Supporting Learners in a Remote CSCL Environment: The Importance of Task and Communication

David Graves, Maria Klawe

Dept. of Computer Science, University of British Columbia

Abstract

This paper describes novel research in the area of remote Computer-Supported Collaborative Learning (CSCL). A multi-media activity (*Builder*) was designed to allow a pair of players to build a house together, each working from their own computer. Features of the activity include: interactive graphical interface, two- and three-dimensional views, sound feedback, and real-time written and spoken communication. Mathematical concepts, including area, perimeter, volume, and tiling of surfaces, are embedded in the task. A field study with 134 elementary school children was undertaken to assess the learning and collaborative potential of the activity. Specifically the study addressed how different modes of communication and different task directives affected learning, interpersonal attitudes, and the perceived value and enjoyment of the task. It was found that playing led to academic gains in the target math areas, and that the nature of how the task was specified significantly impacted the size of the gains. The mode of communication was found to affect attitudes towards the game and the player's partner. Gender differences were found in attitude to game, communication and partner.

Keywords— remote CSCL, distance education, electronic games, multi-player games, cooperative learning, gender

INTRODUCTION

Motivation

Much of the promise and excitement of CSCL rests with the fact that it combines Cooperative Learning with Computer-Assisted Learning (CAL). Cooperative Learning studies have shown positive results both in achievement (task-related learning) [JMJN81] and socio-motivational outcomes [Slav80]. Combining this successful teaching strategy with CAL may be advantageous for the following reasons. Firstly, there are the benefits of CAL itself. It allows flexibility in terms of level of difficulty so that students can proceed at their own pace, and can be useful for visualization and as an easily-manipulated handler of information. CAL can also be intrinsically motivating, particularly in the form of games, and even more so for multi-player games [S91, IUK+94]. Secondly, as [JJS86] have proposed, CSCL provides a potential solution to the drawbacks of CAL. One weakness of CAL is that it may result in less interaction with teachers and classmates and hence not allow for sufficient social modelling or building of social skills and healthy social attitudes. Finally, and of particular relevance for the current study, CSCL provides the potential for remote collaboration. Several investigations into CSCL have looked at co-present collaboration, often with groups working together at one computer. In this study we investigate the potential and limits of remote collaboration. Although co-present collaboration may have several advantages over remote collaboration, there is an increasing interest in and need for support of remote collaboration, as seen, for example, in distance education [GS97, H86]. Current distance education systems, such as WWW-based projects like WebCT [GS97], use computers effectively in the presentation and distribution of learning materials, but there has been little investigation to date on the use of computers to support collaboration in such settings.

Research Focus

The issues addressed in the present study can be summed up in two broad questions:

- Can the positive outcomes of Cooperative Learning be achieved in a remote CSCL environment?

- How can we best facilitate collaboration within the remote CSCL environment?

The experimental design is focussed primarily on the latter question, with between-group comparisons across elements manipulated within the activity. Although the prior question is partially addressed by a comparison between all groups that used the activity and a no-instruction control group, the fact that there was no comparison with other learning techniques precludes any definitive conclusions on remote CSCL as a teaching method. This is appropriate because we are interested in understanding the elements that effect learning given the constraints of a remote setting. Such an approach is useful in the generation of guidelines for software design in distance education projects.

Variables investigated

Within the remote CSCL context, the first area investigated was that of the interaction between the learners. The communication between co-learners is thought to be the key to many of the gains seen in Cooperative Learning: "Increased verbalization forces cognitive restructuring and reprocessing of information, as well as rehearsal and practice of relevant information and skills" [HKM92, p. 258]. Researchers have argued that for true Cooperative Learning to occur, face-to-face interaction is necessary [HZD94]. In CSCW applications we have seen increasing investigation of simulated face-to-face communication [IM91], but much research remains to be done on what type of communication is necessary or ideal in the context of educational environments for children. Our study investigated how adding a level of spoken communication and virtual presence to written communication influenced the outcomes.

