effectiveness of the implementation at each stage were assessed with student evaluation questionnaires.

1 Introduction

In this paper we address the problem of incorporating the graphics calculator as a teaching and learning aid in a large first year service university mathematics unit. At Edith Cowan University (ECU), the unit MAT1161: Discrete Mathematics for Computing has an enrolment each year of approximately 250 students in semester one and another 70 in semester two. The majority of these students are enrolled in the Bachelor of Science (Computer Science) programme. Class time comprises two one-hour lectures and two one-hour tutorials for each of the twelve semester weeks. The unit is offered on three campuses and makes extensive use of sessional staff both for lectures and tutorials. The unit MAT1162: Vectors and Matrices comprises half the content of MAT1161. It has an enrolment of approximately 70 students in semester one and 10 students in semester two. It is a core unit in the Bachelor of Engineering and Bachelor of Technology programmes and is taught concurrently with MAT1161. The content common to both units includes vectors, matrix and complex number arithmetic, analytical geometry and systems of linear equations.

Prior to 1999, because of equity considerations, a graphics calculator was not compulsory and the minimum requirement was a scientific calculator. Despite this, there was no restriction on the type of calculator able to be used in mathematics tests or examinations and students were encouraged to purchase and use a graphics calculator. Few in fact did so and the unit content was arranged so that all required calculations could be performed on a scientific calculator. What has caused our policy change to a minimum requirement of a graphics calculator in MAT1161 / MAT1162 is that graphics calculators have now been adopted in secondary schools in Western Australia and were used for the first time in the Year 12 Tertiary Entrance Examinations (TEE) in November 1998. Therefore, from semester one 1999, these school leavers were expecting to use their graphics calculator at university for all calculations where appropriate.

2 Implementation Stages

The fact that the students were expected to use their own calculators presented different problems from those that arise when calculators are made available to students [3] or a specific brand and model calculator is required [1, 2]. The main problems we faced were problems of equity of access, instruction and examination fairness, problems that result from the wide range

of calculator skills and experience of commencing students.

The implementation was planned to take place in three stages. Stage one was a pilot study with MAT1162 students to develop and trial supplementary teaching material in a more controlled environment. The 1999 implementation of the new calculator requirement with both units was stage two. It involved the provision of tutorial time instructing students in the use of graphics calculators and changing some of the tutorial and assessment questions to be more computationally intensive. This was an interim stage and less than a full implementation of graphics calculators. The implementation of graphics calculators is planned to be completed in stage three next year with the inclusion of more assessment questions where graphics calculators are expected to be used. The two-year implementation was designed to give staff adequate time to gain familiarity with the different models of graphics calculators and smooth the implementation process. This paper describes the results of the first two stages, the pilot study and the 1999 implementation.

3 Pilot Study

The small number of students enrolled in MAT1162 in 1998 semester two provided an opportunity to develop and trial the supplementary calculator material in a more controlled learning environment. The content of the unit is specified by a textbook and comprises 12 weekly topics. In preparing the calculator material, the decision was made, for convenience, to consider mainly the graphics calculators permitted to be used in the Year 12 TEE, namely the Casio cfx9850GPlus, the Hewlett-Packard HP 38G, the Sharp 9300 and the Texas Instruments TI-82/83, together with the TI-86. For simplicity, we chose to omit any consideration of more sophisticated calculators such as the HP 48G.

The graphics calculator workbook comprises a set of notes and learning exercises to be used in conjunction with the text. Calculator commands are given in generic form together with the means of a student adapting them for their own calculator. Specific commands use the notation of the corresponding calculator manual. The following examples illustrate the format of the generic notes.

