COOPERATIVE LEARNING IN THE CLASSROOM: The Importance of a Collaborative Environment for Computer-Based Education

Kori Inkpen, Kellogg Booth, Maria Klawe

Department of Computer Science
University of British Columbia
Vancouver, British Columbia, V6T 1Z4
Phone: (604)822-8990 E-mail: inkpen@cs.ubc.ca

Rena Upitis

Faculty of Education
Queen's University
Kingston, Ontario, K7L 3N6

ABSTRACT
Cooperative behavior of students playing an educational computer game was investigated. The combination of gender and whether one or two computers were present significantly affected the level of achievement as measured by the number of puzzles completed in the game. Female/Female pairs playing on two computers, on average, completed less puzzles than any other pairs in any other condition. Differences were also observed for gender pairs sharing control of the mouse while playing on a single computer. Male/Male pairs had a higher number and percentage of refusals to give up control of the mouse.

KEYWORDS
Human-computer interaction, Computer-supported cooperative work, Computer-supported cooperative learning, Collaboration, Education, Gender, Games.

INTRODUCTION
This paper examines computer-supported cooperative work (CSCW) issues in an educational domain. Computer-supported cooperative learning (CSCL) is a new branch of research combining research from CSCW and education.

We are interested in how computers can be used in educational settings and whether collaborative use of computers is appropriate. Our study is designed as a first step in a larger project investigating how electronic game technology can be used to stimulate interest in math and science among pre-teenage students.

Many stereotypes are reported in the research and popular literatures concerning electronic games and education. Among these stereotypes are gender differences (girls play less than boys), social consequences (game players don't develop social skills), and educational value (games are mindless entertainment).

Our study examined a number of factors concerned with how school-age children interact with electronic games in a classroom-like environment: isolated play vs. group play; a single shared computer vs. one computer per student; and gender and gender pairings (Figure 1). A somewhat surprising result, perhaps contrary to stereotypes, was that girls appear to perform better when sharing a single computer or when working in isolation than they do when they have a dedicated computer of their own in a collaborative environment. This is true whether they share with other girls or with boys.

After a discussion of how electronic games offer a unique collaborative environment for computer-based education, we summarize previous research on cooperative learningand then describe our own study, the results we obtained, and the conclusions we have drawn thus far.

ELECTRONIC GAMES AS TESTBEDS FOR COOPERATIVE LEARNING
Research on computer-based learning is an important topic in the field of CSCW because of three factors. First, there is a growing emphasis on cooperative learning in the schools. Second, computer learning environments can play a key role in support of learning. Third, issues in CSCL typify many concerns in CSCW and hence study of CSCL can benefit research in all areas of CSCW. In this section we briefly discuss these topics further.

Figure 1.
Research Setting

A workshop in 1992 brought together researchers from both academia and industry with an interest in CSCL to discuss directions for study [12]. Cooperative research in education falls within Bannon and Schmidt's broad description of the CSCW field, being that "which covers anything to do with computer support for activities in which more than one person is involved" [1, p.4]. This view is supported by Koschmann et al., "Learning is, after all, another form of work" [12, p.60].

Bannon and Schmidt [1] discussed three requirements that constitute a core issue in the CSCW field: articulating cooperative work; sharing an information space; and adapting the technology to the organization, and vice versa. The structuring and integration of multiple tasks is important for collaborative school projects using computers. The sharing of an information space is of particular concern in education because children often prefer to work in small groups around one computer. In addition, having groups of students work at a singleworkstation is an efficient method of using the limited amount of computer resources in many schools. Finally, integration of the technology into the classroom, the curriculum, and teacher's lesson plans is a key element of the major education reform taking place in North America and needs significant research attention.

Does collaboration fit into the present school system? Researchers have investigated the benefits of cooperative learning; many teachers are utilizing cooperative learning methods in their classrooms; and curriculum development is headed towards incorporating more group-based interaction.

Many researchers, primarily psychologists, educational researchers, and teachers, have studied issues in cooperative learning. The focus has been on how to design tasks and compose groups to achieve the largest benefit from cooperative learning. Simpson [18] suggests that computers can be used effectively for collaborative work if there is a constant search for new ways to use hardware and software. Apart from mere suggestions, issues related to the design of computers and their interfaces to facilitate collaborative learning have yet to be explored in the context of the traditional classroom. Thus now is the time to explore computer-based issues in education.

