Investigating the Effects of Using Spreadsheets in a Collaborative Learning Environment

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Abstract

Computer-supported collaborative learning (CSCL) is one of the most promising ideas to improve the teaching and learning of mathematics with the help of information technology. However, despite the rapid increase in the use of technology in mathematics education over the last decade or so, the number of studies investigating the effects of its use in schools has been surprisingly low. The reality seems to be that the integration of technology into mathematics curriculum at secondary school is not widespread. The introduction of technology into mathematics instruction raises new possibilities for teaching and learning. International as well as national curriculum documents have pointed out that computers can be a valuable tool in the enhancement and representation of mathematical concepts. They also stress the importance of utilising technology to allow students to explore mathematics. The study of attitudes toward using computers in mathematics learning has a relatively short but intensive history when compared to studies investigating attitudes toward mathematics in general. The emphasis has tended to be toward interaction with technology rather than on its use in particular learning contexts. In response to this, we have designed teaching materials that use computer spreadsheets in the learning of algebraic concepts at secondary school, particularly in the area of Financial Mathematics. We have designed a study that compares technology-based instruction with equivalent pencil-and-paper based instruction via quantitative and qualitative analysis. This paper will present a brief literature review, the materials used as well as the methodology and design of the study.

Introduction

> A teacher from the late nineteenth century entering a typical classroom today would find most things quite familiar: chalk and talk, as well as desk and texts, predominate now as they did then. Yet this nineteenth-century teacher would be shocked by the demands of today's curricula.... Although computer technology is a pervasive and powerful force in society today with many proponents of its educational benefits, it is also expensive and potentially disruptive or misguided in some of its uses and in the end may have only marginal effects.... As ever-increasing resources are committed to bringing computers into the classroom, parents, policymakers and educators need to be able to determine how technology can be used most effectively to improve student learning.
>
> Roschelle *et al.* (2000, pp. 76-77)

Schools today face ever-increasing demands in their attempts to ensure that students are well equipped to enter the workforce and navigate a complex world. 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 mathematics in a collaborative learning environment. We have designed teaching materials that use computer spreadsheets in the learning of algebraic concepts at secondary school, particularly in the area of Financial Mathematics. A sample of these can be found in Appendix A. We have designed a study that compares technology-based instruction with pencil-and-paper based instruction via quantitative and qualitative analysis. This is discussed in the methodology section of this paper. Sample test items for the pre-test and post-test are included in Appendix C. We are interested in determining whether or not:

- there is a difference between the achievement of students using spreadsheets to solve problems and the achievement of students using pencil-and-paper for the same unit of work;
- using spreadsheets increases motivation of students and improves their attitudes toward using computers in a collaborative learning environment; and
- collaborative learning (CL) is an effective and appropriate learning strategy at secondary school level with or without the integration of technology.

The first section of this paper explores technology and what curriculum documents say about technology use in schools. The discussion then reviews the literature on computer supported collaborative learning (CSCL) and its effects on students' achievement and learning. A mention is also made of the various applications of spreadsheets, finally closing with a discussion on students' role in a CSCL environment. The second section gives an overview of the design of our study including the measurement instruments used. As mentioned above, sample spreadsheet and CL materials designed by us and sample test items are in Appendices A, B, and C.

Technology

The introduction of technology into mathematics instruction raises new possibilities for teaching and learning. According to the Panel on Educational Technology (1997), there are two key points with regards to the uses of technology in education today:

- Focus on learning *with* technology, not *about* technology, and
- Emphasize content and pedagogy, not just hardware... Particular attention should be given to the potential role of technology in achieving the goals of current educational reform efforts through the use of new pedagogic methods focusing on the development of higher order reasoning and problem-solving skills.

Panel on Educational Technology of the President's Committee of Advisors on Science and Technology (1997, p.1)

The *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989), point out that computers can be a valuable tool in the enhancement and representation of mathematical data. This document also stresses the importance of utilising technology to allow students to explore mathematics.