The second aspect addressed was the nature of the task. Cooperative Learning studies have looked at the influence of content [DHH89], nature of instructions [HZD93] and structure of task [C94] on learning and other outcomes. All these questions need to be revisited within the domain of CSCL, and thus our study manipulated task as well as communication to consider which had the most effect on each of the measured outcomes of collaboration. Some subjects were given a very specific goal, such that they would know immediately when they had reached it, while others were given a general goal which was partly open to their interpretation (further details are given below).

Finally, many researchers have addressed how the characteristics of the learner influence the outcomes of Cooperative Learning [e.g. W82b, JJSR85]. One much-researched characteristic is gender, which is particularly relevant in the fields of CAL and CSCL due to the apparent gender differences in interest in, and mastery of, computer applications [P92, IUK+94, B94, P94]. Therefore in the current study, gender differences were considered by comparing results between same-sex pairs in the data analysis.

Outcomes measured

Two tools for assessing outcomes were developed for the *Builder* study. Firstly, following a typical model used in the Cooperative Learning literature, a pair of academic tests on the target mathematical areas were developed, in consultation with math teachers and standardized tests, for use in a pre-post comparison. The ten items of the two tests consisted of rote-style questions calculating area, surface area and volume; task-related questions about bricks and windows in walls; and application questions. They assessed ability in the following areas:

- the relationship between perimeter and area;

- additive and subtractive areas and volumes; and

- tiling of surfaces.

On the basis of pilot studies, items in the pre- and post-tests were adjusted in an attempt to balance the difficulty level. Items on the two tests were symmetrical, differing only in the numbers used and the scenarios given in the word problems.

Secondly, a questionnaire consisting of 20 5-point Likert-style items was developed to assess the following socio-motivational outcomes of playing the activity:

- attitude towards the game;

- attitude towards partner;

- desire to continue playing (a measure of motivation); and

- attitude towards communication and collaboration in the game.

The formal outcome measures were supplemented by log files recording players' success and

