
ENHANCED MATHEMATICS LEARNING: DOES TECHNOLOGY MAKE A DIFFERENCE?

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This paper investigates the effectiveness of technology-based instruction in secondary mathematics, by comparing students' achievements resulting from technology-rich assignments with those achievements resulting from equivalent assignments presented in traditional format. In addition, the development of the technology-rich assignments, from traditional paper-based instruction and within existing curricula, provides an example of the relative ease of integrating technology into the curriculum. Within the context of mathematics, issues of attitude towards computers, motivation and gender differences are examined.

Background

Since educational computing today is still in the formative stages (Kaput, 1992; Joiner, 1996), its final impact on the structure of education cannot be completely extrapolated from current experimentation. Clearly there is a need for further research, so that bounds can be established as the field matures. Although there are a number of studies comparing the effectiveness of traditional instruction with computer-based instruction (for example McCoy, 1991; Morrell, 1992; Stick, 1997), none have been sighted that are specific to the area of Australian secondary mathematics. The honours thesis reported here (Dix, 1998) is therefore potentially important and of particular relevance in that it responds to the void of qualitative and quantitative data in this domain.

Research Questions

The broad issue of whether the use of technology enhances mathematics learning can be broken down into a number of specific inquiries, providing a foundation for the current study:

1. Is there a difference between achievement of students using computers to generate work and the achievement of students using the traditional methods of pen and paper?
2. Does the use of computers motivate students and influence their subsequent level of achievement?
3. Do attitudes towards computers differ between male and female students, and how are attitudes affected following a number of technology-rich lessons?

The Study Sample

The study sample involved students from two Year 8 Mathematics classes at a public Secondary school in the Adelaide metropolitan area. This school was selected on the basis that it typified current secondary education practice, and the computing facilities were both extensive and available for this investigation. Class A comprised 28 students, 11 female and 17 male, and Class B comprised 19 students, 8 female and 11 male. The differences in average age of students, on class and gender comparisons, were considered to be of insufficient size to bias the study in any way.

Of greater concern was the determination of any differences in mathematical ability between the two intact classes. The Standard Progressive Matrices Test (Raven, 1960) was selected as an appropriate test measure. Commonly referred to as Raven's test, it utilises pattern recognition to test non-verbal reasoning ability. Although no significant difference (at the pre-designated level of 0.05) in age was determined, a similar finding for ability levels

between classes was ideally required. The results of the Student's two-tailed t-test for independent groups ($t = 1.17$, $p = 0.25$) suggest no significant difference. Mean class scores of 47.4 (SD = 5.6) and 45.7 (SD = 4.8) confirm the similarity in ability with a discrepancy of only 3% in favour of Class A.

The Comparative Design

In essence, two different instructional methodologies (technology-rich and traditional) were used to teach two classes of similar age and mix of ability. Within a curriculum topic, the majority of the unit was taught in exactly the same way to both classes. The assessable variation involved two assignments designed to satisfy the two formats, technology-rich and traditional, each requiring several lessons to complete. Results from the assignments and a common end-of-unit test provided a comparable measure of the effectiveness of the methodology (Morrell, 1992).

The Assignments

The use of the geometry-related topic, *Constructing and Drawing*, was predetermined by the school's curriculum. However, the topic was highly suitable for flexible delivery and for the purposes of this study. Within the topic, two assignments were designed which utilised and fulfilled the requirements of existing curriculum content and allowed for easy presentation in the two formats, technology-rich and traditional. The assignments, *Tessellations* and *Angle Sum in a Polygon*, had been taught successfully in previous years using traditional methodology. The conversion of the two assignments into a technology-rich format required little modification. To draw comparisons between achievement levels in each assignment, classes received both assignments but in alternating format. Thus, neither class was disadvantaged since each was given the opportunity to use computers in mathematics, and curriculum coverage was equally achieved. Special attention was given to ensure that methods used in the two formats fulfilled the same objectives, preventing study bias. Furthermore, the possibility of bias arising from differing teaching styles between classes was minimised by having the same teacher teach both classes for the respective units of work. A visual representation of the research design is presented in Figure 1.