Example 1 *The command* $\boxed{INV}$ $\boxed{\boldsymbol{M1}}$ *denotes finding the inverse of a square matrix and abbreviates*

- For the HP-38G
  $\boxed{\mathbf{M1}}$ ■ [X^{-1}] $\boxed{\text{ENTER}}$

- For the TI-86
  M1 2nd [X^{-1}] ENTER

- For the TI-82/83
  MATRX *Select* **M1** ENTER X^{-1} ENTER

- For the Sharp9300
  In Matrix Mode: 2nd F [MAT] **M1** 2nd F [X^{-1}] ENTER

- For the CASIO CFX-9850 G Plus
  OPTN F2 F1 **M1** SHIFT [X^{-1}] EXE

Example 2 *The symbol* *cross* *denotes the vector function cross product. The command* *cross* ***V1*** , ***V2*** *abbreviates*

- For the HP 38G
  MATH *Select* **Matrix** {{OK}} *Select* **CROSS** {{OK}} **V1** , **V2**) ENTER

- For the TI-86
  2nd [VECTR] F3 F1 **V1** , **V2**) ENTER

- The TI-82/83, Sharp9300 and CASIO CFX-9850 G Plus do not provide any facility for calculating the cross product of two vectors.

The class commenced with 10 students but student numbers quickly dropped to the six who completed the unit. In this trial, students were not expected to purchase their own graphics calculator. A small class set of HP 38G graphics calculators was obtained on loan from Hewlett-Packard. An HP 38G calculator was made available to each MAT1162 student during all tutorial sessions, tests and the examination. Furthermore, five HP 38G calculators were placed in closed-reserve in the library and available for short-term loan. The use of the same brand and model calculator with a small number of students enabled the notes and exercises to be developed and trialled with minimal detrimental effect to the students' learning. The MAT1162 tutorials ran smoothly indicating the effectiveness the class material and its use in

the tutorials. However, this implementation was made easier through the strategy of having all students use the same type of calculator.

A questionnaire was used to assess the student response to the calculator materials and to the actual calculator use. The results were very positive. All students rated the value of the graphics calculator as 5 on a five point scale (1: poor through to 5: excellent) and the value of the learning exercises for the graphics calculators as 4 or 5.

4 Calculator Policy

A written calculator policy is used to provide ECU first year mathematics students with a clear set of guidelines governing the use of calculators in all mathematics units.

The new policy states that students in these mathematics units from 1999 onwards are expected to have a suitable hand-held graphics calculator. The policy elaborates on the set of minimum graphics calculator facilities for specific mathematics units. No single brand or model graphics calculator is recommended but the Casio cfx9850GPlus, Hewlett-Packard HP 38G, HP 48G and Texas Instruments TI-86 are listed as suitable for undergraduate student use. The special role of Hewlett Packard calculators for research and teaching purposes is also included. The policy also addresses and clarifies issues with respect to the use of graphics calculators in tests and examinations. Finally, students are provided with information on some of the limitations inherent in graphics calculator technology and their assessment consequences.

A copy of this document was supplied to each student enrolled in MAT1161 and MAT1162. In addition the semester outline for each unit containing information on matters such as classes and assessment stated that "all calculations expected of students in this unit can be performed on a hand-held graphics calculator with vector, matrix and complex number facilities".

5 The 1999 Implementation

The two units MAT1161 and MAT1162 commenced at the beginning of semester one as planned. The new calculator requirement was explained to students at the first lecture, as part of the overall introduction to the unit. At this session, each student was provided with a copy of both the calculator policy and the graphics calculator workbook.

The first problem faced by many students concerned the purchase of a graph-

ics calculator. Some students were concerned to discover that the Sharp 9300 calculator that they had used in Year 12 was inadequate for use at the tertiary level as it did not contain the facility for performing the necessary vector, matrix and complex number arithmetic. Despite the information contained in the calculator policy that all students were expected to have and use a graphics calculator, students were concerned with the issue of whether such a calculator was really necessary. What were the consequences to them of working with only a scientific calculator? Could they the still pass the unit? While some students immediately purchased a new calculator, others adopted a "wait and see" strategy to gain information on the consequences of not having a graphics calculator.

The main classes at which calculators were used were the one-hour weekly tutorials. There were ten tutorial classes in the two units, each with 30 to 40 students and a single tutor. At each tutorial session, students worked from two sets of questions on the topic for the week, one a non-graphics calculator set used in previous semesters and the other the set of questions in the graphics calculator workbook. Tutors were quickly faced with three distinct groups of students each with their own set of needs.