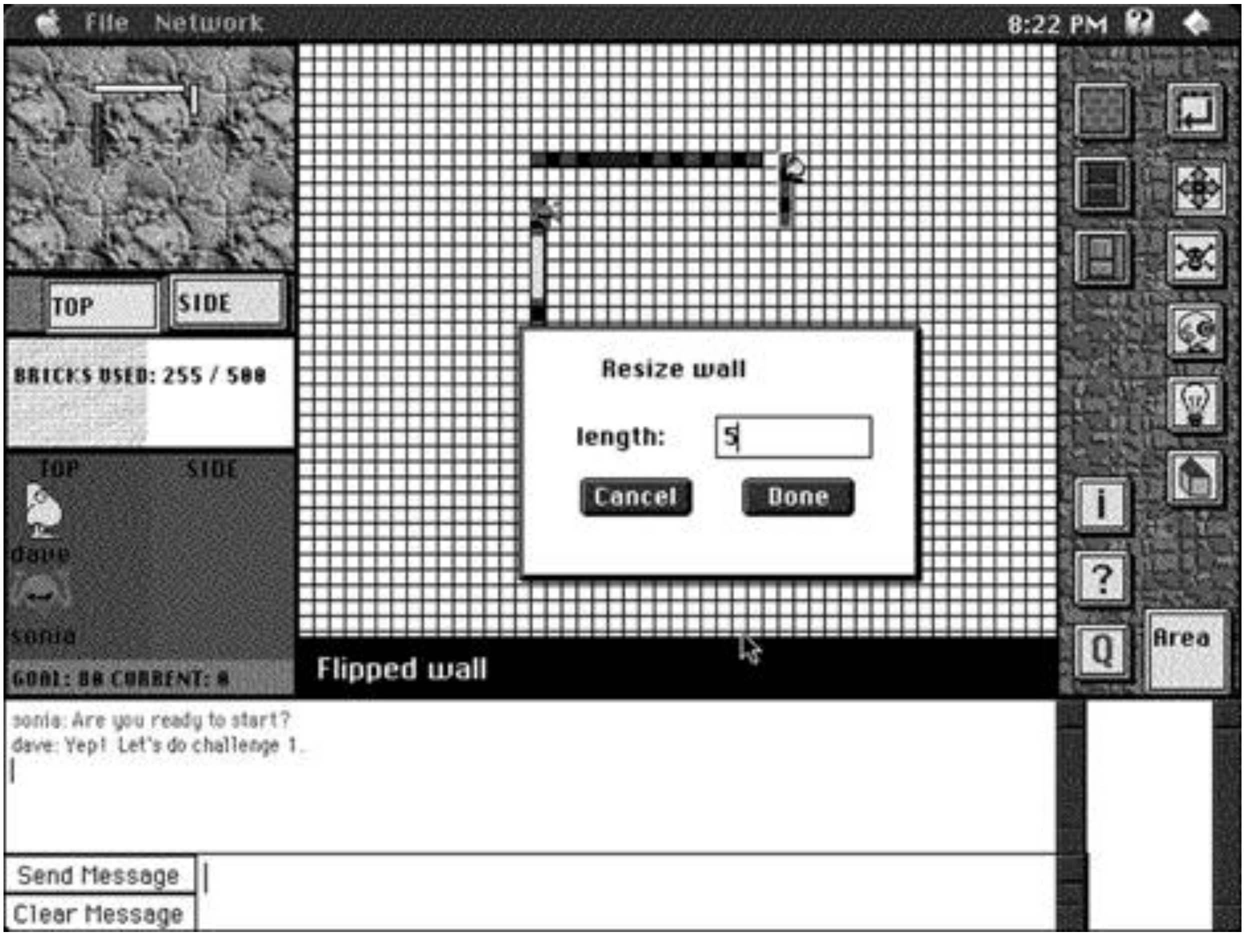

Figure 1: Screenshot from Builder showing the dialog box to resize a wall in top-view

communication in the game, and the anecdotal observations of the researchers. The short paper context, however, precludes an exhaustive presentation of these additional data.

BUILDER

Overview

Work on the CSCL activity *Builder* has been done within the context of the E-GEMS (Electronic Games for Education in Maths and Science) group at the University of British Columbia. E-GEMS is a collaborative effort involving computer scientists, mathematicians, educators, professional game developers, classroom teachers and children, aimed at motivating children to learn and explore mathematical and scientific concepts with the aid of computer games. Among E-GEMS' current projects is the multi-player game *Island*, in which the *Builder* activity is set. *Island* is a graphical, educational Multi-User Dungeon (MUD) in which players solve mathematical puzzles to collect materials to build houses on the island.

Implementation Details

Island was created for the Macintosh platform in the programming language C++ using a client-server model. It runs over an AppleTalk network, using the NetSprocket library and OpenTransport. The 3-D renderer within the *Builder* activity uses Macintosh's QuickDraw3D library. Two forms of communication have been implemented: written and spoken. Written messages require typing in a Send-Message box at the bottom of the game window, and then clicking on the “Send Message” button (see Figure 1). All messages, including one's own, appear in a scrollable Receive-Message box also at the bottom of the game window. Spoken messages require the user to hold down the “Control” key while speaking into the microphone. Sound compression allows speech to be transmitted with minimal delay.

For research purposes, two modes of communication within *Builder* are defined. The *basic communication mode* (BCM) allows only written communciation. The *enhanced communication mode*

(ECM) allows both written and spoken communication as well as the element of "virtual presence". The term, virtual presence, refers to the simulated presence of other participants in shared virtual spaces, and has been a focus of several CSCW applications [e.g. IM91]. There has been relatively little research on virtual presence in CSCL applications. In *Builder* virtual presence is implemented in two ways. Firstly, within the 2-D building environment a small icon representing the player appears on top of the wall s/he is working on (see Figure 1). Secondly, when both players are exploring the 3-D model of the house they have constructed, each of them can see the other's icon moving around. Due to constraints on time and subjects, we were not able to examine the effects of speech and virtual presence separately. The relative lack of previous research, however, makes a coarse-grain comparison such as this an excellent starting point upon which to base more refined future investigations.

