The Effects of a Computer Algebra System on the Learning of, and Attitudes towards Mathematics amongst Engineering Students in Papua New Guinea.

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This paper reports on a study which investigated the effects of a computer algebra system, *Derive*, on the learning of, and attitudes towards mathematics amongst engineering students in Papua New Guinea. The study compared the traditional course approach to an experimental approach integrating *Derive*. The findings indicate no statistically significant differences in achievement performances between control and experimental groups, nor in students' attitudes towards mathematics. However, positive indicators of enjoyment, motivation and usefulness of mathematics observed with the experimental group are considered educationally significant.

Introduction

Only a moderate amount of literature is available relating to research in mathematics education and the learning of mathematics in the South Pacific region, and Papua New Guinea (PNG) in particular. In PNG, with computers only relatively recently finding their way into the education system, a paucity of research (Arganbright, 1989; Seldon, 1984; Sheridan, 1985) exists pertaining to the use of computers in the teaching and learning of mathematics. No literature was available on any studies or findings relating to the use of a computer algebra system (CAS) in the country, or on students' attitudes towards the use of computers in the learning environment.

World-wide, research in connection with the use of computer algebra systems in the educational setting has been steadily growing since the early nineties (e.g., Berry, Graham & Watkins, 1993; Hillel, Lee, Laborde & Linchevski, 1992; Hunter, Marshall, Monaghan, and Roper, 1995; Judson, 1990; Mayes, 1995; Palmiter, 1991). The majority of these researchers have performed control experiments with CASs and, while observing improvements in student performance and attitudes, they have not generally shown their findings to be statistically significant. They are usually cautious in their conclusions, stating that the improvements cannot be attributed only to the use of the CAS and suggest extensions to their studies.

Some published research has shown that PNG students have problems with language in mathematics (Clarkson, 1987; Jones, 1982, Roberts, 1989), and Audrey and Michael Wilson (1983) demonstrated that about one quarter of PNG students entering tertiary studies were at Piaget's 'abstract reasoning' level, while another quarter was still at the 'concrete material' level. The remaining half of the Wilsons' sample was at a transitional stage of thinking abstractly when on familiar problems, but turned to a concrete approach when confronted with new ideas. Students completing grade 12 in PNG are thus, from a curriculum point of view, approximately 1.5 to 2 years behind that their counterparts in Australia and New Zealand. The Foundation programme at the PNG University of Technology (UNITECH) attempts to bridge the gap from grade 12 to the commencement of certificate, diploma and degree studies. As a result, the foundation courses tend to be heavy in content, and many topics are covered superficially and with little depth. The Foundation Year Engineering (FYE) mathematics course thus tends to be structured around procedural knowledge and which emphasises routine methods. Concepts of generalisation, proof and logical reasoning have to be developed very gradually, and are usually met with frustration and confusion by many students. In this course, students work with locally written modules and tutorial groups consist of 15 to 20 students. Although attempts are made at stretching students' minds to apply learnt concepts, they find difficulty in independently extending their thinking beyond the familiar. Students need to be given 'thinking' assistance to help them to recognise patterns and generalisations. Roberts (1989, p. 196), commenting on his observations of grade 12 school leavers in PNG has said that, on entry to tertiary studies, only a minority of students are "ready to proceed to more formal deductive mathematics" and "problems and situations which stress logical thinking and generalisation should be presented" to the bulk of students.

The author of this paper, as coordinator of the FYE Mathematics Programme at UNITECH, was familiar with the computer algebra system, *Derive*, and felt that with its interactive and visual approach, it could provide students with 'thinking assistance' in recognising patterns and generalisations, as well as being a medium of visual and interactive learning where the teacher's role of a verbal communicator was reduced. Much of the emphasis in the learning would thus be centred around student interaction with *Derive* and student-to-student discussion in a language of their choice. Tutors would also be present for further assistance. It was also hoped that this mode of learning would encourage more student motivation and help to develop improved attitudes towards mathematics. These expectations formed the basis and underlying motive for this research. The objectives of the *Derive* sessions were seen as:

- reinforcing the learning that was taking place. Worksheets would be staggered by two weeks, that is, students would work through material on the computer which would have been presented in lectures about two weeks earlier. Thus, students would have had a good opportunity to try fairly routine and regular problems with pencil, paper and calculator in their classroom tutorials before reviewing similar work in a computer session.
- extending some of the learning to real-world application situations where the computations could be taken care of by *Derive* and students could think a little more about the structure of the problem.
- helping to develop an investigative attitude to mathematical problems.
- motivating students' interest in the mathematical concepts they were learning
- helping to improve students' attitudes towards mathematics.
- making students more aware of the need for, and use of, correct notation and meaningful interpretation of the symbols used.