The research described in this paper investigates cooperative interactions in an educational computer game environment. Achievement in the game, verbal interactions, sharing of the mouse, attitudes towards cooperative play and motivation were examined. Possible gender differences for each of these areas were also examined. This study is one part of a large-scale project on Electronic Games for Education in Math and Science (E-GEMS). E-GEMS is a collaborative effort among scientists, mathematicians, educators, professional game developers, classroom teachers and children. The goal is to increase the proportion of children who enjoy learning and exploring mathematical and scientific concepts through the use of electronic games. Electronic games in this context include both video and computer games; we will use the term *electronic game* to mean either.

Electronic games were employed in this study because of the cooperative play they promote. Children playing electronic games are often highly motivated to improve their skills and solve problems throughout the game. Children frequently exhibit collaborative behavior while playing. Another motivation is discussed by Papert [17],who observed that electronic games can be a gateway for children to enter the world of computers. Computers have the capability of "empowering children to test out ideas about working within prefixed rules and structures in a way few other toys are capable of doing" [17, p.4].

Malone and Lepper [16] have created a taxonomy of intrinsic motivations for learning that includes individual motivations (challenge, curiosity, control and fantasy) and interpersonal motivations (cooperation, competition, and recognition). All of these factors are found in electronic games. This view is supported by Long and Long. "Video games clearly possess powerful learning components. Studies indicate that the games are based on the same principles--challenge, fantasy, and curiosity--that motivate learning" [14, p.36].

Electronic games may also promote group interactions and cooperation. Observations from a previous study by the E-GEMS team at an interactive science museum (Science World BC) showed many examples of positive group interactions [7,13]. In that study, groups of children often spontaneously collaborated on the computer games, discussing various suggestions and solutions. Cooperative play was also observed on the video game platforms. Children playing *Mario World*, although playing individual characters, would work as a team to create a path to the final level. Children could be seen passing the game controllers back and forth amongst themselves, each child performing tasks in which she or he excelled.

PREVIOUS WORK ON COOPERATIVE LEARNING

Since the 1970's a great deal of research has been performed on various facets of cooperative learning. This research covers a wide range of cooperative issues including cognitive and social outcomes, reward structures, group composition, lesson control, and gender differences [2, 4-6, 8-10, 15, 18-20, 22-26].

Studies on the cognitive benefits of cooperative learning have been performed in a large number of varied settings. The results of this research often show a positive increase in student achievement as a result of cooperative learning [4, 5, 10, 11, 21, 25], although some studies show no significant variations on achievement [2, 20]. Slavin suggests that the discrepancy between these findings resulted from "particular techniques, settings, measures, experimental designs, or other characteristics" [19, p.333]. Although studies of the cognitive benefits of cooperative learning vary in some respects, some conclusions may still be drawn. In reviewing these studies Slavin [21] observesthat cooperative learning methods can increase student achievement under specific conditions, namely having group goals as well as having each group member contribute to the group score on an individual basis. He concludes that, in general, "for academic achievement, cooperative learning techniques are no worse than traditional techniques and in most cases they are significantly better" [20].

Social benefits of cooperative learning are more clearly demonstrated in the research literature. Cooperative learning has been shown to positively affect students' self-esteem and attitudes towards school and classmates [8, 9, 18, 19]. These outcomes are very important for the development of children and they alone are a good argument for cooperative learning even if cognitive improvements are not observed. It has been suggested that an increase in students' moods and attitudes will in turn increase motivation for academic achievement [9, 15, 20].

Curriculum development in many subject areas strongly recommends increasing the number of cooperative group learning situations. For example, the curriculum and assessment standards for school mathematics, prepared by the National Council of Teachers of Mathematics [3], emphasizes the importance of group work for children in grades five to eight.

> Working in small groups provides students with opportunities to talk about ideas and listen to their peers, enables teachers to interact more closely with students, takes positive advantage of social characteristics of the middle school student, and provides opportunities for students to exchange ideas and hence develops their ability to communicate and reason [3, p.87].

In addition, there is also a movement from instructional teaching to project-based learning where "students are active problem-solvers and theorists" [12 p.57].

The purpose of our study was to examine childrens' achievement, behavior and attitudes towards cooperative play in an educational computer game. We used a commercial game, *The Incredible Machine*, running on a personal computer, similar to those found in schools. The study resembled previous research in that the gender pairings of Male/Male, Female/Female and Female/Male were used both in a cooperative setting and with students playing alone. An added variation included a further division of the parallel setting into two distinct conditions, playing together on one computer and playing in parallelon two computers.