Figure 1.
A Visual Interpretation of the Research Design

Two assignments in Geometry		
Two formats	Tessellations	Angle Sum in a Polygon
Technology - rich method	Class A	Class B
Traditional method	Class B	Class A

Generally when assignments are given, students have the opportunity to work on them at home. In the present study, such a procedure would unfairly disadvantage those students doing the technology-rich assignment since they, more than likely, would not have access to the relevant software, or perhaps even to a computer. To prevent this possible source of bias, students were only given class time to complete the work.

The length of each assignment was designed to be achievable in the three lessons allocated. It was anticipated that not all students would finish at the same time, and therefore extension work was provided for those who completed the assignment quickly. By the end of the third lesson, however, all students were required to submit their assignments, incomplete if necessary. Approximate length of time on task was monitored, and all efforts were made

to provide an equal amount of support to every student. The assignments were structured so that marks were specifically allocated for method as well as accuracy, reducing the possibility of personal judgement.

Geometry Software

The software package, *Geometer's Sketchpad* (Klotz, 1991), used for both technology-rich assignments was chosen, principally, because it was judged to be pedagogically appropriate (Pegg and Daveys, 1991; Kaput, 1992; Arnold, 1996). A second factor in selecting the software package was its ease of installation on the school network.

Although subjects in the two classes considered themselves to have at least some level of computer experience, none had used this particular software package. Three orientation lessons were therefore conducted for each class. These highly structured lessons, while still covering the curriculum, exposed all students to the basic geometric manipulation tools needed for the subsequent assignment.

Anecdotal Assignment Questions

To gain a greater understanding of how each student felt specifically about mathematics and the assignments, the following questions were asked at the completion of each assignment.

1. If this assignment had to be done *with/without* the computer, do you think it would be easier or harder? Explain why.
2. Write down what you currently think of maths and how it makes you feel.
3. What did you like/dislike about this assignment?

Computer Attitude Survey

To assess general attitudes about computers, an attitude scale by Jones and Clarke (1994) was adopted in a slightly modified form. The adapted scale was distributed to both classes before the start of the study, and again at its completion. The instrument comprised 38 questions to be answered on an ordinal scale of 5 choices, ranging from strongly agree to strongly disagree. Although the primary purpose of the scale was to establish the effects of motivation on gender and achievement, the readministration of the scale provided a brief insight into longitudinal changes, if any, of these attitudes.

End-of-Unit Test

The final measure used in this study made use of the traditional pen and paper, end-of-unit test. To be completed in a single 45-minute lesson, the test was restricted to 10 questions that were posed in a variety of formats to accommodate a range of learning styles. Although the 10 questions were written to assess all major objectives covered in the topic, two questions were designed as specifically pertinent to the assignments. By assessing the level of retention and understanding, the test results provided another means to gauge the effectiveness of computer technology.

Statistical Analysis

Descriptive statistics (means and standard deviations) were used to describe the central tendency and dispersion on all measures. To test for differences between groups, Student's t-test was used. This was the appropriate statistic as just two groups were compared in each case. The 0.05 level of significance was set for the rejection of all null hypotheses.

The assignments and end-of-unit test were graded and the raw scores provided the database upon which statistical analysis was performed. To assist in analysing the student attitude

questionnaire, the five categories of student responses on the survey were assigned numerical values: strongly agree = 5, agree = 4, undecided = 3, disagree = 2, and strongly disagree = 1. To generate all statistical calculations, Microsoft Excel spreadsheet was used. In particular, the Student's t-test and its associated probability were utilised to test for gender and classes differences between groups.

Similarly, correlational analysis was applied to check validation of the assessment tools. Pearson's product moment correlations between the Raven's test, assignments, and end-of-unit test are presented in Table 1. For the purposes of correlation, subjects with missing data were removed thereby reducing the degrees of freedom (with 72 df, a correlation of 0.23 is required at the 0.05 level).