Computer-supported collaborative learning (CSCL)

CSCL is one of the most promising ideas to improve the teaching and learning of mathematics with the help of information technology. A technologically sophisticated collaborative learning environment can provide advanced support for a distributed process of inquiry, facilitate advancement of a learning community's knowledge as well as transformation of the participants' epistemic states through a socially distributed process of inquiry. All components of knowledge-seeking inquiry, such as setting up goals, research questions, explanations or search for scientific information, can be shared or distributed among inquirers. A socially distributed process of inquiry provides strong support for the development of the participants' metacognitive skills. Further,

computer-supported collaborative learning 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).

Collaborative learning

Cooperative learning is generally understood to be learning that takes place in an environment where students in small groups share ideas and work collaboratively to complete academic tasks. However, such a general definition overlooks the fact that there are actually a number of different models for cooperative learning, models that vary considerably in their assumptions about the nature of learning and about the roles of teachers and students in the classroom.

(Sharan, 1990, in Davidson & Knoll, 1991, p.362)

With regards to this discussion, the terms *'cooperative'* and *'collaborative'* are regarded as having relatively the same meaning and hence may be used interchangeably throughout.

Effects of CSCL on learning and achievement

Long research tradition has shown that collaborative conditions are helpful for learning (Slavin, 1997). Theories of collaborative learning are based on the notion that knowledge construction is basically a social event, and adequate collaboration is particularly important for learning complex knowledge and higher order cognitive skills (Lehtinen *et al.*, 1998). Meta-analyses on the effectiveness of computers have shown that in the majority of experiments the use of technology has markedly improved the learning outcomes (eg. Fletcher-Flinn & Gravatt, 1995; Khaili & Shashaani, 1994; Kulik & 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, Bereiter, & Lamon, 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 (eg. Amigues, & Agostinelli, 1992; Crook, 1994; Fishman & Gomez, 1997; Lamon *et al.*, 1996; McConnell, 1994; Rysavy & Sales, 1991; Scardamalia, Bereiter & Lamon, 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 (eg. Anderson, Mayes & Kibby 1995; Hooper, 1992).

Spreadsheets and their applications

Spreadsheets have enormous potential for assisting in the learning of algebraic concepts. They can be of great benefit at all levels. Spreadsheets enable students to concentrate on thinking about the subject matter at hand rather than on the software. There are many mathematical applications of spreadsheets as noted by Beare (1993) in Figure 1 below:

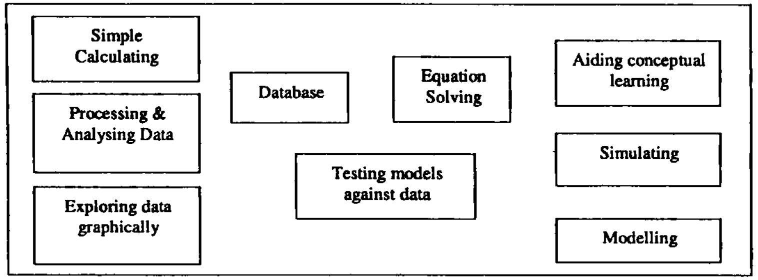

Figure 1. Applications of spreadsheets

Therefore, as summarised by Beare (1993):

> Spreadsheets.... have a number of very significant benefits many of which should now be apparent. Firstly they facilitate a variety of learning styles which can be characterised by the terms: *open-ended, problem-oriented, constructivist, investigative, discovery oriented, active* and *student-centred.* In addition they offer the following additional benefits: they are *interactive*; they give *immediate feedback* to changing data or formulae; they enable data, formulae and graphical output to be *available on the screen at once*; they give students a large measure of *control* and *ownership* over their learning; and they can solve complex problems and handle large amounts of data *without any need for programming*.... (p.123).

Effects of using spreadsheets

Spreadsheets have been found to be valuable from the point of view of developing algebraic understanding (Sutherland & Rojano, 1993). Spreadsheets allow students to represent and test mathematical relationships without having to take on board all the complexities of a symbolic language. Recent studies such as those conducted by Abramovich & Nabors (1997) point out the value of using spreadsheets with middle school mathematics students as they develop problem-solving skills. These studies found that using spreadsheets helped students learn through problem *posing*, higher levels of thinking, decreased intellectual risk, and increased dialogic exchange and that the use of spreadsheets can help develop higher level thinking skills and foster an experimental attitude toward learning mathematics. Asp *et al.* (1992), showed that students can learn to use a spreadsheet with guess and check to solve a linear equation. Students who used the computer spreadsheets in the study were not able to discover on their own how to make full use of the spreadsheet capabilities in order to refine their guess and check approach.