METHOD

Subjects

Subjects for this research project consisted of 52 boys and 52 girls from grades four to six in a public school located in an upper-middle-class neighborhood. None of the subjects had played the computer game *The Incredible Machine* before. Students were arbitrarily placed into one of three experimental conditions and, for two of the conditions, randomly assigned a partner corresponding to a particular sex-dyad.

Setting

The experiments took place at a school in Vancouver, British Columbia, Canada, during a two-week period in January, 1994. A room was provided by the school and equipped by the researchers with either one or two IBM-compatible computers each equipped with a mouse, depending on the experimental condition. The experiment consisted of two phases. In the first phase a single child or pair of children were asked to play *The Incredible Machine*. At the beginning of the first phase, the chairs to be used by children in the study were located away from the computer table to ensure that the final placement of chairs within the setting was at the discretion of the children. The room contained a camcorder and a VCR equipped with a VGA to Video converter box to record the children's interactions. The camcorder captured the

children's physical and verbal movements while the VCR was used to record the screen output to create an archived copy of the children's achievement within the game.
The second phase of the research took place in a separate section of the room. There children were given a snack, participated in discussion, and filled out a questionnaire.

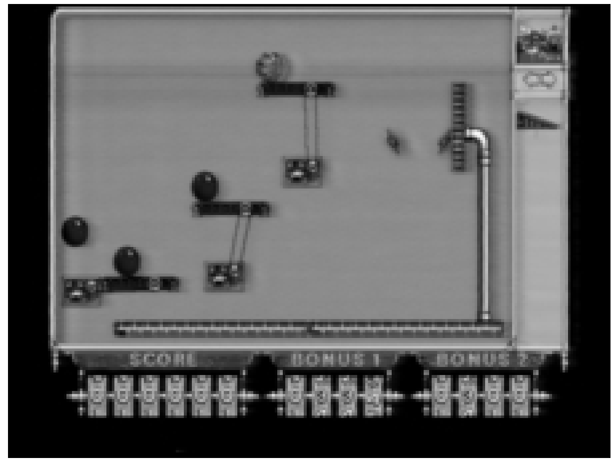
Software

The game chosen for the experiment was *The Incredible Machine* created by Sierra. It runs on an IBM-compatible computer. *The Incredible Machine* is a puzzle-solving game featuring a wide variety of simulated tools used to construct machines to solve particular challenges. Typical challenges include building a machine to shoot a basketball into a hoop and trapping Mort the Mouse in his cage. The tools within the game consist of those used in everyday life (such as gears, pulleys, ropes, ramps and levers) along with a host of characters and entertaining objects (such as cats, mice, balloons, various types of balls, scissors, and trampolines).

Figure 2.
The Incredible Machine Playing Screen

In order to start solving puzzles in *The Incredible Machine*, a puzzle is selected through the control panel and the puzzle screen appears. This screen contains three main areas, the playing area, a parts bin, and a start machine icon. Figure 2 shows these three areas for the first puzzle. In order to solve the puzzles, pieces must be selected from the parts bin and placed onto the playing area. Some pieces such as ropes or elastics must be attached to fixed objects (i.e. conveyor belts, motors, balloons). To run the machine, the start machine icon isclicked on with the mouse. To stop the machine, the mouse is pressed anywhere on the puzzle screen. This process of placing pieces and starting the machine can be repeated until the correct solution is found. When the machine performs the appropriate action, a window will appear on the screen stating that the puzzle was solved. The completed machine for the first puzzle is shown in Figure 3. It is important to note that for many of the puzzles, there exist more than one correct solution.

Figure 3.
Solution to Puzzle Number 1



Procedure

The total length of each session within the study was forty minutes. In each session the children were asked to play *The Incredible Machine* using the computers that were supplied. On entry to the room, the children were welcomed and given a brief introduction to the project and the environment. Next, the children were requested to try to complete at least three puzzles within the game and told that they were allowed to play for as long as they desired up to a maximum of thirty minutes. The children were given no directions on how to play to game. They were asked to try to work out any problems amongst themselves. The game manual was placed on the table beside the computer and the children were told that it contained information about the game and that they could look at it if they wished. They were also told that when they finished playing, they could come into the other section of the room for a snack. The snack consisted of healthy foods (raisins, cheese and crackers, granola bars, etc.) and a drink of either milk or juice. Once in the snack room, the children completed a questionnaire and engaged in casual discussion until their forty minutes of research time was completed. Following this, the children returned to their classes.