Table 1

Correlation Matrix for Five Measures of Achievement – the Raven's test (standardised measure), the Tessellations and Angle sum in a Polygon Assignments, the end-of-unit test, and Q.1 (angle sum) and Q.2 (tessellations)

	Tessellations	Angle Sum	End of unit test		
			Total	Q.1	Q.2
Raven's Test	-0.01	0.11	0.45*	0.37*	0.23*
Tessellations		0.31*	0.38*	0.07	0.21 [†]
Angle Sum			0.25*	0.29*	-0.14

* denotes significance at the 0.05 level

[†] denotes significance at the 0.10 level

Using Raven's test as a standardised test measure, comparison with the end-of-unit test questions, reveals that the significant correlation of 0.45 indicates that the developed test measure is an adequate index of mathematical achievement. Internal consistency between the assignments, irrespective of methodology, is indicated by a significant correlation of 0.31 at the designated level. Although the assignments do not significantly correlate with the Raven's test, they do so with the end-of-unit test, suggesting they are adequate assessment tools for the purposes of this study.

Results

Statistical analysis of the scores resulting from the various test measures, and qualitative analysis of the anecdotal questions and informal observation, provide answers to the research questions.

Differences in Achievement

Analysis of the assignments suggest no significant statistical bias towards traditional or computer based methodology. However, assignments completed via traditional methods achieved marginally higher averages within each class.

Clarification of the assignment findings is supported by the results from two questions in the end-of-unit test, specifically pertaining to the assignments. Irrespective of class, the answers to those questions learned through traditional methods marginally outperform those learned through technology-assisted methods. The differences between these values, however, are not significant.

Thus, in response to the first research question, there are no significant differences between the achievement of students using computers to generate work and the achievement of students using the traditional methods of pen and paper. These finding, however, should be viewed in the light of the circumstances under which the computer-enriched assignments

were completed. Prior to this study, the subjects had no previous experience with the computer software, *Geometer's Sketchpad*. Comments from a number of students suggest that they were actually learning about two things, both the assignment and how to use the program. The achievement of outcomes, gained through unfamiliar software, similar to those gained through traditional methods, reflects the relative ease of using the software package. Accordingly, on the basis of this study, *Geometer's Sketchpad* commends as an appropriate and effective mathematics tool for teaching and learning geometric principles.

The Influence of Computers on Motivation

Motivation towards learning due to the use of technology has been qualitatively analysed through the end-of-assignment questions and through informal observation. In general, both classes:

- agree that computers made the task easier;
- value higher levels of accuracy gained through using a computer;
- are less willing to leave their computer-based work to attended break or other classes;
- find *Sketchpad* easy to manipulate and readily achieve success independently;
- produce more computer-based work (not evident in final marks); and
- feel negative about maths but less so when computers are used.

In the light of the findings, response to the second research question is mixed. The use of computers in mathematics does appear to positively influence student motivation. However, a corresponding shift in achievement is not apparent.

Gender Differences and Changes in Computer Attitude

Administration of the Computer Attitude survey, prior to and after the study period, supports quantitative analysis of gender differences and changes in attitude over the course of teaching. Statistical analysis of results, presented in Table 2, indicates that differences in attitude between male and female students are significant, for both the pre- and post-computer surveys. In addition, longitudinal changes in attitude reveal a significant positive change in male attitude towards computers, whereas a similar shift for female students is also evident, though not at the 0.05 level of significance.

Table 2

Mean and Standard Deviations on the Computer Attitude Scale together with t-test Results for Gender Differences and Differences Between Pre- and Post-Computer Surveys

	Pre-computer survey Mean (SD)	Post-computer survey Mean (SD)	t-test (paired)	prob- ability (2-tailed)
Male	149.3 (16.0)	153.9 (16.7)	2.80	0.007*
Female	137.6 (15.3)	140.6 (15.6)	1.50	0.14
t-test (unpaired)	2.51	2.77		
probability (2-tailed)	0.02*	0.01*		

* denotes significance at 0.05 level

In response to the final research question, differences in attitudes towards computers do exist between male and female students, and are positively affected, significantly so for male students, following a number of technology-rich lessons.

Discussion

In addition to the findings relating specifically to the research questions, a number of equally important observations were made.

Although results indicate that students achieved similar scores for the technology-rich and traditional assignments, the quantity of work produced for each assignment varied. It was evident that much more exploration and investigation by students occurred in the technology-rich environment, resulting in the completion of several versions of each assignment, and extension of the task beyond the original scope (eg. animating the tessellation pattern). Due to the limited method of assessment, there was no component in the marking scheme to accommodate such achievement, effectively biasing the study against technology-rich methodology, a problem alluded to by Lesh (1990). However, it does provide a direct example of the development of new curricula that would otherwise be impossible without the use of technology, and the need for authentic assessment methods that respond to these changes.

