Effects of Computer-Based Cooperative Learning on the Problem Solving Skills of Grade Six Students

by

Steven Poris

ISBN: 1-58112-101-6

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Steven Poris

A Dissertation submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy

School of Computer and Information Sciences
Nova Southeastern University

1997

We hereby certify that this dissertation, submitted by Steven Poris, conforms to acceptable standards and is fully adequate in scope and quality to fulfill the dissertation requirements for the degree of Doctor of Philosophy.

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I hereby certify that this dissertation constitutes my own product and that the words or ideas of other, where used, are properly credited according to accepted standards for professional publications.

Signed______________________
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An Abstract of a Dissertation Submitted to Nova Southeastern University in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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Steven Poris

October 1997

This study was designed to determine if sixth-grade students' problem solving skills were improved by means of their experience with a computer-based logical puzzle game designed to increase reasoning skills, and, in turn, problem solving ability. Students worked on this game either in cooperative learning pairs or alone. Baseline and post-experimental problem-solving ability was measured through the administration of a Problem Solving Test; Form A was utilized as a pretest for this purpose, Form B was used as a post-test. Comparisons of problem-solving ability based upon post-test scores (Form B) were made among four groups of students (N = 106):

Group 1: Students (n = 26) who worked on the computer-based puzzle game in cooperative learning pairs
Group 2: Students (n = 27) who worked on the computer-based puzzle game as individuals
Group 3: Students (n = 24) who worked on a computer-based social studies simulation in cooperative learning pairs
Group 4: Students (n = 29) who worked on a computer-based social studies simulation as individuals.

A t-test comparison of post-test data between all students who worked on the puzzle game and all students who did not work on the puzzle game showed no significant difference between the two groups' problem solving abilities. However, an analysis of variance comparing the means of all four groups showed that the students in Group 1 performed significantly better ($F=3.783$, $p<.05$) than those in the other three. These results indicate that students who participated in a computer-based cooperative learning experience using software that fostered the use of problem solving skills showed significant improvement in their problem solving ability. Students who used the same

software as individuals showed no such improvement, nor did students who participated in a computer-based cooperative learning experience using social studies software. Therefore, the data can be interpreted to suggest that the combination of cooperative learning and the use of a computer-based puzzle-solving game led to increased problem-solving ability.

Acknowledgments

I would like to express my gratitude to the members of my dissertation committee, Dr. Trudy Abramson and Dr. Laurie Dringus, and especially to my committee chairperson, Dr. Steve Terrell, for offering unflagging support as I worked my way through the arduous dissertation process. Each served as teacher, mentor, editor, critic, and advisor as I got closer and closer to my goal, and I cannot imagine working with a more helpful, supportive group. The assistance they freely gave and the expertise they freely shared was unsurpassed.

I also want to acknowledge the contribution of the principal of my school, Mrs. Bonnie Epps Burgess, whose understanding and support made it possible for me to complete my studies while continuing my more-than-full-time job as assistant principal.

I would especially like to convey my appreciation for the support of my daughters, Michelle and Lisa, who served as additional sources of motivation for me as they worked toward their own educational goals. They also willingly served as editors, proofreaders, and consultants with each new iteration of my dissertation. Without their assistance and encouragement, my work would have been even more difficult.

Most of all, I want to thank my wonderful wife Sandra. Without her, there would have been no dissertation at all. Her patience was unending; no matter how many hours of work I had to put in, she voiced no complaint. Her words were always those of inspiration and encouragement. Her assistance took every possible form: proofreading, collating, copying, offering suggestions, and, most often, being a sympathetic listener. The opportunity to complete my studies has been a precious gift. With all my love, I thank her for it.

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Chapter I

Introduction

Statement of the Problem

> Problem posing and problem solving involve examining situations that arise in mathematics and other disciplines and in common experiences, describing these situations mathematically, formulating appropriate mathematical questions, and using a variety of strategies to find solutions. By developing their problem solving skills, students will come to realize the potential usefulness of mathematics in their lives (New Jersey State Board of Education, 1996).