Independent Variables

The independent variables in this experiment were cooperative conditions and gender groupings of the children. The cooperative conditions included three physical set-ups using either one or two computers and varying in the amount of interaction implicitly encouraged between the students. The first condition, Solo Play, consisted of one student playing the game on her or his own. The second condition, Parallel Play, consisted of the use of two computers by a pair of children. Here the children had the choice of using one or both computers as they desired. The third scenario, Integrated Play, consisted of two children playing the game using only one computer and one mouse.

Within the Solo Play condition, equal numbers of girls and boys (eight girls and eight boys) were studied. For theremaining two conditions, both involving group play, the children were placed into one of three gender pairings: (a) Male/Male, (b) Female/Female, and (c) Female/Male. There were eight Male/Male dyads, eight Female/Female dyads and six Female/Male dyads for a total of forty-four cooperative dyads in addition to the sixteen solo participants.

Dependent Variables

The dependent measures for this study were grouped into four classes: achievement in the game, sharing of the mouse during Integrated Play, motivation to play, and attitude towards cooperative play on electronic games.

Achievement in the game was measured by determining the total number of puzzles completed by each student.

Sharing of the mouse was measured by counting the number of requests for the mouse, actual exchanges of the mouse, and the number of refusals to hand over the mouse. The nature of the requests and exchanges was also recorded. These included verbal interaction, physical movement without touching the mouse or the other person (such as reaching), and physical touching of the mouse or the other person.

Motivation was measured by the length of time each group played the computer game. In addition, the children were asked whether or not they would have liked to continue playing or participate at another time, outside of school. Children's attitudes towards cooperative play were measured in the questionnaire. Qualitative observations were also gathered concerning the cooperative play of the children and group dynamics, including issues such as whether one child in the dyad dominated the game.

Analyses

This study employed both group-based and individual measurements. The factors of achievement and mouse-sharing were analyzed as group-based while the motivational and attitude measurements were analyzed individually. For the achievement factor a 3x2x2 randomized factorial design was used, with three levels of groupings (solo, homogeneous gender pair, heterogeneous gender pair), two levels of gender (female, male) and two levels of equipment (one computer, two computers). The dependent measure was the total number of puzzles completed by each student. For the Integrated Play conditions, each student was assigned a value according to the number of puzzles the pair completed. In the Parallel Play condition, each child was assigned a value according to the number of puzzles she or he completed. The values for any pair in the Parallel Play condition that chose to play on one computer were calculated as if they had been Integrated Play scores.

Mouse sharing was studied using a randomized design with three levels of gender pairings (Male/Male, Female/Female, Female/Male). The number of mouse exchanges, requests and refusals to exchange the mouse were used as the dependent measures.

RESULTS

Achievement

The numbers of puzzles completed during each experimental condition are reported in Table 1a and the statistical analysis in Table 1b. Considering any one of

Table 1a.
Mean Number of Puzzles Completed

		Solo	Integrated Homogeneous Pairing	Integrated Homogeneous Pairing	Parallel Homogeneous Pairing	Parallel Heterogeneous Pairing
Male	Mean	1.75	2.40	2.14	2.50	1.80
	SD	2.05	2.00	2.23	1.55	1.94
	n	8	20	7	12	5
Female	Mean	1.88	2.20	2.14	0.42	1.00
	SD	1.54	1.83	2.23	0.76	2.00
	n	8	20	7	12	5

Table 1b.
3x2x2 ANOVA table results for number of puzzles completed

Source	SS	df	MS	F	p
Total	387.3846	103	----	----	----
Grouping	0.6294	2	0.3147	0.0836	n.s.
Equipment	11.7308	1	11.7038	3.1155	<.1
Gender	9.8462	1	9.8462	2.6150	n.s.
Grouping x Equipment	2.1143	2	1.0571	0.2808	n.s.
Grouping x Gender	4.0236	2	2.0118	0.5343	n.s.
Gender x Equipment	15.0177	1	15.0177	3.9885	<.05
Grouping x Equipment x Gender	-2.3833	4	-1.1917	-0.3165	n.s.
Error	346.4060	92	3.7653	----	----

Note: n.s. means no statistical significance found

the three independent factors, grouping (individual, homogeneous gender pairing, and heterogeneous gender pairing), gender, and equipment (one computer, two computers), none showed a strong effect on the achievement results, although the equipment factor did show a small effect, $F(1,103) = 3.12$, $p<0.1$. The interaction between gender and equipment showed a significant difference, $F(1,103) = 3.99$, $p<.05$.