The Task

In the target age group (grades 5-9), the mathematics syllabus includes the concepts of perimeter, area and volume, as well as tiling of surfaces, all of which are present in the *Builder* activity. The learning target is that conceptual understanding will be improved in the following areas: additive and subtractive areas and volumes; tiling of surfaces; and the relationship between perimeter and area, for example the fact that a square provides a more optimal (in terms of achieved area) use of perimeter than does a rectangle.

Builder allows two players to design a house using various 2-D layouts and view it in 3-D. In the 2-D design phase players can switch between top-view and side-view, creating and manipulating walls, windows and doors. The size of the house they can build is constrained by their available resources. In each challenge players are given a limited supply of bricks for making walls, and frame pieces for making windows and doors. Inserting windows and doors in the walls frees underlying bricks according to the surface area covered by the window or door, which in turn is set by the horizontal and vertical frame pieces they choose. Players are further constrained by a maximum allowable floor-area per room so that they cannot simply build one big room. Players choose from 5 possible challenges at the start of play. The first 3 challenges record house size in area; the latter 2 in volume. Players can check the current area or volume at any time by clicking a button, which results in graphical and numeric feedback.

After choosing which challenge they want to do, a "Challenge Info" screen is presented which explains the goal of the challenge and the available resources. *Builder* can be played in either of two task modes: *specific goal mode* (SGM) or *maximize goal mode* (MGM). In SGM, players are given a numeric target which they have to reach exactly. For example, the first challenge asks players to build a house with a floor-area (not including the width of the walls) of 80 square units. If this is achieved, players will hear the message "You got it!" when they click on the "AREA" button. In MGM, players are asked to build the biggest possible house given the materials available. In every other way the two modes are identical. Players in MGM are given an indication of expected performance by the high score records on the introductory screen, but deciding when the house is sufficiently large is left entirely up to them. Both players must decide to exit a given challenge before the next one can be started.

STUDY DESIGN AND METHODOLOGY

Design

The experiment was a 2x2x2 factorial design, with the following independent variables.

- **Communication** (COMM) – Basic Communication Mode (BCM) vs. Enhanced Communication Mode (ECM).
- **Nature of task** (GOAL) – Specific Goal Mode (SGM) vs. Maximize Goal Mode (MGM).
- **Gender** (SEX) – male-male dyads vs. female-female dyads.

The dependent variables were:

- **Academic improvement** – post-test score minus pre-test score.
- **Performance in game** – number of challenges completed and challenge scores.
- **Socio-motivational effects** – attitude to the activity, attitude to partner, persistence of interest in game, and perception of collaboration.

In addition to the eight groups defined by the 2x2x2 design, a no-instruction control group was used to provide a baseline for pre- and post-test comparisons, so that any differences seen in the experimental conditions could be judged relative to differences seen in the control group. It was hypothesized that those who played the game would show greater academic gain than the control group. Based on previous work in Cooperative Learning, it was hypothesized that the ECM group would show greater gain and more positive socio-motivational attitudes than the BCM group. For the nature of task hypothesis, the situation was less clear. Based on findings that unstructured tasks lead to more effective Cooperative Learning [C94], it might be expected that MGM players would improve more than SGM. However, a specific goal might make players focus more on the numbers involved, which could be particularly helpful in mathematics learning. Furthermore, clear goals and direct computer feedback have each been found to be motivating, both in electronic game research [M82], and in co-present CSCL [NC93]. Hence no clear hypothesis was made on the effect of nature of task.