The first group comprised the school leavers who were confident with their graphics calculator together with the additional few students who managed to learn the essential basics sufficiently quickly. These students proceeded to use the graphics calculator workbook as planned and appeared to have few problems. The second group comprised the largely mature age students each with a newly purchased graphics calculator. Despite the tutor at the first tutorials rearranging seating so students with the same model calculator were seated together, opportunities for direct instruction were limited. Time permitted no more than the tutor showing a small group of students at a time how to get started on the first examples with their calculator and showing how to relate the generic code in the workbook to the corresponding key presses on their calculator. At best, the tutor was reasonably familiar with only one model of graphics calculator and had only a passing familiarity with the others. This group of students found this way of learning how to use a graphics calculator frustratingly slow. The initial stage of a student getting started is of particular concern. Few students seemed to be able to use the manual accompanying the calculator to learn the essential basics quickly. Most students still need at least one tutorial session devoted exclusively to getting started with their specific make and model calculator. The third group of students were those without a graphics calculator who had decided to "wait and see". These students were content to use the tutorial time to work through the non-graphics calculator exercises. As the

semester progressed, some members in the third group purchased a graphics calculator and joined the second group, while just as many from the second group decided to give up on the graphics calculator and join the third group. The main difficulty for the tutor was to manage time adequately between the three groups of students and to give sufficient assistance to all students.

Assessment items in both units this semester were not substantially different from those used in previous semesters. In particular, neither the tests nor the examination contained any question for which the use of a graphics calculator was essential for the solution. The main penalty incurred by students with only a scientific calculator was a lack of efficiency, being unable to work through examples and solve problems as quickly and as accurately as their colleagues with graphics calculators. This factor certainly contributed to the decision of the minority of students who chose not to use a graphics calculator.

6 Student Evaluation

Two questionnaires were given out in class at the end of the semester to measure student reaction to the unit. The first was the ECU unit evaluation questionnaire assessing students' perceptions of the unit. The second was used to seek information on the students' use of graphics calculators during the semester and their perceptions of the value of the resources used in this implementation. Unfortunately only 41% of enrolled students actually completed the questionnaires as many students happened to miss the relevant class session. For simplicity, the results of the students in the two classes have been combined in the latter. Student responses to aspects of graphics calculators need to be interpreted in the light of the information that students regarded the units as quite satisfactory. Of all students responding to the questionnaire, 73% and 85% considered the units MAT1161 and MAT1162 respectively to be almost always or mostly satisfactory on a five-point scale. However, these results are likely to have a positive bias due to the selective nature of students who attended the last two lectures of the semester and returned the completed questionnaires.

The relevant questions from the calculator survey are as follows.

1. At the beginning of the year, my experience with a graphics calculator was
   Nonexistent 1 2 3 4 5 Extensive

2. My use of the graphics calculator this semester has been

Nonexistent 1 2 3 4 5 Extensive

3. The value of the calculator policy in informing me about calculator use at ECU is
   Poor 1 2 3 4 5 Excellent

4. The value of the set of notes and exercises on graphics calculators is
   Poor 1 2 3 4 5 Excellent

5. My use of the set of notes and exercises on graphics calculators has been
   Nonexistent 1 2 3 4 5 Extensive

6. The value of the tutorial sessions on vectors and matrices has been
   Poor 1 2 3 4 5 Excellent

7. The value of the graphics calculator as a tool for this unit is
   Poor 1 2 3 4 5 Excellent

Beginning students comprise two distinct groups with respect to calculator use, school leavers with at least two year's experience with a graphics calculator and the completely naive with little or no calculator experience. In the 1999 implementation, the sizes of these two groups were approximately equal. When asked to assess the extent of their prior experience with a graphics calculator, 44% of all students responding rated it as 4 or 5 while 39% rated it as 1. Furthermore, as 22% of all students responding rated their use of the graphics calculator this semester as 1, this implementation resulted in a rather poor uptake of graphics calculator use among naive users. The most likely reasons for this were the high initial cost of a graphics calculator, the perceived complexity of learning how to use it and the student belief that they could still pass the unit without using one.

The main resources used in this implementation were the calculator policy and the graphics calculator workbook comprising the set of notes and learning exercises. Student responses to the value of the calculator policy were fairly uniform, with 34% of all students responding rating its value 3 and 37% of students rating it 4 or 5.