The follow-up analysis in Table 2 indicates that females playing on two computers in the Parallel Play condition solved significantly less puzzles than females playing on one computer in the Integrated Play condition, 0.59 and 2.19, respectively ($t(49)=1.60$, $p<.05$). No significant difference was found between the achievement of females playing in the Solo Play condition and those playing in the Integrated Play condition.

Males in the Parallel Play condition significantly outperformed the females in that condition, with means of 2.29 and 0.59, respectively ($t(31)=2.29$, $p<.001$), as shown in Table 3. No significant differences were found for males under the various experimental conditions.

Table 2.
Achievement of Females by Condition

	Solo	Integrated	Parallel
Puzzles Completed	15	59	10
n	8	27	17
Mean	1.88	2.19	0.59*
SD	1.64	1.98	1.33

*p <.05

No significant difference was detected for either females or males in the mean achievement score for homogeneous gender pairs versus heterogeneous gender pairs on either the Integrated Play or Parallel Play conditions. No significant difference was found between achievement scores for students in the Solo Play condition and those in the Integrated Play condition, for either gender.

Table 3.
Achievement for Parallel Play by Gender

	Female	Male
Puzzles Completed	10	39
n	17	17
Mean	0.59*	2.29
SD	1.33	1.76

*p <.05

Mouse Sharing

Gender differences with respect to sharing of the mouse were observed between all three gender pairings during Integrated Play. These results are reported in Table 4. Male/Male pairs tended to have more exchanges of the mouse as well as more refusals to give up the mouse than any of the other combinations. The high standard deviation for the Male/Male pairs in Requests and Refusals was because three of the pairs had 16 or fewer requests and no refusals compared to three pairs having between 25 and 57 requests and 15 to 37 refusals.

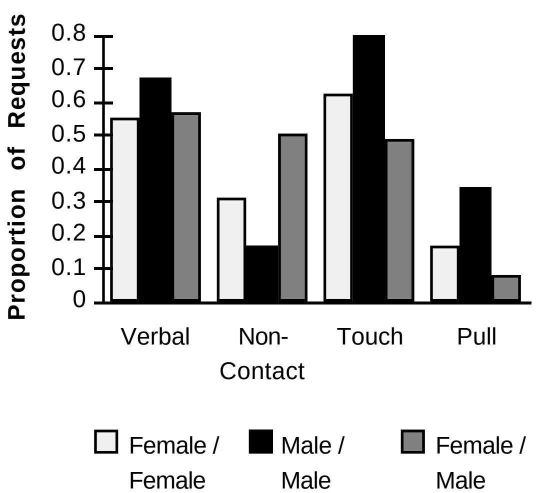
The results from the Female/Male pairs were divided. Three of the six pairs had a small number of exchanges, requests and refusals while the other three pairs had relatively large counts.

Figure 4 shows the distribution of requests for each gender pair. Verbal includes all requests that used verbal cues alone or verbal cues in conjunction with another form of request. Non-contact requests include reaching for the mouse or bringing the hand close to the mouse but not actually touching the mouse or the other child. Touch includes all types of requests that involve physical touching of the mouse or the partner. Pull requests consist of occurrences where one partner tries to actually pull the mouse away from the other partner.

Table 4.
Mouse Sharing for Integrated Pairs

		Exchanges	Requests	Refusals
Female/Female	Mean	18.00	15.63	4.88
	SD	6.00	7.95	4.40
	n	8	8	8
Male/Male	Mean	21.38	27.38	11.63
	SD	5.24	15.82	12.82
	n	8	8	8
Female/Male	Mean	21.00	23.83	6.00
	SD	15.97	22.10	8.82
	n	6	6	6

Figure 4.
Distribution of Mouse Requests



Both genders used touch as the dominant form for requesting control of the mouse, but Male/Male pairs had a higher percentage of Verbal requests as well as more occurrences of pulling the mouse away from their partner. Conversely, Female/Male pairs had the highest percentage of Non-contact requests and the lowest percentage of Touch requests.