With these objectives, the role played by *Derive* was seen as pedagogical in nature, with the emphasis on helping to develop and encourage student thinking, which in turn could aid conceptual understanding.

Aims of the Study

The overall aims of the study were twofold:

- to determine the efficacy of computer algebra systems in aiding and improving the achievement in mathematics of engineering students at the PNG University of Technology.
- to determine whether the use of computer algebra systems could assist in improving the attitudes that students have towards mathematics.

'Achievement in mathematics' here means the student's performance in the tests and examinations taken as the part of the normal Foundation Mathematics programme. As these assessment measures would involve, in the main, procedural knowledge and routine applications, they could not be interpreted as reliable indicators of a student's conceptual knowledge of the mathematics involved.

Methodology

The research was concerned with a comparison of the traditional lecture/tutorial-based approach with an experimental approach which integrated the computer algebra system, *Derive*, into the traditional programme. The subjects of the research were 186 Foundation year students, and these were divided into experimental and control groups. Due to a variety of constraints, full experimental control in the allocation of students to class groupings was not possible and random assignment and equivalence of groupings could not be assumed. The design of the research was therefore quasi-experimental using a non-equivalent control group design (Campbell & Stanley, 1966). In addition to the quantitative measures, the design further involved a qualitative aspect based on written comments made by students on the use of *Derive*. The students' achievement in mathematics, as determined by their performance in tests and examinations, and their attitudes towards mathematics, as measured through questionnaires, were the dependent variables in this research.

A pilot study was conducted with the 1994 intake with the view to develop and trial worksheets for the computer sessions, determine logistics, familiarise staff with *Derive*, observe students and obtain feedback from them. The main research was conducted over two semesters in the following year, with the experimental groups having one of three regular weekly tutorials replaced by a computer tutorial. All students did a common review exercise at the beginning of the first semester.

To minimise bias, as far as possible, an experimental group and a control group were assigned to a same tutor. Under the staffing and time-tabling restrictions, it was possible to do this with three experimental/control pairs. The main analysis was centred on these six groups.

Researcher-designed questionnaires based on Sandman's (1980) attitude subscales were administered to obtain students' views on the use of *Derive* and to determine their general attitudes towards mathematics. The items were designed by the researcher specifically for the FYE students, with wording on the items being kept simple, unambiguous and pertinent to the PNG context. The comments from students with respect to working with *Derive* would provide a qualitative aspect to the research. It was hoped that the analysis of objectively measured variables could be given further interpretation through the use of qualitative measures. The students' comments relating to *Derive* would also provide vital feedback towards improving and modifying future approaches with computer tutorial sessions.

Results

A one-way analysis of variance for unequal sample sizes performed on the achievement scores on the common review exercise determined that the experimental and control groups could be considered to have the same means and be treated as statistically equivalent (Computed $F(1,176) = 0.7010 < F_{0.01} = 6.63$). Bartlett's test (Walpole, 1990) further indicated that both experimental and controls groups belonged to populations with equivalent variances ($b = 0.9986 > b_2(0.05; 88, 89) \approx 0.9778$).

As three experimental/control pairs of groups shared the same tutor and sample sizes were unequal, it was decided to use the tutor as a 'blocking' factor and implement a two-factor non-orthogonal or unbalanced design (Keppel, 1991). The two factors involved in this design were the treatment and the tutor. While the focus of the investigation would be on the treatment, the second tutor factor would help to facilitate the study of the treatment factor. The non-orthogonal analysis of variance performed on student mean achievement scores indicated that treatment has not produced any significant effect on achievement after two semesters at a 5% level of significance ($F(1,109) = 1.570 < F_{0.025} \approx 5.176$), setting $\alpha = 0.025$ in order to compensate for the slight bias associated with this test. This analysis further indicated that the tutor had not produced any significant effect on achievement after two semesters ($F(2.109) = 0.783 < F_{0.025} \approx 3.824$), and that there was no significant interaction between the tutor and the treatment ($F(2,109) = 0.315 < F_{0.025} \approx 3.824$).