Ghazali and Ismail (in Borba *et al.*, 1997) reported on the use of technology in the teaching of mathematics in Malaysian secondary schools and in particular, on the use of spreadsheets. Their papers include a report on the use of spreadsheets with sixteen year old students, of the 'Fence

Problem' involving a farmer who is fencing a section of field and trying to maximise the area. They outline the use of a numerical solution by using the spreadsheet (although not a graphical or visual representation). The students' response to the use of spreadsheets is to see it as 'not as abstract', and 'more exciting than straightforward differentiation'. The authors suggest that the students found mathematics more meaningful when using spreadsheets by enabling them to focus on the underlying concepts and processes rather than on the final numerical answer.

Shimizu, Ueno and Tanaka (in Borba *et al.*, 1997) reported on the use of function plotting software with 11^{th} grade students in Japan. They outlined classroom activities based on observing the behaviours of polynomial functions. The activities were designed to help students understand the concept of function and properties of families of functions. They involved guided exploration, observing similarities and differences in order to find characteristics of cubic functions. The use of technology prompted activities such as 'trial and error' methods, 'conjecturing and testing and working' with dynamic images to explore common properties of families of functions. They characterised the use of the computer 'as a tool' for exploring characteristics of cubic functions and for checking results. They observed that the sequence of the mathematics curriculum changes as a result of the use of technology.

Therefore, these studies have shown that the use of technology in classrooms has resulted in improved attitude and attention to underlying concepts and processes.

Students' role in a CSCL environment

When students are using technology as a tool or a support for communicating with others, they are in an active role rather than the passive role of recipient of information transmitted by a teacher, or textbook. The student is actively making choices about how to generate, obtain, manipulate, or display information. Some of the new roles for students are directly related to engaging in group problem solving. If students are to work with partners in problem-solving tasks, they must learn to cooperate and collaborate. Leadership roles within a group are likely to change. In an environment of collaborative problem-solving, students can learn to use their fellow students as legitimate resources for learning. Computer-laboratory explorations in pairs or groups can also increase the need for students to communicate both orally and in writing. Oral communication is a necessity if joint discussion-making is to evolve and written communication is needed for computer-laboratory reports. Moreover, when technology is used as a tool to support students in performing tasks, the students are in the position of defining their goals, making design decisions, and evaluating their progress. Project-based and cooperative learning approaches prompt this change in roles, whether technology is used or not.

Methodology and design of study

Mathematics can be learned in a variety of ways – with or without technology, individually or collaboratively. We are investigating the effects of CSCL in algebra, particularly the area of Financial Mathematics, using computer spreadsheets. As stated earlier, the aim of this research study is to investigate the effectiveness of collaborative group-work in mathematics learning using spreadsheets. This study also aims to try and improve the overall learning of algebraic concepts in a collaborative and technology-rich environment, and hopes to determine how useful and enjoyable students find this approach to learning. The design of the proposed research study includes three methods of data collection – a questionnaire administered to students, observations of collaborative activity, and audio-recordings of selected groups in the classroom. A pre- and post-test will be administered to determine students' knowledge of algebra particularly in the area of Financial Mathematics, one at the beginning of term and the second towards the end of term, after students have had an opportunity to work with the materials. The post-test is mostly aimed at detecting any change in students' understanding and/or problem-solving using the materials. Student's feelings and/or opinions towards collaborative group-work using spreadsheets will be determined from the responses to questionnaire items administered upon completion of the post-test. The second method of data collection involves observations of students working collaboratively using technology. Finally, selected students will be asked to participate in an interview where responses would be audiotaped and totally anonymous. The diagram in Figure 2 below, outlines the design and methodology of our research study:

