Using CSCL Methods in Secondary Mathematics

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This study compares computer supported collaborative learning (CSCL) based instruction and traditional pen-and-paper methodologies and is aimed at investigating the effectiveness of using spreadsheets and collaborative learning methods in mathematics instruction for enhancing student learning. Ten Year 11 mathematics classes comprising of 172 students from six high schools across Sydney participated in the study. This study showed that majority of students found the collaborative learning activities very interesting and enjoyable although positive effects of using spreadsheets were not apparent. Statistical analysis of the pre-tests and post-tests showed significant differences in the mean improvement scores between the schools and also between the teaching interventions when only schools 4, 5 and 6 were taken as part of the analysis. Implications of the findings as well as recommendations for future research are discussed.

Following the rapid increase in the use of technology in education over the last decade, one would perhaps expect to find an overabundance of literature regarding the effects of its use (Dix, 1998). However, the number of technology related studies has been surprisingly low (Jones, 1997) especially those pertaining to the curriculum area of mathematics. Morrell (1992) suggests that the availability of quality software, the need for curriculum redesign, and limited research on the effectiveness of computers as a teaching tool, are factors to have retarded the rate of implementation and of subsequent research. This remains true even today. Statements from administrative bodies like the *Australian Association of Mathematics Teachers* (AAMT, 1996) and the *Curriculum Development Centre* (AEC, 1991) have given momentum but little bearing to the integration of technology in the mathematics curriculum. The reality appears to be that the use of computer technology in the mathematics curriculum is not widespread.

Significance of Study

Since educational computing today is still in the decisive stages (Joiner, 1996), its final impact on the structure of education cannot be completely extrapolated from current experimentation. There is clearly 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 (e.g. Morrell, 1992; Stick, 1997), none have been found that are specific to the area of Australian secondary mathematics. This study is therefore potentially important and of particular relevance in that it responds to the void of qualitative and quantitative data in this domain and also hopes to put at ease the minds of people with significant oppositions toward the introduction of the new *General Mathematics* syllabus which is seen to have ambitious aims and objectives. The new *General Mathematics Stage 6 Syllabus* replaced the 1981 *Mathematics in Society* (MIS) and the 1989 *Mathematics in Practice* (MIP) syllabuses. GM takes on an information processing approach toward learning mathematics, characterised by collecting, organising, interpreting and analysing data (Yen, 2000). The importance of language, technology and the interpretation of graphs and tables are promoted throughout this new course. Technology should play a major role in the form of

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spreadsheets, graphics calculators, computer software and the Internet.

Aims and Objectives

Research indicates that computer technology can help support learning, and that it is especially useful in developing higher-order skills of critical thinking, analysis, and scientific inquiry (Roschelle et al., 2000). However, the mere presence of computers in the classroom does not ensure their effective use. This paper explores the various ways in which computer technology, in particular, spreadsheets can be used to improve how and what students learn in a *collaborative learning* (learning in small groups where students share ideas and work together to complete tasks) environment. We designed a study that compared technology based instruction with traditional pen-and-paper methodologies. We were interested in determining whether or not (1) there was a difference between the achievement of students using spreadsheets to solve algebraic problems and the achievement of students using pen-and-paper for the same unit of work; and (2) students were more interested and motivated to learn mathematics collaboratively using spreadsheets or when using pen-and-paper individually.

Literature Review

Computer supported collaborative learning (CSCL) is one of the promising ideas to improve the teaching and learning of mathematics with the help of computers. CSCL appears to engage students to participate in in-depth inquiry over substantial periods of time and to provide socially distributed cognitive resources for comprehension monitoring and other metacognitive activities (Lehtinen et al., 1998). Meta-analyses on the effectiveness of computers have shown that in the majority of studies, the use of technology markedly improved learning outcomes (Fletcher-Flinn & Gravatt, 1995; Kulik, 1994). These studies do not, however, distinguish between different pedagogical ideas on how computers have been implemented in classrooms. Thus, it is impossible to draw any conclusions about the effectiveness of CSCL on the basis of these general impact studies (Lehtinen et al., 1998). Several empirical experiments offer some evidence that CSCL environments like *Computer Supported Intentional Learning Environments* (CSILE) have proved to be helpful for higher order social interaction and, subsequently, for better learning in terms of deep understanding (Scardamalia et al., 1994). The primary goal of CSILE is to support structured collaborative knowledge building by having students communicate their ideas and criticisms - in the form of questions, statements, and diagrams - to a shared database classified by different types of thinking (Roschelle et al., 2000).