Concerning the value of the graphics calculator workbook, 40% of all students responding rated it as 3 while 30% rated it as 4 or 5. With respect to only those students who rated their calculator experience as non-existent at the beginning of the year, 42% rated the value of the workbook as 3 while 26% rated it as 4 or 5. This shows the consistency of these ratings for the value of the workbook between naive and experienced users. The questionnaire also

asked students for information on the extent to which they used the workbook during the semester. The distribution of the responses was very similar to that for the value of the workbook. However, with respect to naive and experienced users separately, the experienced users reported making more use of the workbook.

The questionnaire sought information on two further aspects of the 1999 implementation, the value of the tutorial sessions themselves and the value of the graphics calculator as a tool for the unit. Concerning the value of the relevant tutorial sessions, 73% of naive users responding and 83% of experienced users rated it as 4 or 5. Concerning the value of the graphics calculator as a tool for the unit, 44% of all students responding rated it as 3 while 37% rated it as 4 or 5. As was to be expected, responses were slightly more positive for experienced users of the graphics calculators than for the naive ones.

7 Conclusions

The 1999 implementation of graphics calculators as teaching and learning aids was reasonably satisfactory as the interim stage of a two-year implementation process. Despite some problems, a large majority of the students considered the units to be mostly satisfactory. The small number of students taking these two units in semester two this year means that most of following proposals to address these issues are planned for implementation in semester one next year.

The first issue concerns the range of makes and models of calculators used by students. In the 1999 implementation, the most commonly used models were the Casio cfx9850GPlus and the Hewlett-Packard HP 38G. The use of the HP 48G was restricted largely to Engineering students in MAT1162. Very few students used a TI calculator and no student used a Sharp. In the next implementation, we plan to support only the use of the Casio and the HP 38G in MAT1161 and only the HP 48G in MAT1162. Offering additional model-specific instruction and teaching materials will reinforce this restriction to the range of calculators.

The next issue is concerned with the initial learning stage of students getting started with their new graphics calculator. Naive calculator users need at least one tutorial session devoted exclusively to gaining familiarity with their make and model calculator. For these sessions to be effective students need to be convinced very quickly that the purchase of a graphics calculator is necessary for the unit and that they have it in time for the introductory ses-

sion. Students will therefore need to be strongly discouraged from choosing a "wait and see" strategy. In the next implementation, we plan to include in all tests and the examination assessment items for which the use of a graphics calculator is the most reasonable solution strategy and essential for the solution of the problem. We will need to stress to students in the first session that if they do not use a graphics calculator they will be at a serious disadvantage. We must have ample supplies of the recommended calculators for sale in the bookshop. Implementing all these strategies should enable beginning students to get started more effectively with their new graphics calculator.

The final issue is concerned with the running of the tutorial sessions themselves. Restricting the range of models of calculators used by students and commencing the semester with a model-specific calculator tutorial session next year should go a long way to reduce to a more manageable level the demands on tutors during tutorial sessions. Timetable restrictions for MAT1161 students do not permit the offering of specific tutorial sessions to specific model graphics calculators in this unit. However as most MAT1162 students are studying full-time, such a strategy can be implemented in this unit. In the next implementation we plan to make the two MAT1162 tutorials specific to the brand of graphics calculator used. One tutorial will be for users of the HP 48G calculators while the other will be for users of the Hewlett-Packard HP 38G and Casio cfx9850 series of calculators.

Despite the above plans, we anticipate that the task of finding and implementing effective strategies to exploit contemporary calculator technology in a large first year mathematics unit will remain a challenge for the immediate future.

References

[1] Bradley, J., Kemp, M. & Kissane, B., (1994). Graphics calculators, equity and assessment. Australian Senior Mathematics Journal, 8(2), 31-40.

[2] Kemp, M., Kissane, B. & Bradley, J., (1996). Graphics calculator use in examinations: accident or design? Australian Senior Mathematics Journal, 10(1), 36-50.

[3] Mueller, U., Pedler, P., Anderson, M. & Bloom L., (1998). The implementation of a graphics calculator in undergraduate linear algebra units. Australian Senior Mathematics Journal, 12(2), 47-57.