Participants

134 children from two elementary schools in the Vancouver-Richmond area took part in the study. All participants were from grades 6 and 7 (10-12 years old). 100 students played the game, 48 girls and 52 boys. The other 34 students were in the control group and therefore did only the pre- and post-tests. To minimize the confound of sampling from 2 different populations it was ensured that half of the subjects for each of the cells were made up of students from either school.

Materials

The study was run using two Power Macintosh computers connected via AppleTalk running the game *Builder*. For academic and attitude assessment the study used the "pencil and paper" pre- and post-tests and 20-item attitude measure described above.

Procedure

During the week prior to the start of game-play, the pre-test was administered by the teacher of each of the participating classes during normal class-time. This was followed by a general orientation given in front of the whole class by the researcher, to put the research and game in context. When students came in pairs to play *Builder* they were given a 5-minute specific orientation in front of the computer. To emphasize the positive goal dependence and individual accountability necessary for Cooperative Learning [see HZD93], players were told that resources and scores within *Builder* were entirely shared, but that pre- and post-test scores were on a purely individual basis. The interface, task, scoring method and means of communicating were also explained. One of the students was then taken to a separate room, where the other computer was set up, and playing commenced. The duration of play was 30 minutes, after which players were given the questionnaire to complete. After all students from a class had played *Builder*, the post-test was administered in the same style as the pre-test.

RESULTS

Achievement Outcomes

Reliability of tests

The data analysis began with confirming the reliability of the tests. Firstly, to ensure that the pre-test assessed the same mathematical areas as the post-test, a Pearson Product moment correlation between the two scores was preformed for the control group (who had no between-test instruction). If there is not a strong relationship between the control group's scores on the two tests, it is likely that the tests are measuring different constructs and are therefore not comparable. The result of the correlation was significantly high to support the pre-post comparison ($r(29)=0.74, p<0.01$, *2-tailed*). Another concern is whether it is valid to look at total scores on the tests, rather than clusters of related items. To determine whether all the items of the tests "hung together", reliability analyses were performed on the 10 items of each test with the following results: *pre-test alpha coeffecient = 0.812 (n=134)*; *post-test alpha coefficient = 0.727 (n=131)*. An alpha of 0.6 or above is considered acceptably high for research purposes, hence it is appropriate to use total scores as the dependent variable. We will refer to the difference between the pre-test total and the post-test total (POST − PRE) as the "improvement" score.

Unit of analysis

In studies involving dyads, it is often unclear whether results should be analysed on an individual or dyad basis. For example, while improvement scores were obtained on an individual basis, the scores of two partners may be related due to the fact that they played together, in which case it is not statistically valid to analyse individual scores [GG95]. Accordingly, Pearson Product moment correlations were computed for improvement scores for *partner1* and *partner2* (with the dyad taken as a single case). The relationship was not significant ($r(43)=0.22$, *ns, 1-tailed*), hence the improvement score analysis was performed on an individual basis.

Game group vs. control group

To investigate whether playing the game, irrespective of communication or task mode, led to greater academic improvement compared to no instruction, an initial GAME(Play, Control) x SEX(M,F) *analysis of variance* (ANOVA) was performed. Results indicated a significant main effect for GAME (*F(1,126)=8.36, p<0.01*), with the game group (*M=1.22, SD=3.56*) showing greater improvement than the control group (*M=–1.23, SD=3.31*). Sex was included in the analysis to avoid averaging over an unseen gender difference. There was no hypothesis that gender would have an effect, nor was any effect found.

Within-game comparisons

Table 1 shows the means and standard deviations of improvement scores for each of the eight cells in the SEX(M,F) x GOAL(SGM,MGM) x COMM (BCM,ECM) design (now excluding the control group). Inspection of the means across each of the independent variables indicated higher scores for ECM (*M=1.58, SD=3.79*) than BCM (*M=0.84, SD=3.31*) and for males (*M= 1.32,SD=3.92*) than females (*M= 1.09,SD=3.15*), but only the GOAL main effect was significant (*F(1,92)=8.95, p<0.01*), with SGM (*M= 2.11,SD=3.45*) scoring higher than MGM (*M= 0.28,SD=3.47*). There were no significant interactions.