The total scores on the attitudes questionnaire were also analysed using a non-orthogonal analysis of variance. This analysis also showed that the treatment had not produced any significant effect on students' attitudes towards mathematics at the end of the second semester ($F(1,90) = 0.4965 < F_{0.025} \approx 5.22$). The analysis also indicated that the tutor had not produced any significant effect on achievement after two semesters ($F(2,90) = 1.3993 < F_{0.025} \approx 3.865$), and that there was no significant interaction between the tutor and the treatment ($F(2,90) = 0.8722 < F_{0.025} \approx 3.865$).

Similar analyses were carried out with respect to five attitude subscales: enjoyment in mathematics; self-concept in mathematics; anxiety towards mathematics; motivation in mathematics; general value/usefulness of mathematics. While no statistically significant differences were found in relation to these subscales, the control group tended to have a slightly higher mean on all subscales except on 'general value/usefulness of mathematics'. This subscale related mainly to how students perceived mathematics as a subject. It may be possible that working with *Derive* has brought some realisation that mathematics is not just a matter of learning rules and applying them, but rather one of reasoning and logical thinking.

Responses and optional written comments made by the experimental students on additional questionnaire items pertaining to the use of *Derive* indicated quite a favourable and positive reaction to working with *Derive.* 81% clearly felt that the computer tutorials helped with improving their understanding of the mathematics; 85% agreed that a computer package such as *Derive* should be used in FYE mathematics; 62% stated that working with *Derive* had made them more careful in their reading and writing of symbolic algebraic expressions; 81% indicated that they had a more positive attitude towards mathematics as a result of the computer tutorials. It is noteworthy that 84% of the students wrote down optional comments. As there was no compulsion for students to write down anything or place their names on the questionnaire, it was interpreted that their comments were frank and honest and reflected genuine concerns, suggestions or appraisals.

A generally good and positive attitude comes through on reading through students' comments. Words such a 'pleasure', 'helpful', 'interesting', 'enjoyable', 'fascinating', are quite frequent. The students have quite clearly been excited with the chance to use *Derive* in their learning. Students were writing these comments at the end of the semester, by which time it could be taken that much of the excitement due to the novelty of working with computers would have diminished considerably. Many commented that working with *Derive* had helped with their understanding, and clarified the mathematical ideas. There was much support for computer interaction in learning. Many students expressed the desire for more availability and access to computers in order to work with *Derive* in their spare time. With a high percentage of students having little or no prior interaction with computers, it was not surprising to see frequent comments relating to general computing skills. There was also a desire present to know more about computers. One student stated, "*Using derive ... also aids the student to be comfortable when using a computer without fear as is always evident with such a pro-primitive society*". The student, clearly aware of the way the new technology is impinging on PNG society, is recognising the user-friendly nature of a computing package as an introduction to working with computers.

From other comments, it was also evident that a few students had misunderstood the role of *Derive* in their sessions. These students were almost certainly simply following the instructions on the worksheets, pressing keys, and so on, and merely observing results obtained on the screen. Such students expressed concern that the computer was merely giving them answers and not showing them the intermediate steps. They saw *Derive* as a glorified graphical calculator and ceased to do any thinking beyond their actions with the keyboard. The exercises in the worksheets were designed to create an investigative approach to the mathematics, while at the same time reinforcing ideas met in lectures. This clearly was not having its effect with some students. Other students were concerned about the effect that using computers may have on their own "*natural computer*", namely their own thinking and analytic processes. These students, too, were most likely to be preoccupied with obtaining correct answers and less concerned with the processes involved. While there were a few negative aspects, the overall picture, in relation to the comments made by the experimental group students, has been one of much encouragement to the researcher lending support to the argument that the results could be considered as educationally significant.