This study observed clear differences in attitude and approach between male and female students to the use of computers in mathematics. Male students were more willing to experiment with the software, deviating from the assigned task, while female students were much more task focused and particular about the appearance of their work. Despite the differences, a significant positive change in attitude of the participants resulted.

Through the use of anecdotal questions, this study revealed that most students begin their high school mathematics career with a general dislike for mathematics. Encouragingly, the inclusion of computers in the mathematics curriculum appeared to alleviate, to some degree, negative attitudes felt by students towards mathematics.

Findings from this study conclude that the computer-enriched lessons provided a positive learning experience for the participants. The preference for computer-assisted learning is not surprising, considering the generally positive attitudes towards computers, evidenced by the results of the computer attitude survey. Although not an objective of this study, it should be noted that from a teaching perspective the computer-enriched lessons provided an equally positive experience for the teacher.

Implications for Education

As a result of this study, a number of implications for education, and for junior secondary mathematics in particular, arise. These findings, however, should be considered in light of the limited nature of the study.

Above all else, this study highlights the need for authentic assessment, especially when a dynamic software package, such as *Geometer's Sketchpad*, is involved in the learning and assessment process.

The wide acceptance of *Geometer's Sketchpad* by participants provides confirmation and recommendation of the program as a pedagogically appropriate mathematics construction and exploration tool.

By allowing students to pose, investigate, and extend problem situations, an environment can be established in which students (and teachers) can recognise the power and usefulness of mathematics.

Gender differences in attitude and approach to computers in mathematics identifies the need for teachers to provide an environment that supports and encourages a diverse range of learners and their needs.

Integration of technology into mathematics, by modifying existing curricula, is a viable and effective method for current curriculum development. In the longer term, however, complete curriculum reform may be required on a whole school level.

Recommendations for Future Research

Due to the limited nature of this study, and the apparent absence of similar studies, multiple directions for future research exist.

Clearly, further research examining different age groups, and a larger population, is needed. The issue of equity, arising from computer illiteracy, poverty, disability, or non-English speaking background, was not applicable to students in the current study. However, the same may not be so for students in other year levels, or in other schools. Accordingly, research into the effect of these possible causes of inequality should be considered.

Although the use of technology in education has traditionally predominated in mathematics, its occurrence in other curriculum areas, such as art, science, and English, is increasing. Further research is necessary into the effectiveness of educationally appropriate software packages and their application within their respective curriculum areas.

For many students the use of computers in any curriculum area, aside from technology classes, may be a novel experience and a source of motivation. Reflecting a concern of this study, changes in motivation due to the novelty of the experience could not be completely discounted. Whether levels of motivation towards mathematics (or any curriculum area) are maintained or increase as the novelty *wears off*, provides a further avenue for research.

The research and development of effective technology-rich curricula requires a corresponding adjustment in the assessment process. Due to the nature of dynamic software, current forms of assessment may no longer be appropriate indicators of achievement. Although authentic assessment provides direction, further research is needed to validate it as an appropriate method of assessing computer-assisted achievement.

In many evaluative studies, the computer is perceived as an independent variable, the direct effects of which can be observed and quantified. Due to unavoidable limitations, the current study also adopted this approach. However, the introduction of technology into the classroom clearly changes the whole learning environment. Thus, there is a need for evaluative research into the impact of technology on learning that focuses on the total system (Rowe, 1996; Neal, 1998). Such research may most effectively be achieved though in depth qualitative rather than quantitative research.

Finally, the concern of context validity resulting from the rapid pace of curriculum development highlights the need for ongoing research and affords the unique opportunity for school teachers, students and university researchers alike, to participate in the process of curriculum design and reform.

The expectation that a clear result would emerge from a study of such short duration was considered optimistic. However, the findings do provide greater insight as to the effectiveness of computers as a tool to enhance mathematics learning. In short, this study suggests that computers do have the potential to make a positive difference in both the learning and the teaching of mathematics.

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