		SGM		**MGM**	
		BCM	**ECM**	**BCM**	**ECM**
Male	*M*	1.93	2.36	0.0	1.18
	SD	3.79	4.62	3.20	4.13
	N	14	11	14	14
Female	*M*	1.71	2.43	-0.6	0.23
	SD	2.52	3.03	3.19	3.33
	N	12	14	10	11
Total		2.11		0.28	

Table 1: Improvement across three independent variables

Game performance

Log files were maintained during game-play to record the number of challenges players completed, as well as their brick and area/volume scores. To briefly summarize the performance results, significant gender differences were found both in number of challenges completed and best challenge score attained, with males scoring higher than females on both measures.

Socio-Motivational Outcomes

The investigation of the questionnaire data began with a factor analysis on the 20 Likert-style items to suggest sensible groupings of items. A Principal Components Analysis produced six factors, with a Scree Plot suggesting that only the top three factors accounted for sufficient variance to be worth considering. Most of the items that loaded to a degree of 0.4 or higher into each of these factors appeared conceptually related, and the factor names and their associated items are given below. For Factor 1, however, which was loaded on mostly by items measuring attitude to collaboration, some items had to be omitted on conceptual grounds to make the factor interpretable. Therefore, to supplement the measure of perceived collaboration, one item (Q16: "I would prefer to have my partner in the same room") was considered separately. The "same room" question and each of the three factors were subjected to SEX(M,F) x GOAL(SGM,MGM) x COMM (BCM,ECM) ANOVAs, after initially addressing the unit of analysis issue for each measure.

Attitude to collaboration (Factor 1)

Factor 1 consisted of the questions: "I liked communicating with my partner", "Communicating with my partner was easy using the computer", "I would prefer to play alone"[reverse scored], "Communicating with my partner helped us play the game", and "I like playing computer games with a partner". The correlation revealed a significant relationship between partners on Factor 1 scores, so the dyad was used as the unit of analysis. There were no significant main effects in the ANOVA, but there was an interaction between SEX and COMM (*F(1,42)=4.64, p<0.05*). As the means in Table 2 suggest, a post-hoc analysis (Tukey) revealed that females were significantly more positive when in ECM than in BCM (*F(1,23)=4.36, p<0.05*), whereas the two conditions did not differ significantly for males.

		BCM	**ECM**
Male	*M*	4.33	4.15
	SD	0.57	0.46
	N(pairs)	13	12
Female	*M*	4.08	4.50
	SD	0.62	0.39
	N(pairs)	12	13

Table 2: Means for Factor 1 showing SEX*COMM interaction

Persistence of interest in game (Factor 2)

Factor 2 consisted of the questions: "I enjoyed playing *Builder*", "I would like to play *Builder* at home", "I wish I could have played *Builder* for longer", "Computer games like *Builder* should be used more in school", and "I would like to play *Builder* again". There was no significant correlation between partners for Factor 2 so the unit of analysis was the individual. The ANOVA revealed a significant main effect for SEX ($F(1,91)=4.00$, $p<0.05$), with males ($\underline{M}=4.43$, $SD=0.54$) scoring higher than females ($\underline{M}=4.17$, $SD=0.87$), and a GOAL*SEX interaction ($F(1,91)=5.22$, $p<0.05$). Post-hoc analyses (Tukey) revealed that males in SGM showed significantly greater persistence of interest than females in SGM ($F(1,46)=7.43$, $p<0.01$), but there was no parallel gender difference in MGM (see Table 3).

