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## The Cooperative Computer-Assisted Instruction in Mathematical Education

Mahmood Farhadian, Esfandiar Eslami and Mohammad Reza Fadaee  
Department of Mathematics,  
Shahid Bahonar University, Kerman, Iran

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**Abstract:** In this research, we study the cooperative learning, Computer-Assisted Instruction (CAI) and combination of these two methods, called Cooperative Computer-Assisted Instruction (CCAI). In fact CCAI is one of the cooperative learning strategies. In CCAI method with the use of computer and attractive softwares, there will be appropriate grounds in instruction and educational achievement of mathematics for students. This method is examined for small groups of students in a workshop. On the basis of our observations from this workshop and other small samples, we have investigated some hypotheses on the reduce of students' negative beliefs about mathematics, the response of mathematics teachers and students to CCAI, the speed of learning mathematics and its independence from time scheduling. The students in this workshop are taught heuristic strategies with the use of produced computer softwares via Cooperative Computer-Assisted Instruction. Despite of the limited amount of training and other limitations, the difference between pretest and posttest scores is meaningfully significant.

**Key words:** Cooperative learning, computer-assisted instruction (CAI), cooperative computer-assisted instruction (CCAI), mathematical problem solving, heuristic strategies

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### INTRODUCTION

In the recent two decades, the cooperative learning research has been increased because of the educational progression and change of social behaviors in schools and universities. We implement this method with the help of other instructional methods such as CAI.

In cooperative environment, students are motivated to help each other in order to gain the teaching skills. The students who learn easier and faster, take the advantage of describing the information to the weaker students. In cooperative learning, sometimes the students are asked to do group projects and report them for grading. Since there is only one report and one grade for each group, they try their best to get a good grade. Using computer and related softwares makes cooperative learning easier and more attractive.

In fact, cooperative learning is a kind of teaching and learning strategy in which pupils study together in small groups. The effort of every member in a small group is important for the enhancement of all members' performance. In this method, students interact by using skills such as communication, observation, support and reasoning. These improve the relationship between students from the social point of view. This technique is

used in classrooms in several ways. One of its emotional features is supporting the interaction between students, by group work and learning in small groups. This method is a suitable replacement for traditional instructional competitive methods. Also, this method is useful for learners who learn better in social and practical conditions. The management and the social behavior of the students will be improved and lead to greater achievements in writing, doing mathematics, critical thinking, problem solving and comprehension (Stevens and Slavin, 1995). This method is also very useful in classes in which there are students from various cultures and nations (Dyson, 1995).

The use of computer in teaching, dates back to more than four decades. Today, using computer in teaching mathematics has become widespread because of its efficiency. The CAI in mathematics can be used for the following goals:

- It can be used effectively for the development of mathematical skills. The multimedia compact disks and intelligent softwares can be used for learning mathematics effectively.
- It can be used collectively or individually for educational achievement in mathematics. Computer

can provoke the students' emotions, support their primary skills and attract their attention. It also simulates the environment, simplifies the calculations, gives immediate feed back and can do most of the hard tasks to be done by the teachers, otherwise.

### COOPERATIVE COMPUTER-ASSISTED INSTRUCTION

When the two mentioned instructional methods are combined with each other, a new method is created which is called Cooperative Computer-Assisted Instruction (CCAI). In fact it is one of the strategies of cooperative learning. We used this method in an experimental project and got satisfiable results for teaching mathematics in various academic plans.

In this method, the employed softwares have animated graphics and sound. The effects of graphics may reduce achievement differences between students of different ability levels and help form mental images as students are learning the skills (Joseph and Dwyer, 1982). This visual imagery technique may result in motivated learning and provide a chance for students at diverse learning levels to discuss and explore skills together.

In the cooperative computer-assisted learning environment, students discuss the problems appearing on the monitor with each other, try to recall the appropriate procedures and examine errors before pressing the Enter Key to record the result (Xin, 1999).

Usually, teaching by the use of computer is designed for individual learning; but research done by Dalton *et al.* (1989); Kelin and Pridemore (1992); Mevarech (1993) and Xin (1999) indicated that instruction in a small group works better than individually. There are many reasons to support idea that using cooperative learning methods improve students' learning and educational achievement. Some of these reasons are economical profits, reduction of math-anxiety in low ability students, enhancement of high-level problem solving skills in students and reduction of gap between weak and strong students. Individual learning with CAI decreases the interaction between teachers and students. The instructional softwares in individual learning with CAI go forward to a situation in which the teacher has a small role in teaching, whereas in learning mathematics the role of teacher is essential.