Many state education departments, as well as the National Council of Teachers of Mathematics (1989), are focusing on problem solving as one of the most essential skills in which students must demonstrate a high level of proficiency. For example, in New Jersey, the State Board of Education has adopted the <u>New Jersey Core Curriculum Content Standards</u>, in which the first standard states that “all students will develop the ability to pose and solve mathematical problems in mathematics, other disciplines, and everyday experiences.”

The higher order reasoning skills, inferential strategies, and divergent thinking patterns essential to mathematical problem solving often have been difficult for many elementary school students to grasp (Kulm, 1990;

Thornton, 1995). For some of these students, inadequate reading skills may prevent full understanding of written problems; others may be unable to employ their knowledge of mathematical concepts as they try to solve a problem (Chinnappan & Lawson, 1996). Other students may not yet have reached the developmental levels necessary for understanding and solving problems (Nadler, 1994). Still others may find that unrealistic problem solving models hold no interest for them, and are therefore unwilling to devote much effort toward finding solutions (Heiman, 1985).

The significance of the ability to solve problems cannot be overstated; the fact that specialists in mathematical education place such a high priority on the teaching of the skills necessary to achieve this ability speaks to the fact that there is widespread concern over the current level of students’ problem solving abilities.

Therefore, this study addresses the following problem: educators must find a means of teaching problem solving skills more effectively.

Background and Significance of the Problem

Developing methods for teaching problem skills effectively has been a concern of many educational writers and practitioners. This section of Chapter I describes several approaches to problem solving and the relationship of these approaches to the specific area of research that this study focuses upon: computer-based cooperative learning as a means of improving problem solving ability.

Numerous authors (e.g. Polya, 1974; Bransford, 1993; Campbell, 1995) have developed generalized constructs for solving problems. While these constructs may have differed in certain details, certain steps were universally considered to be essential for students' success. For example, Polya (1974) suggested these four steps to solve a problem:

1. Understand the problem.
2. Devise a plan or strategy.
3. Carry out the plan.
4. Look back.

A modification of these steps was offered by Bransford (1993). He suggested a five step process known as IDEAL:

1. **I**dentify the problem.
2. **D**efine the problem through thinking about it and determining what information is relevant and what information is not.
3. **E**xplore solutions by looking at alternatives, brainstorming, and examining the problem from different points of view.

4. **A**ct on the strategies.
5. **L**ook back and evaluate the effects of your activity.

Similarly, Campbell (1995) suggested that students should solve problems by means of a step-by-step approach; he calls this approach “P.A.C.E.”. This acronym stood for “Problem” (identifying the goal), “Alternatives” (determining possible solutions), “Consequences” (examining the likely consequences of one’s actions), and “Evaluation” (selecting the most promising choice).

Clearly, the common threads of problem solving strategies include the recognition of information relevant to the problem and the development of a systematic approach to developing a solution. However, it is much easier to describe these strategies than it is to teach them. Chisko and Davis (1986) have suggested the following general topics around which teachers can develop lessons in various subject areas to help students develop problem solving skills:

1. Recognizing and defining problems
2. Organizing information and using modeling techniques
3. Analyzing data, recognizing trends, and making decisions
4. Being flexible and thinking creatively
5. Generalizing and consolidating

Chisko and Davis (1986) felt that ideally, students will become actively involved with the problem by asking questions such as: What do we know? What do we want to know? What immediate information would be useful? What is a reasonable solution? Does our solution satisfy all the requirements of the problem? Can we use the solution to this problem to draw general conclusions about similar problems?

How to teach children to ask (and answer) these questions as they solve problems is central to the present study. These types of questions represent what the National Council of Teachers of Mathematics (NCTM) considered when, in its Curriculum and Evaluation Standards for School Mathematics (1989), it placed "Mathematics as Problem Solving" as its first standard for students at every grade level from Kindergarten through Grade 12. The NCTM states that problem solving skills should not be limited to traditional word problems, but that these skills should be considered as a "method of inquiry and application" to provide motivation for students to explore concepts in every phase of the mathematics curriculum. In order to provide students with worthwhile experiences in the development of problem solving abilities, the NCTM suggested:

> Students should model many problems concretely, gather and organize data, identify patterns, and...use computers to assist in generating and analyzing information...Students would frequently work together in groups to solve problems. They can discuss strategies and solutions, ask questions, examine consequences, and reflect on the process. (National Council of Teachers of Mathematics, 1989, p. 7)

Two widely-increasing trends in elementary education are alluded to in the above passage: cooperative learning and computer-based instruction. Cooperative learning is generally defined as an educational setting in which a group of two or more students work together to perform a learning task, and where each student is not only responsible for his/her own learning, but for the other group members' learning as well (Sapon-Shevin and Schniedewind, 1992). Cooperative learning, a relatively new approach to teaching and learning, gained its initial momentum from Johnson and Johnson (1975). It proved to be an extremely appealing strategy, emphasizing the value of students working with their peers to acquire information and/or skills, to formulate concepts, to build products, or to refine ideas. As they work together to achieve a common goal, students also learn a number of valuable social skills, including interdependence, positive interaction, and group processing (Johnson & Johnson, 1991). Cooperative learning gained popularity steadily and was the subject of research in many subject areas (see Chapter II), and was consistently found to have positive effects upon learning and upon students' acquisition of social interaction skills.

The second educational trend alluded to, computer-based instruction, generally refers to the increasingly widespread use of computers to serve a significant role within the standard educational curriculum (Schofield, 1995). Taylor (1980) originally classified educational computing in terms of the computer's role as either tool, tutor, or tutee. However, it is difficult to confine the categorization of the current educational use of computers to these three roles. For example, Seymour Papert, who created the LOGO programming language for children, says that computers in schools today are often used to create a "community of learning" shared by students and teachers, in which the computer "is a medium in which what is made lends itself to be modified and shared" (1997). Further, when the computer is used to facilitate cooperative learning experiences, it also cannot be easily pigeon-holed; the computer, in such circumstances, serves several roles. One aspect of computer-based instruction is constant, however: computers are but one element of a total instructional environment, along with teachers and other media (Alessi and Trollip, 1991).

Chapter II of this study provides extensive documentation which demonstrates how each of these approaches, cooperative learning and computer-based instruction, has been shown to be an effective means of instruction in a broad range of curriculum areas. There is a special emphasis on the use of these approaches in the teaching of problem-solving skills. This documentation serves to support the current study, in which students participated in both approaches to instruction simultaneously. The interactive and cumulative roles of these approaches, when implemented in a learning experience designed to enhance problem solving skills, are examined.

The specific goal of this study was to determine if sixth-grade students' problem solving skills were improved by means of their experience with a computer-based logical puzzle game designed to increase reasoning skills, and, in turn, problem solving ability. Students worked on this game either in cooperative learning pairs or alone. Baseline problem-solving ability was established through the administration of a Problem Solving Test available in two forms (A and B); Form A was utilized as a pretest for this purpose. Comparisons of problem-solving ability based upon post-test scores (Form B) were made among four groups of students:

Group 1: Students who worked on the computer-based puzzle game in cooperative learning pairs

Group 2: Students who worked on the computer-based puzzle game as individuals

Group 3: Students who worked on a computer-based social studies simulation in cooperative learning pairs

Group 4: Students working on a computer-based social studies simulation as individuals.

The formal mathematics instruction received by all four groups both prior to and during the study was essentially similar. All sixth grade teachers follow the same pacing calendar for instruction, and follow a rigid curriculum called the Comprehensive Instructional Management System (CIMS). While there was no way to control for variation among the teachers' expertise, the students in all four groups were exposed to substantially the same instructional material, including lessons in problem solving that emphasized several of the skills needed for solution of the puzzles.

The computerized puzzle game that the students used, called Sherlock for Windows (Kaber, 1995), presents puzzles to students which can only be solved by correctly applying such problem solving skills as:

a. using information given

b. identifying relevant information

c. elimination of information which is irrelevant

d. recognizing patterns

e. making inferences based upon generalizations

f. determining several possible courses of action

g. selecting the most promising solution from among various possibilities

Each of the above skills is essential to the ability to solve mathematics problems; it was predicted that by working together in cooperative-learning pairs to solve the puzzles posed in the Sherlock for Windows game (hereinafter referred to as Sherlock), students' ability to solve mathematics problems would improve.