There are numerous studies on CSCL environments demonstrating encouraging effects on the amount and quality of social interaction and other procedural features of teaching-learning processes (Amigues, & Agostinelli, 1992; Fishman & Gomez, 1997; Lamon et al., 1996; McConnell, 1994; Scardamalia et al., 1994). The number of studies on CSCL has dramatically increased during the last decade. There have been many studies aimed at investigating the effects of CSCL on students' achievement. Many studies on small group computer based instruction, published in the late eighties and the early nineties, indicated at least some positive impact on students' learning (Anderson et al., 1995).

Methodology and Design of Study

Mathematics can be learned in a variety of ways - with or without technology, individually or collaboratively. We investigated the effects of CSCL in the area of

Financial Mathematics, one of the five strands in the new *General Mathematics* (GM) syllabus. The design of this study included three methods of data collection - an attitudinal questionnaire administered to students; pre-tests and post-tests; observations of classes and interviews with randomly selected groups of students. Figure 1 outlines the design and methodology of the research study and Table 1 summarises the allocation of teaching intervention to each class.

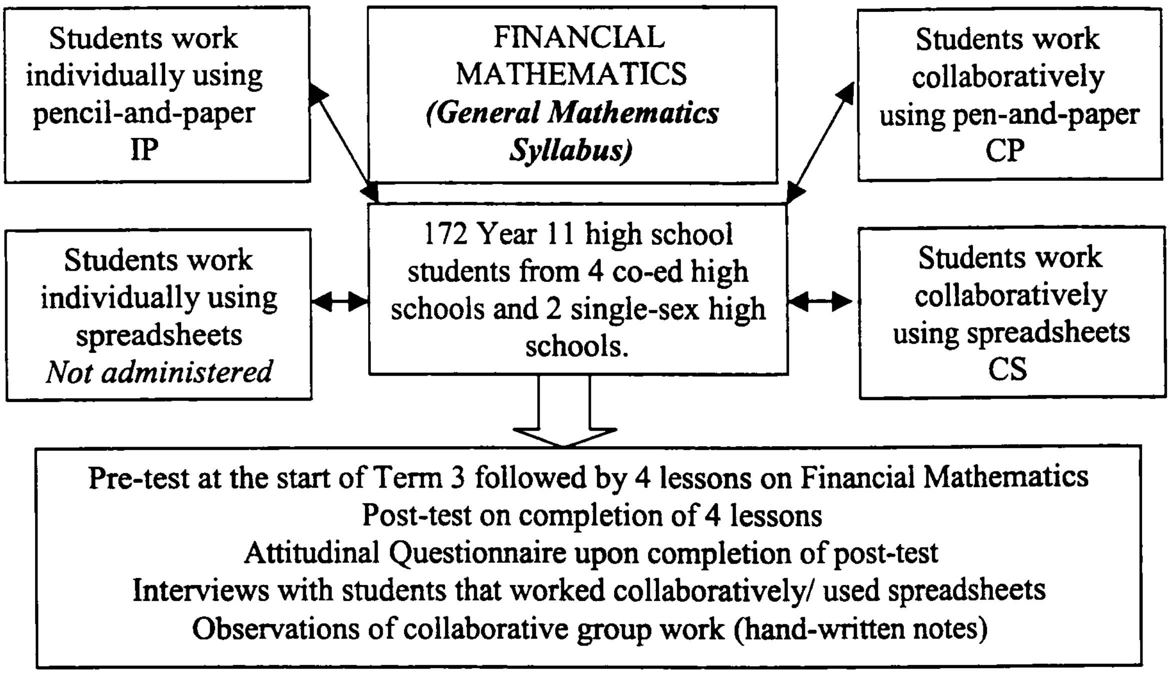

Figure 1. Design of study.

The pre-test and post-test was administered to determine students' knowledge of mathematical concepts like simple interest and compound interest in the area of *Financial Mathematics*, one at the beginning of term and the second towards the end of term, after students had an opportunity to work with the materials. Students under the CP intervention worked in groups of 3-4 students on tasks set out on cards and divided up into parts. Students under the CS intervention working in pairs on similar activities using spreadsheets while students under the IP intervention worked on 'standard-type' problems individually. The pre-test and post-test were based on the content covered in the four lessons under each of the three teaching interventions. Student's feelings and/or opinions towards collaborative group-work using spreadsheets were determined from the responses to questionnaire items administered upon completion of the post-test. The analysis of the questionnaire items, however, is not discussed in this paper. The last method of data collection involved informal observations of students working in each teaching intervention group. Finally, randomly selected students were asked to participate in an interview where responses were handwritten by the researchers, as students felt uncomfortable with the idea of having their responses audio-taped.