Nowadays, research about mathematics instruction with CCAI and calculators show the importance of teachers' role. For example, a teacher in a classroom can divide the class into small groups and check the process of problem solving by a control computer and when necessary, he or she can help the groups.

### CREATED RESEARCH HYPOTHESES

According to our pre-research and studies we realized that in addition to the advantages given in previous section, we may have more positive responses. Based on some theoretical and practical results, we make four research hypotheses. In the following we discuss them and provide the related results.

**The first hypothesis:** The students' negative beliefs about mathematics are reduced in CCAI. In the book *Mathematical Problem Solving* (Shoenfield, 1985) we read: Belief systems are one's mathematical world view, the perspective with which one approaches mathematics and mathematical tasks.

One's beliefs about mathematics can determine how one chooses to approach a problem, which techniques will be used or avoided, how long and how hard one will work on it and so on. Beliefs establish the context within which resources, heuristics and control operate.

It seems that one of the basic duties of teachers is forming the correct beliefs and correcting the false ones about mathematics in students. Some of the incorrect beliefs among the students are as follows.

- Mathematics is difficult, tedious and arid.
- The word problems are more difficult than numerical and computing ones.
- There is no relation between real life problems and mathematics exercises.
- The questions and problems in mathematics tests must be the same as those given in the textbooks or assigned as homeworks. Any other problem is considered to be difficult and out of context.

We believe that these have roots in the early education of the students in preschool and primary school and have been gradually powered and fixed in later years as firm or stable beliefs. By providing and using softwares which have features such as designing the word problems with random digits, or designing different word problems which are related to the real life and combining film, animation, paint and some specific multimedia softwares, we can change the negative beliefs and go toward the positive ones. Continuation of this method can make a noticeable change in mathematics learning.

**The second hypothesis:** The teachers and students would welcome CCAI method.

If we hear and see a subject, we will be more affected. By using CCAI in learning, students transfer more information easily to their memories. Since students work

with each other in collective groups and do their tasks and assignment which computer has designed, The students become less tired. The computer software guides students intelligently and actively and helps them to communicate with the computer through a multimedia software. In this method, teaching by computer is used as one of successful cooperative learning strategies. The multimedia softwares not only complete the teachers' work but also test students throughout the educational period. In traditional teaching, instructors teach large classes and it is very tedious for them to work with all students on to give tests continuously to make sure that they improve. Therefore the teachers do not have sufficient time for their tasks. These type of classes are boring for both teachers and students. The CCAI method is a strong means by which the teachers can control and manage difficulties. Therefore it is expected that teachers also welcome this method.

**The third hypothesis:** Students learn easier and faster by CCAI method.

In this method mathematics concepts and related exercises are carried easily to the long-term memory and are kept longer than traditional method of teaching. From the time that new concepts are received by the learner until they pass through the short-term memory and carry to long-term memory when learning is complete, important processes are being done. These processes are related to understanding or recognizing. They are well known as recognizing processes of memory. These processes can be categorized in three stages: repetition or review, developing or extending and organization. These processes are also named recognizing strategies. The softwares which are used in this method provide the use of recognizing strategies in a good level, specially the repetition strategy. Therefore, it helps to learn the concepts and carry and keep them in the long-term memory. In this regard let us consider the problem of multiplication and division in the primary school. The students usually memorize the multiplication table but many of them find it difficult to memorize this table and using it in division. Some parents and teachers also emphasize on memorizing it and this causes the reaction of the students. If these situations would not be well handled it may form false beliefs about mathematics. Since the concepts of multiplication and division are basic and prerequisite to later subjects, mathematics is considered as a difficult and complex course. Attractive softwares and various computer games which are along with cooperative learning can be used for teaching multiplication table. The students enjoy playing games, memorize the multiplication table and use it in division. This helps to make mathematics as an interesting subject.

If this method is continued, it will have the positive effects on the students' views about mathematics generally.

**The fourth hypothesis:** Learning mathematics by CCAI is independent of time scheduling.

In various academic plans, it is proposed that the mathematics classes should be held in the early morning. This causes to provoke unconsciously that mathematics is a difficult course. Some students and non-mathematics teachers believe that mathematics is a hammer and the mathematics teachers are those who hammer the brain of students in the beginning of the morning and this makes the students tired and exhausted for the remaining classes of the days. Probably with present situation, there is no other way. But if the instruction is changed according to the students' desire and their attention, we can schedule the mathematics classes at any time, without negative effects on instruction.