Discussion

These results demonstrate that the attempt to integrate *Derive* into the FYE mathematics programme *in its current state* is not very likely to help students with their achievement scores. Despite experimental students stating that *Derive* brought more understanding, enjoyment and motivation, it would seem that these had little effect on the students' performance in tests and examinations. Currently, students are tested on the performance of routine algorithms and reproduction of memorised procedures, with little emphasis on testing for conceptual understanding. If *Derive* did enhance experimental students' understanding, then this suggests that the present assessment of student achievement in the FYE mathematics course needs to be reviewed.

The findings from this research have also shown that despite the experimental students showing much eagerness to work with *Derive*, their enthusiasm has made no difference in their attitudes towards mathematics in general, as a subject. The same students, however, do see more value in mathematics and have a better appreciation of it as a logical system.

Much of the researcher's initial concern in regard to students' anxiety in working with computers was also dispelled by this research. PNG students have shown themselves to be enthusiastic and readily adaptable to this new medium of learning. Computer tutorials virtually ran themselves, with students taking charge almost as soon as the sessions started. They demonstrated no difficulty in starting up *Derive* and setting up the necessary screen windows for the tutorial sessions. Students were observed by their tutors to be often actively involved in experimentation with the computer and in serious and searching discussion with their peers. Much of this discussion was in pidgin English. This interaction with mathematical ideas being thrown back and forth provided further indication that possibly more 'thinking' around the concepts involved was taking place, and more so than in the normal classroom tutorial sessions. Students in the experimental groups also displayed little desire to leave the computer room when a tutorial session ended and were usually quite engrossed with the mathematics.

This research was principally exploratory in it aims. It was concerned with the application of a computer algebra system to a learning environment, and as such, there were naturally some preferred expectancies and outcomes. While *Derive* has not made any statistically significant impact on students' achievement in mathematics, the results of this research have highlighted the role of *Derive* as a catalyst for stimulating enthusiasm and bringing excitement to the students' learning of mathematics.

This research has implications for students, teachers, instructors, and researchers, both at the secondary and tertiary levels in PNG. There are also implications for the PNG national curriculum. Results of the study should provide some motivation to instructors of mathematics, and other related subjects, to begin to explore the pedagogical possibilities that a CAS can offer in the instruction of their students. It has shown that students in PNG respond very favourably to the new technology and can be motivated by it. There is every indication that PNG students in the upper secondary school would respond equally enthusiastically to working with a software package such as *Derive*. These students would, at the same time, be gaining a gradual and much-needed exposure to computers through their learning process. A computer algebra system will offer these students the ability to shift quickly between numeric, graphic and symbolic representations enhancing concept development.

Limitations

Limitations to this research were in the areas of existing pertinent literature, instrumentation, sampling, facilities, and constraints of time. Almost all literature reviewed relating to the design of the research were based in countries with very different cultural and socio-economic backgrounds to PNG. Findings reported by these studies were incorporated into the present research based on their relevance to this study. As much care as possible was taken to ensure the validity and reliability of the findings from this research. Instruments were researcher-constructed due to the lack of existence of similar instruments in PNG research and were designed to specifically address the situation as perceived in PNG. The randomness of selection of subjects for the research was also compromised in part by the preselection of student groupings by the university's admissions section. Availability of computer rooms dictated the frequency and scheduling of the *Derive* tutorials. Electricity power cuts are a fairly frequent occurrence at UNITECH and on several occasions disrupted a *Derive* session. The heavy demand for use of computer laboratories made re-scheduled bookings difficult. Staffing movements caused further disruptions to a smooth running programme.

Conclusion

This research has shown that a computer algebra system has the capability of
- making students more enthusiastic about learning mathematics
- holding the students' attention and making them think more about the mathematics
- encouraging students to experiment with mathematical ideas
- helping students to see mathematics more as a logical system.

Students in PNG have responded well to the experiment of integrating *Derive* into their mathematics learning, and this paves the way for further thought, experimentation, and research which can bring about improvements to the present system. This study has highlighted a need for a reassessment of, not so much what is presently being taught in the FYE mathematics course, but how that mathematics can best be taught to the benefit of the students. With changes in the emphasis on learning objectives towards conceptual outcomes, there is every indication that a computer algebra system, such as *Derive,* has a successful role to play through its integration with the mathematics programme. Its role as a pedagogical tool and a means of exposing students to much needed computer awareness provides an exciting and fruitful opportunity for advancing education in PNG.

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