A total of ten year 11 classes from six high schools in Sydney, Australia participated in the study and each class was allocated a particular teaching intervention. It is important to note that, although these were arranged to be randomly allocated, some arrangements changed in order to accommodate teachers' preferences for particular treatments. Some teachers for instance, requested that the CS intervention be administered to their students because they wanted to learn about using spreadsheets in the classroom. Also, due to lack of computer resources, the *individual work using spreadsheets* (IS)' teaching intervention did not get administered in this study.

Table 1
Allocation of Teaching Interventions

School	No. of Classes	Teaching Interventions Administered
School 1	1 class	Collaborative work using spreadsheets (CS)
School 2	1 class	Collaborative work using spreadsheets (CS)
School 3	1 class	Individual work using pen-and-paper (IP)
School 4	2 classes	Collaborative work using pen-and-paper (CP) Individual work using pen-and-paper (IP)
School 5	3 classes	Collaborative work using spreadsheets (CS) Individual work using pen-and-paper (IP) Collaborative work using pen-and-paper (CP)
School 6	2 classes	Collaborative work using spreadsheets (CS) Collaborative work using pen-and-paper (CP)

Although there may be value in studying a range of year levels within the secondary school, this study was limited to one-year level. Year 11 students were selected for the reasons such as: (1) the new General Mathematics syllabus for Year 11 students; (2) the recommendation for the use of spreadsheets in different areas of the syllabus; (3) the non interference with end of year examinations during the course of the study; (4) students below Year 11 not generally requiring access to computers for mathematics; and (5) research on year 11 students not having been conducted often.

Results and Analysis

Analysis of Pre-Tests and Post-Tests

Out of the 172 students that participated in this study, 150 did the pre-test, while 116 did the post-test. It is important to note that fewer (and different) students sat for the post-test. In some schools it was difficult to get the students to do the post-test seriously. They enjoyed the activities and participated well in class but did not enjoy being tested. Also, the fact that the study was voluntary in nature, implied that students did not have to do any component of the study if they did not want to. An *Analysis of Variance* (ANOVA) using the *general linear model* for improvement scores (difference between pre-test and post-test scores) and *sex*, *school*, and *intervention* as explanatory variables showed very significant differences in effects between schools (n.b.** denotes $p<0.001$) The highest mean improvement score was recorded for school 2 (11.7 out of 40) while the lowest (negative) score was recorded for school 3 (-7.2). This may have been due to the 'holiday mode' of the students as the study was carried out in the last week of term in some schools, but may be a real effect. A similar analysis using only schools 4, 5, and 6 showed differences between the three teaching interventions, with the greatest improvement being in the IP intervention and the least (negative) improvement in the CS intervention. The researchers wanted to investigate any differences in the mean improvement scores between schools that had more than one class in them, namely, schools 4, 5 and 6. In both analyses, no differences between genders were observed. There were difficulties in using computers in the teaching intervention, which will be discussed later.

Observations of Classes

The informal observations of the classes were impressions gained over the four lessons, as opposed to minuting them lesson-by-lesson. These observations were analysed using Bell's (1993) indicators of learning: (1) interest and enjoyment; (2) involvement and engagement of students in the learning activities, (3) ownership of work and (4) on-task behaviour. Overall, in the CP intervention groups, there was a large degree of interest and enjoyment during the four collaborative group lessons. Over the course of these four lessons, noise levels became quite high at times, and students were frequently observed in animated and enthusiastic discussions. Engagement levels and involvement in the activities seemed to be high, especially as measured by task completion. On-task behaviour was relatively high, and there were no instances of obviously distracted behaviour seen for whole groups. Students under the CS intervention showed reasonable interest at the start, which slowly appeared to 'dwindle off'. The same was observed with engagement and involvement levels where students appeared to become disinterested later in the study. Shared ownership of work was high in these groups, and off-task behaviour was also high with students getting distracted and going off to check their emails *et cetera*. Students under the IP intervention appeared to do the work set out as they would have done during any of their normal mathematics classes, engagement and involvement levels were very high in this group as measured by task completion, as was on-task behaviour.

Limitations of the Study

A number of constraints served as limitations in this study. These include the duration of the study, the timing of the study, sample size, access to computers, and computer resources in schools. However, steps were taken to minimise these affects. In cases where students were involved in the CS intervention, computers with *Microsoft Excel* (at least) were required. In most schools, problems were experienced with being able to book laboratories for a particular time or day and also, many computers in the schools were non functional which meant that in most cases, more than two students had to share a computer, which got a bit tricky in terms of workload, and could account for some of the non participation in this study. During the first lesson, most students experienced difficulty with operating and working with the software and so got exasperated. However, as the lessons progressed and students became familiar with the software, they found the activities enjoyable and interesting.