## **PROBLEM SOLVING AND HEURISTIC STRATEGIES**

The discussion about problem solving and enhancement of students ability in performing problem solving has been one of the most important bases in mathematics education. A glance at the history of problem solving shows that the bright, systematic and notable points related to this debate has been found on Polya's works. Polya (1945) in his famous book *How to Solve It* points out the ways and techniques by which we can solve problems. He believed that to solve any mathematics problem, we must go through four processes: understanding the problem, designing the plan, carrying the plan and looking back. In this book these four processes have been described in details.

In the last 1970's and early 1980's, Schoenfeld designed courses in problem solving, arranged sessions and prepared videocassettes from these sessions. When analyzed them, he found some behaviors which are useful for problem solving process. The results of his studies have been published in his mathematical problem solving book (Schoenfeld, 1985). Schoenfeld in his book introduced and discussed four fields related to knowledge and behavior of mathematical problem solving: resources, heuristics, control and beliefs systems. Schoenfeld's work is important because he examined most of Polya's thoughts and theories in a fine frame and mixed them with psychological and social aspects and tested them in practice. He improved the Polya's instructive ideas.

As mentioned above, one of the effective factors in mathematical problem solving is attending the heuristic strategies. Schoenfeld defined heuristic strategies as the

rules of thumb for successful problem solving, general suggestions that help an individual understand a problem better or make progress toward its solution. Such strategies include exploiting analogies, introducing auxiliary elements in a problem or working auxiliary problems, arguing by contradiction, working forward from the data, decomposing and recombining, exploiting related problems, drawing figures etc. Heuristics are usually general designs which can be used in every mathematics domain. In spite of the fact that heuristic attracts a lot of writers' attention, there is no an exact definition for heuristic strategies. Obviously they are methods which help anybody to find and learn something by oneself. For seeing details and examples of heuristic strategies, the book (Shoenfeld, 1985) is proposed.

The research done by Schoenfeld and our studies show that the explicit and obvious teaching of heuristics is certainly effective for students to solve the problems.

**AN EXPERIMENTAL DESIGN**

Thirteen students have participated in our experimental design. They have 10 year experience of mathematics teaching in different middle schools. They are back in university in order to continue their studies towards B.Sc. degree in Mathematics. They were asked to participate in an experimental design with the use of CCAI. This project in the form of a workshop was performed in the computer Lab in Mathematics and Computer Department. To analyze the workshop results, we assigned randomly a number from 1 to 13 to each student. The worksheets given to students at any part of the workshop were identified by these numbers only known to the students.

**Scoring scheme:** In this experiment we used the following scoring scheme. Any problem had 5 scores. If a student proposed a special way or evidence for solving problem such as pointing to induction strategy but he (she) had not followed his (her) proposal, got 1score. When he (she) pursued his (her) proposal but he (she) had a little progress, got 2 scores. The student who had some progress in solving problem received 3 scores. If a student almost solved a problem with a particular approach but it marred by an incorrect calculation received 4 scores and the student who solved a problem completely with one approach received 5 scores. Table 1 shows this scoring.

**Pretest:** At the beginning of the workshop, after a short discussion about the way it works, the students took a pretest containing three problems which could be solved, respectively by the three heuristic strategies: induction,

fewer variables and drawing diagram. Each of the problems could be solved by at least two different ways. For any problem, the allowed time was 10 to 15 min. Any problem had been written on a single page of size A4 paper with a provided blank space for its solution and followed by two questions on the bottom of the page: (1) Have you seen this problem before? and (2) Have you seen any problem similar to this?. All of the students answered NO. The results of the pretest using the mentioned scoring scheme are shown in Table 2.

**Computer software:** Because there was no suitable software for heuristic strategies instruction, a software was produced by instructors with the use of multimedia builder software. The problems which were created by software, could be solved by heuristic strategies. The process and the frame of the work will be described in the following section.

**Cooperative learning:** The Cooperative Computer-Assisted instruction was done throughout the following processes.

**Stage 1: Making groups.** After describing the cooperative work to students, they were asked to form groups of three or four members. The groups were formed as below and they began to learn the heuristic strategies by computer. The random numbers assigned to the students in the first and the second group were numbers 1, 2, 3 and numbers 4, 7, 8, respectively. The third and the

Table 1: For every problem: 5 scores

Scores	Progress	Pursuit	Evidence
1	-	-	+
2	-	+	+
3	Some	+	+
4	Almost	+	+
5	Complete	+	+

The plus sign is used for achieved aim and the minus Sign is used for unachieved aim

Table 2: Individual pretest scores

Student's No.	Problem 1 (induction)	Problem 2 (fewer variables)	Problem 3 (drawing diagram)	Total score
1	0	0	0	0
2	0	0	0	0
3	1	0	0	1
4	4	0	0	4
5	0	0	0	0
6	1	0	0	1
7	2	0	0	2
8	0	0	0	0
9	3	0	0	3
10	0	0	0	0
11	2	0	0	2
12	0	0	0	0
13	0	0	0	0

fourth group contained four and three students numbered 5, 6, 12, 13 and 9, 10, 11, respectively.