		SGM	**MGM**
Male	*M*	4.64	4.27
	SD	0.30	0.63
	N	23	26
Female	*M*	4.05	4.31
	SD	0.95	0.66
	N	26	24

Table 3: Means for Factor 2 showing SEX*GOAL interaction

Attitude to partner (Factor 3)

Factor 3 consisted of the questions: "If I play *Builder* again I would like to play with the same partner", "I would enjoy playing other games with the same partner", "My partner was friendly", and "My partner was helpful". There was a significant relationship between partners for Factor 3 so the unit of analysis was the dyad. The ANOVA again revealed a significant main effect for SEX ($F(1,42)=4.78$, $p<0.05$), with females ($\underline{M}=4.05$, $SD=0.46$) being more positive towards their partners than males ($\underline{M}=3.75$, $SD=0.97$). There was also a GOAL*COMM interaction ($F(1,42)=5.78$, $p<0.05$) for which none of the post-hoc tests were significant at the 0.05 level. The strongest comparison, however, approached significance ($F(1,23)=3.46$, $p=0.07$). This was the comparison between the two GOAL modes with COMM held constant at BCM. The interpretation of this comparison is that within BCM, MGM players were less positive about their partners than SGM players (see Table 4).

		SGM	**MGM**
BCM	*M*	4.18	3.63
	SD	0.46	0.90
	N(pairs)	12	13
ECM	*M*	3.85	4.14
	SD	0.58	0.60
	N(pairs)	12	13

Table 4: Means for Factor 3 showing COMM*GOAL interaction

"Same room" (Q16)

Individual scores were the unit of analysis for Q16 as their was no significant partner correlation. The ANOVA revealed a significant main effect for COMM ($F(1,92)=4.19$, $p<0.05$), with those in ECM ($\underline{M}= 3.96$, $SD=1.19$, $N=50$) scoring higher than those in BCM ($\underline{M}=3.38$, $SD=1.48$, $N=50$). The intent of this question was to ascertain how frustrated players became by not being able to communicate in person. It was reverse-scored because a high desire to have one's partner in the same room indicates a negative attitude towards the communication. Hence the results indicate that those in ECM felt less frustrated in their attempts to communicate than those in BCM.

DISCUSSION

Remote Collaborative Learning?

It was found that pairs playing the remote CSCL activity *Builder* showed significant improvement in the target mathematical areas, compared to students who received no instruction. Additionally, the results of the questionnaire showed that players had a positive attitude towards the learning activity, possibly as a result of its game-like nature. The most positively-answered items on the questionnaire were: "I enjoyed playing *Builder*" and "I would like to play *Builder* again" (each with a mean score of 4.55 on the 5-point scale). Although it is not clear whether academic and affective results were a result of the collaboration or the task itself, the fact that the learners were subjectively aware of collaborating is indicated by the third highest scoring item (with a mean of 4.46): "Communicating with my partner helped us play the game".

The above descriptive data and control-group comparison indicate an encouraging replication within a remote setting of the positive academic and social outcomes found in Cooperative Learning. As there was no comparison with other forms of learning, these results do not suggest preferential use of this style of learning. However, given that the goal in the design of educational games should be that of stimulating interest within and supporting a broader instructional environment [KP95], the current results are a promising step towards incorporating computer-supported collaboration into distance education.

The Role of the Task

The most important variable manipulated within the task, in terms of academic improvement, was the nature of the task. Specifically, players who were given a clear, numeric area or volume goal in the house-building activity showed greater academic improvement than players who were given the more open-ended goal of maximizing the area or volume. These results need to be explained, given the apparent conflict with the success of ill-structured tasks in Cooperative Learning [e.g. C94, JMJN81].

Differences between the two task modes that may be responsible for the results include: the fact that SGM has a clearer goal; the direct feedback in SGM; and the relative difficulty of performing optimally in MGM. Having a clear goal has been found to be the most important deciding factor in the popularity of games [M82], hence it may have been more engaging for learners. Immediate and simple computer feedback has also been found to be more motivating than less-tangible, self-regulated feedback in co-present CSCL [NC93].