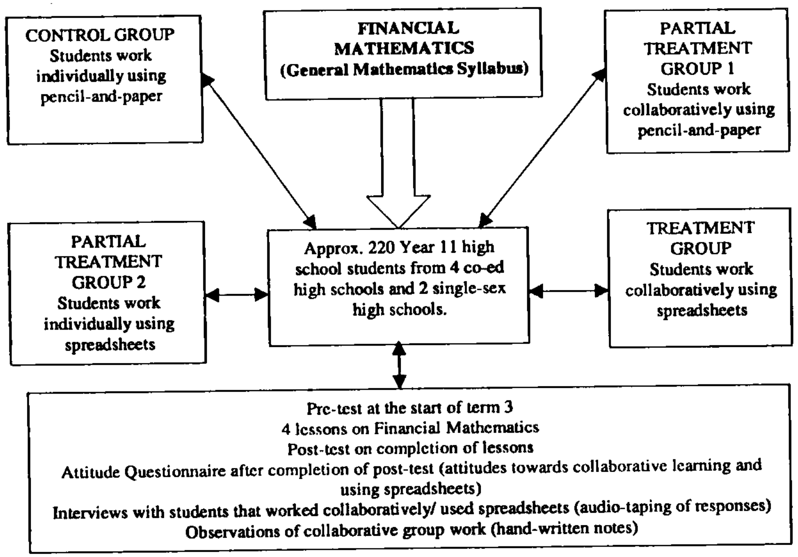

Figure 2. Design of study

Conclusions

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. The question remains: Can the use of technology in a collaborative learning environment give rise to a much richer classroom environment that fosters student exploration and investigation?

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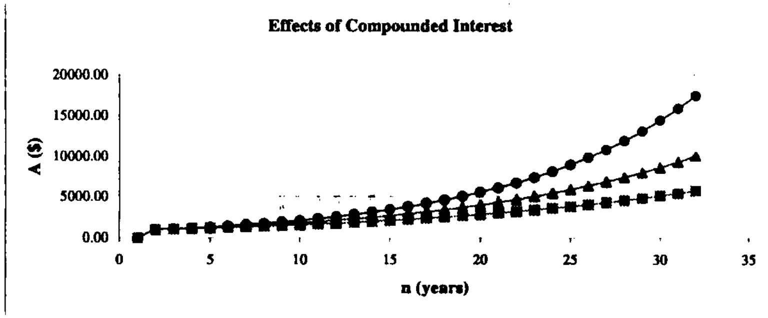
Appendix A. Calculating Simple and Compound Interest Using Spreadsheets

You have just inherited $1000.00 from your grandparents. Your parents advise you to invest the full amount. You discover, from investigations, that you have three options for investing your money: Commonwealth Bank of Australia offers an account with 6% annual interest; Westpac Bank offers a certificate of deposit with 8% annual interest; and ANZ offers a mutual fund that has historically earned an average of 10% per year.

1. Which of these options appears to offer the best return on your money? Why do you think so?
2. If you were to invest your $1000.00 for a period of 15 years, what do you predict your ending balance will be if you chose each of the three options.
3. Compute the simple interest on your $1000.00 investment after 2 years for each of the accounts. What is the formula that you used to compute your interest.
4. Describe the formula that you would need to compute your ending balance after 30 years for an account that has a 6.25% interest rate compounded annually.
5. Use the above formula to create a spreadsheet to represent your three investment options over a 30-year period.
6. What formula (algebraic as well as spreadsheet formula) did you put in cell that contains the value $1060.00?
7. Create a graph to display the three investment options. Make sure you create an appropriate title, label the axes, and make a legend. Looking at the graph, what do you observe about the three investment options?
8. Now that you have completed your spreadsheet on your investments, what are your ending balances for a 30-year period in your passbook account, certificate of deposit and mutual fund?
9. What conclusions can you finally make from your work?



Growth of Investment	P	$1,000.00		
Effects of Compounded Interest	n/r	0.06	0.08	0.10
where:	1	$ 1,060.00	$ 1,080.00	$ 1,100.00
n - Number of years	2	$ 1,123.60	$ 1,166.40	$ 1,210.00
r - Rate of interest per annum	....	....	....	....
	30	$ 5,743.49	$ 10,062.66	$ 17,449.40