**Stage 2:** Showing the problems to the groups by computer. The first problem was shown on the monitor. the students were asked 5 min to think about the problem. They got engaged in problem solving on a their worksheet named The solution without hints and the results written on the worksheet. When the first 5 min passed, a bell rang by computer and the first hint appeared on the monitor. The hint read as Review each of the following strategies: (1) drawing figure, (2) induction, (3) contradiction, (4) similar problem with fewer variables and (5) determination of subgoals. Another 5 min was assigned for them to think about the problem with this hint and they were engaged with their work on the worksheets named The solution after the first hint. After the second 5 min, the computer rang again and the students noticed to the second hint which obviously pointing to useful strategies for problem solving. Then they started their efforts during five min on The solution after the second hint section. When the hints for the first problem were finished, a bell rang to assign the end of time for solving the first problem. The same process was repeated for the second and the third problem. If some of the problems needed more hints, with repeating the mentioned process, the computer allowed them to spend more time on that related to that hint. At the end of the stage 2 the students had five min to overview and correct their worksheets. Then the worksheets were collected and graded. The scores are shown in Table 3.

**Stage 3:** The solutions of problems. The solutions of problems were shown on the monitor. The students compared their solutions with the correct ones and discussed with themselves. The instructors answered the questions asked by members of groups.

**Post test:** The students left the university for a period of two week holidays. They were assigned no homework and were not noticed of the continuation of the experiment after their return to the university. On the first class after the holidays, we gave them a test similar to the pretest. We called it the posttest and consisted three problems which were different from what were taught and tested in the workshop and pretest but, of course solvable by the

Table 3: Group test scores with CCAI

Group	Problem 1 (induction)	Problem 2 (Fewer variables)	Problem 3 (drawing diagram)	Total scores
1	5	5	0	10
2	3	5	5	13
3	5	5	0	10
4	5	5	0	10

Table 4: Individual posttest scores

Student's number	Problem 1 (induction)	Problem 2 (fewer variables)	Problem 3 (drawing diagram)	Total scores
1	5	0	0	5
2	4	4	0	8
3	5	4	0	9
4	4	1	0	5
5	1	0	1	2
6	5	5	1	11
7	5	5	1	11
8	5	1	1	7
9	5	2	3	10
10	5	5	2	12
11	2	0	0	2
12	2	5	1	8
13	0	0	1	1
14	0	0	0	0

previous strategies were presented to them. Also in posttest the students were asked to answer 2 questions: Have you seen this problem before? and Have you seen any problem similar to this?. All of the students answered "NO" to the first question and only three students answered "YES" to the second question. The results of the posttest are shown in Table 4.

The student in row 14 was absented on the workshop and the pretest. His scores show the effectiveness of CCAI over the other students.

**Discussion:** In a research project by Schoenfeld, two groups of students (control and experimental) were instructed (individually and without using computer) for a period of two weeks. They were instructed 20 problems which were solvable by 5 heuristic strategies: drawing figure, determination of subgoals, contradiction, similar problem with fewer variable and induction.

The primary difference in the treatments the two groups received was that the solutions shown to the experimental group explicitly included mention of the heuristic strategies used to solve the problems. The control group saw the same solutions but without an elaboration of the heuristic method. Two comparisons of pretest-to-posttest gains, indicated that the experimental group significantly out performed the control group. The results indicated that, the students in the experimental group did learn to use three of the five strategies (drawing figure, similar problem with fewer variables and induction) but they did not learn to use the two other strategies (determination of subgoals and contradiction). Schoenfeld mentions several reasons for that. He believe the last two strategies were complex and the instruction time (two weeks) and the instruction amount (20 problems) were very limited. In particular, the training did not provide enough practice to make it likely that students would master the mechanics of using the subgoals procedure. Nor was it sufficiently explicit about

how to decompose problems and to select subgoals appropriate for their solution.

We believe that using CCAI method, one can teach these strategies better. By designing suitable examples, choosing subgoals, dividing a problem into simpler parts and giving each part to smaller subgroups to solve by the computer software, The group may guide to a general problem solution.