Motivation & Attitude Towards Cooperative Play

The childrens' motivation to play *The Incredible Machine* was high, independent of gender or experimental condition. 99 of the 104 children played for the full thirty minutes while 101 stated that they would have liked to continue playing. Only two of the children who finished early stated that they did not wish to continue playing while the other three said that they would. One child who played the full thirty minutes was undecided as to whether or not she would like to continue playing. All five children who either left early or stated that they did not wish to continue were females.

Questions concerning attitudes towards cooperative play on electronic games were asked in the questionnaire. From this we concluded that between 48.7% and 64.8% of the children in our study prefer to play electronic games with friends while between 4.1% and 13.2% of the children prefer playing alone. Between 49.7% and 65.7% of the children prefer to play electronic games with a member of the same sex. All of these conclusions were made with 90% confidence. No significant differences were found between the responses of females and males.

DISCUSSION

The poor performance of Female/Female dyads playing under the parallel Play condition is particularly interesting, especially considering the near-term possibility of having one computer per child in schools. Females in the Parallel Play condition seemed to vocalize their ideas less than during Integrated Play. On some occasions, these girls would express phrases like “don't copy mine” or “don't look”. On other occasions they would remain very quiet, not requesting or offering any help at all.

Although no statistically significant difference was found for females across the other two conditions, possibly due to the small sample size, the trends we did find should not be ignored. Females in the Integrated Play condition (mean=2.19) outperformed females in the Solo condition (mean=1.88). This could be attributed to the increased communication and vocalization of ideas in the Integrated Play condition.

A difference was also noted between the means of females in the Solo Play condition (mean=1.88) and the Parallel Play condition (mean=0.59). This is a more difficult discrepancy to account for. One observation that mayhelp to answer this problem is that females in the Solo Play condition remained more focussed on the task. In contrast, females in the Parallel Play condition tended to get off-task more easily, jumping around from puzzle to puzzle or playing in the freeform mode. This is illustrated by the comment that one girl made to her partner: “Get the elastic band and you can draw”. This led to a five to ten minute discussion of drawing. Why this tendency to get off-task did not occur in the Integrated Play condition is an issue that needs to be investigated further. One explanation is that when working on one computer, the girls viewed the goal as a group goal and peer norms came into affect. When playing on two computers, the goals were perceived as primarily individual goals.

Figure 5.
Child's loss of interest when not in control of the mouse

Figure 6
Two girls struggling over the mouse

Males also showed trends in performance, although no statistically significant differences were found. Boys in this study performed best in the pair-oriented conditions, Parallel Play (mean=2.29) and Integrated Play (mean=2.33), while performance was lower for the Solo Play condition (mean=1.75). The lack of difference between the Parallel Play and Integrated Play conditions, unlike what was seen in the females, could be due to the more competitive behavior observed in the boys. Boys could be heard making comments such as "yeah, we did it! *That was the level John couldn't get by*", or asking who had solved the most puzzles. This competitive behavior was also exhibited during Integrated Play, causing sharing of the mouse to be a struggle at times. The lower achievement in the Solo Play condition could be due to lack of opportunity to cooperate, share or express ideas.

Dominant children playing in the Integrated Play condition sometimes lost interest when they did not possess control of the mouse. Although they focussed on the screen during their turns, when their partner had control of the mouse they would look around, draw pictures, fidget or slump back in their chairs (Figure 5). This behavior was observed in both genders. The small sample size did not provide enough evidence to investigate this idea, but this is an important area for future study.

CONCLUSIONS

This study provides a basis for several directions of future research. Although much has been done in the area of computer-supported cooperative learning, further examination of the effect of technology is needed.

Current research emphasizes the effects of the teacher through the structuring of cooperative tasks and group compositions, using existing technology. It is important to investigate whether some of the benefits of cooperative learning may be enhanced by changes in the computer hardware, the software, or the choice of user interfaces. Especially intriguing is the opportunity to adapt CSCW inspired multi-person interfaces to educational software.

Students in this study preferred to work with friends, but in an environment with limited resources, sharing the input device was problematic at times, especially with boys or dominant children. Figure 6 shows two girls struggling for control over the mouse. This suggests the need for further research in multi-input systems and other shared-screen issues. A system that allows children to work together as well as maintaining the ability for individual exploration may be an important advance in cooperative learning with computers.

The results of this study suggest that grouping children around one computer does not negatively affect performance and in the case of Female/Female groupings, it can have a positive effect. This, combined with the extensively researched social benefits of cooperative learning, suggests a need to continue research and development in this direction.

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