As mentioned above, access to computer laboratories was a considerable restriction. For a number of reasons the preferred method of comparing whole units of work, requiring several weeks, was reduced to activities, achievable in four lessons. Firstly, time constraints and access to resources did not permit the design and development of whole units. Secondly, with computer rooms fully booked terms in advance, securing several weeks of class time was not possible. The request of one week in the computer laboratory for a certain class was more readily accommodated. Finally, the expectation that a clear result would emerge from a study of such short duration was considered optimistic. It is hoped that this research may provide direction and insight for future studies.

Implications

A majority of students in this study indicated that they found the collaborative activities interesting and enjoyable. However, it must be noted that some students did not agree with these statements, and some even expressed an extreme dislike to collaborative learning (CL) methods. A variety of learning strategies is thus called for, to best meet the needs of all students. It was also seen that collaborative groups do not always function effectively, and instructors employing CL methods must pay constant attention to minimising factors that contribute to such ineffectiveness, and addressing problems where they occur. Despite this, there is a clear indication that we should include some opportunities within mathematics classes for students to work collaboratively and talk about mathematics.

This study also highlights the need for adequate computer resources, support and training when implementing new curricula. The use of software such as *Microsoft Excel* requires time to learn. The package initially interferes with mathematics learning. However the start up time in this study was only about 2 lessons. Over time, and with adequate technological and pedagogical support and training, implementation of technology into the mathematics classroom would receive less resistance from teachers and students. Without proper resources, adequate training of teachers in using computer technology, on-going technological and pedagogical support, and funding, implementation of CSCL methods in the mathematics curriculum is going to continue to be a challenge for both students and teachers. If teachers are not going to receive the support they require to implement technology in their classrooms, they are not going to make the effort to learn the software to be able to teach it. Not many teachers have 'spare' time on their hands during which they could learn how to use computers in the classrooms. This in turn affects students and their opportunities for different learning styles. This is a vicious cycle that needs to be broken sooner than later. Collaborative learning without computers was quick and easy to implement in this study, and students could learn the mathematics almost immediately. However, the design of good collaborative materials is time-intensive and needs to be at an appropriate level. Preference for learning using individual pen-and-paper methods by majority of students implies that students feel that they learn better using traditional teaching methods, having being taught in this way all their lives. An implication for this is that changing teaching and learning methodologies to include CSCL methods may receive initial resistance from students as well as teachers.

Recommendations for Future Research

This study and other reports of studies using computer technology indicate the potential for spreadsheets to dramatically influence the way students learn and the way mathematics is taught in the classroom. The potential for all students to explore powerful mathematical ideas is exciting. Recommendations from this study include giving teachers support to learn about this software package and to find interesting and comprehensive methods for exploring mathematics. The new mathematics curriculum *General Mathematics*, supports the recommendations of the NCTM of promoting the infusion of the mathematics curriculum with technology. As this research study shows, there are problems with the implementation. The syllabus is new and curriculum implementation takes time. More research into teaching and learning with spreadsheets is recommended.

Future studies, therefore, may want to consider the following: (1) This study centred on the use of computer spreadsheets in a collaborative learning environment. Are there similar results when using technology other than spreadsheets, for instance, when using tools such as graphics calculators? (2) This study was completed in 12-weeks, with each class (in the six schools) being administered a post-test at the end of a six-day study. Would results be the same following a study that exposed students to spreadsheets for a longer period of time? (3) This study did not acquire data on student access to computers outside of the classroom. Do students with computers at home perform better than students who only have access at school? (4) The post-test and attitudinal questionnaire was administered in most cases near the time of Year 11 examinations. Would significant changes in attitude be apparent if the timing was different? (5) Attitudes of teachers toward CSCL methods and their teaching approaches were not tested. A future study may want to include actual testing of teacher attitudes and approaches. (6) This study centred on Year 11 students. Would results be the same with tertiary students - those who might already have prior experiences with spreadsheets and/or collaborative learning methods? (7) This study has not considered any assessment issues. What kind of assessment guidelines could be put into place in a CSCL mathematics classroom?

Concluding Remarks

The review of the literature has provided many pointers and suggestions into ways in which the researchers can improve the use of collaborative learning in their own teaching as well as increasing confidence in continuing to use such methods.

The results of this study itself have suggested ways in which the researchers might structure collaborative lessons, in order to further increase the learning opportunities for all students. The study also highlights problems with access to computer technology in real classrooms, which is a serious issue in mathematics teaching and learning. The use of computer spreadsheets can be a valuable tool for secondary school students as they study mathematics. Students who made the greatest gains after the unit of study were not necessarily those who were the most successful, as measured by the post-test. Computers are likely to bring about major changes in the way we teach secondary school mathematics. We need to examine objectively the effects of teaching and learning with or without technology as well as different learning styles. As computers become accessible to all students, changes can be made in the classrooms that enrich students' experiences in mathematics.

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