Schoenfeld points out that the students who took part in the study had a very good background in mathematics. In our study the conditions and the limitations were different from Schoenfeld's study but the results were more than our expectation. Some of these limitations and differences were as follows.

- The time for solving every problem was 10 to 15 min.
- The students participated voluntarily in the experiment.
- From the beginning of instruction to posttest, there were two weeks and during this period the students were on their holidays. They did not have any classes and it was impossible for them to see problems similar to the posttest problems and they were not together to discuss heuristic strategies. Even they had not been said that the instructors wanted to test them again. After holidays, in the first session, they took the test.
- The students who were in this study did not have any good background in mathematics. An example of their weakness was that the problem in the posttest could be solved by drawing figure strategies, most of them have sketched a parabola instead of a circle but they had recognized the correct strategy.

#### **The study results:**

- In this study, we encouraged the students to learn in groups and the teacher had only the role of a guide. The individual ability of each member in the group affected the group ability.
- The progress in scores from pretest to posttest is shown in Table 2 and 4. Also the scores in Table 3 show that when the students were in group, they could use their ability and solve some of the problems by the computer's hints which were a strict point to heuristic strategies and by a group discussion.
- In mathematical problem solving (Schoenfeld, 1985) Schoenfeld says that the instruction of heuristic strategies is effective in the enhancement of solving problems of mathematics. The results of our research and similar studies confirm this idea.

- It seems that the students who were instructed by CCAI are more comfortable than in the traditional classes. The students in each group talk to each other, make tricks and class is less tedious for them. The time period of classes, in most of schools and universities, is generally about 100 min and the role of the teacher is as a lecturer and instructor in these classes is usually limited. Such classes are very tedious for both teachers and students. Weariness in CCAI is very less. In addition, it is easily seen that the students enjoy using the cooperative learning advantages.
- The aim of the ringings in the software was to have the students' attention to control discussion which has an important role in problem solving process. The problem solvers with a good control can take the maximum benefits from their resources and they can solve difficult problems with least effort.

As Schoenfeld indicated in his study "Purposes and Methods of Research in Mathematics Education" (Schoenfeld, 2000), the results of investigations in teaching are improvable because mathematics is a complex subject and is related to different factors. In teaching there is a wide range of investigation methods. We hope this research and using this method would be interesting for mathematics teachers.

#### **RESULTS AND PROPOSALS**

In the light of the fast development of communication technology and the availability of modern computers in the schools, it is expected that education can make best use of them for their extended functions and attractive features. Nowadays, in different countries, computers are used in classrooms individually or by groups and many research have been done on this subject. Since some teachers have tendency to discuss the CCAI method and its instructional and social effects, the researchers in many countries provided a ground to search about it and positive results are obtained such as educational progress, enhancement of problem solving skills, changing in social behavior, changing in learning behavior (from inactive to active) especially in mathematics classes which needs the analysis of the subjects. To take the full advantage of available capacities and also have a better future, we propose the following.

- Since there are only a few suitable softwares that can be used for teaching mathematics in many countries and these are not coordinated to their native language, religious or cultural conditions, we

propose that mathematics teachers with the help of programmers produce suitable softwares to teach mathematical strategies to students. This can also reduce fear of changing computers to a ceremonial or official equipment for schools or a playing object for students in at homes. In addition, self-reliance in producing competitive softwares by native programmers and mathematics teachers provides facilities, persuades the programmers, constructs the competitive conditions in countries. All of these cause a fast move in production of powerful and suitable softwares at national and international level.

- In recent years, in many countries, the effective works have been done for equipping schools and universities with computers but it seems that this process should be faster than before. This can be done by the help of governmental organizations and the teachers and parents associations. The schoolmasters can make parents aware of the use of computers in their children education during different meetings. Some parents may give financial assistance for equipping the computer labs of the schools.
- To our best knowledge, in many countries the CCAI method in schools and universities is not examined actively. Since students are interested in working with computers, playing games and talking with other students, we suggest that this method being examined in various countries and if the results are positive we can extend the use of this method in other schools and universities generally.
- By unofficial conversations with teachers and asking their view on teaching and learning methods, we understand that some of the teachers resist using computer in teaching. Perhaps one of the reasons is the fear by teachers themselves. They do not know how to work with computers. Anyway, they need to learn the use of computer. In order to achieve this aim, it would be efficient to establish official's inner workshops, to provide opportunities for teachers to participate in these workshops and learn how to use computers for making a relationship between effective teaching and assisting instructional equipments.

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