Barriers and Issues

Much of the research concerning the effectiveness of cooperative learning (Johnson & Johnson, 1975; Johnson & Johnson, 1991; Slavin, 1983) was performed before computers became a common educational tool in classrooms throughout the country. Such research was primarily performed in traditional classrooms (utilizing traditional materials) in which teachers were beginning to implement this new approach.

In recent years, the number of research studies that have involved cooperative learning in a computer-based setting has been increasing (e.g. Nastasi & Clements, 1993; Uslick & Walker, 1994; Brophy, 1995). As described in

Chapter II, such studies have examined the results of such experiences at all levels of education, from elementary grades through post-graduate education, as well as corporate and military training experiences. Studies have been performed in a variety of subject areas, including reading, mathematics, writing, social studies, and computer programming. However, the vast majority of these studies have focused only upon the specific skills emphasized by the software being used (although examination of the socialization aspects of the students' experiences are often described). There has been little research in the area of transference and generalization of skills acquired by means of computer-based cooperative learning; specifically, in the area of concern in this paper, the transference of logical thinking skills (acquired by means of experience with a computer-based puzzle game in a cooperative learning setting) to other areas of problem solving has not been examined in a systematic research study.

The challenge of such a study lies in the understanding of the underlying skills necessary for students to select and carry out appropriate problem solving strategies. These problem solving skills should not be relevant to only one type of problem; they should be applicable to a wide variety of problem situations. The circumstances of the acquisition of these skills should be such that students' abilities to internalize them and utilize them with a high degree of flexibility are maximized. One appropriate circumstance for the acquisition of logical thinking skills (such as pattern recognition, elimination of impossible choices, gathering background information, and recognizing whether information is essential or irrelevant) would be the experience of solving a computer-based puzzle game which requires such skills to be utilized in order to reach a solution (Samaras, 1996; Maldonado, 1996). This speaks to the issue that the software utilized in the current study, Sherlock, does not directly present mathematical problems to the student. Instead, it presents graphical puzzles which must be solved using the same problem-solving skills that students must utilize to solve mathematical problems. It is anticipated that when children work together to solve such puzzles, their learning is enhanced and made a permanent part of their bank of essential skills.

Research Questions and Hypotheses

The purpose of this study was to increase understanding of how students' participation in a computerized puzzle game designed to give practice in utilizing problem solving skills affected their problem solving abilities. The specific skills students used while solving the puzzles included: identifying the problem, determining which information is relevant and which is irrelevant, logically exploring of alternative strategies, acting on the strategies, and examining the results of these actions. In addition, this study was designed to determine the relative efficacy of students' utilization of the computer game under two conditions: in cooperative learning pairs and individually. The specific research questions were:

1. Are students' abilities to solve problems significantly improved by individual participation in a computerized problem solving game?

2. Are students' abilities to solve problems significantly improved by participation in a computerized problem solving game as part of a cooperative learning pair?

The first hypothesis investigated in this study was that sixth-grade students (11-12 years old) who work to solve a computerized puzzle game (Sherlock) will demonstrate a significantly greater improvement in problem solving skills than sixth-grade students who receive traditional teacher-presented mathematics instruction and who work on a computerized social studies simulation either individually or in cooperative learning pairs. The second hypothesis investigated was that sixth-grade students who work to solve a computerized puzzle game in a cooperative learning setting consisting of pairs of students will demonstrate a significantly greater improvement in problem solving skills than either those students who work on the computerized puzzle game individually or those students who receive traditional teacher-presented mathematics instruction and who work on a computerized social studies simulation either individually or in cooperative learning pairs.

Students’ problem solving skills were measured both pre- and post-treatment, utilizing both forms (A and B) of a test designed to measure problem solving ability. The results of these measurements were analyzed to determine whether there had been changes in the students’ abilities, and whether these changes were related to their specific cooperative learning experiences while playing the computer game. It was hoped that the results of this research project would offer additional understanding of the types of