More specific features of the current context may also explain the results. If MGM is a harder activity, some players may have failed to grasp the concepts, or at least had trouble doing so during the short playing time. There was support for this in anecdotal observations made by the researchers that more players in MGM appeared to be struggling or confused by the game. From observations of others who have played the game outside of the formal study, it would appear that for adults MGM is more challenging and interesting than SGM. The direct feedback of SGM may also be less important for older players ([NC93]'s study was also with elementary-level students). The age explanation is supported by a comparison with [BTR+95]'s multi-input CSCL study of high-school and college students using a simple activity with a clear goal. Collaboration had no significant learning effect, and many players in the college-student sample said that they would prefer to play alone. The type of activity used by [BTR+95] may work better with a population of younger learners, while tasks such as MGM in *Builder* may work better with older learners.

Finally, it may be that the task results are domain-dependent. In SGM there is a greater need for players to be focussed on the numbers, and this emphasis on detail may be particularly beneficial in mathematical learning. There is a need for further research to ascertain the effect of ill-structured goals in other domains (such as the languages and social sciences). To conclude, the results obtained indicate that within a short time period, the use of a CSCL activity with a specific goal can have a postitive effect on task-related learning in mathematics for young learners.

Supporting Interaction

Turning to the other variable manipulated in the study, the enhancement of communication with spoken messages and virtual presence did not increase academic gain. The enhanced communication did have an effect, however, on the socio-motivational outcomes. Responses to the "same room" question indicated that ECM significantly reduced the frustration of communicating remotely. Females in ECM were also more positive about the collaboration in general than those in BCM. Indication that the enhancements may be important in certain settings was found in the interaction between communication mode and task mode in the measure of attitude to partner. Players in MGM were less positive about their partners if they had only basic communication, suggesting there may be more of a need for enhanced communication within less-structured activities.

The interaction of the effects of task and communication in the attitude data is suggestive of the role different modes of communication play in different types of CSCL activities. Within a certain range of domains (e.g. mathematics) and learning activities (e.g. well-structured), written communication may be as effective as multiple channels of communication. On one hand we can see these results as positive indications for distance education projects that use simple forms of communication, such as email, bulletin boards or chat facilities. These styles might be quite sufficient for collaborative learning within certain domains and types of task.

On the other hand, these results suggest the need for further work in enhancing communication to support less-structured tasks. Furthermore, the attitudinal results suggest that to create a subjective environment of collaboration and positive regard for co-learners, enhancing communication with spoken communication and/or virtual presence may be benificial.

Gender Differences

While there were no significant gender differences on academic improvement, it was found that males completed more challenges and scored higher in the activity than females. Differences were also found in the attitudinal data. Males showed a greater persistence of interest in the game than females, suggesting that the activity was more motivating for males. This supported findings from previous studies that goal-focussed games with record scores were more interesting to boys than girls [OKD96]. The other potential effect, that the central role of communication might make the game more interesting to girls, appeared to be less strong. This gender difference in attitude to the game, however, was not uniform across modes of task. Males only showed more interest than girls when they were in *specific goal mode* (SGM), which provides further support for the influence of goals on males' interest in games. Other attitude measures discussed above also showed gender differences. Firstly, females were more positive about the communication when they had speech and virtual presence, while for males this did not affect their attitude. Secondly, in terms of the social measure of interpersonal affect, it was found that the game had a more positive influence on females than males.

A general way to summarize these findings would be to say that males responded well to having a specific goal, while females responded well to being able to speak to and/or see an image of their partner. There was anecdotal support for this in that more males were observed to be strongly focussed on the task than females. There was also anecdotal evidence of some females being more interested in communicating than in the task, and there were more observations of males communicating ineffectively than females.

Findings such as these gender differences can be used as guidelines in the design of learning activities like *Builder* to ensure the inclusion of elements that are effective for different types of learners.

Future Directions

The current results suggest guidelines for future research to further elucidate the important elements in a remote CSCL setting. One suggestion is to investigate whether the positive effect of a specific goal and the lack of effect of enhanced communication is replicable in different domains, with learners of different ages, and over longer periods of instruction. Two specific questions that have emerged in relation to learning are:

- Is there a set of learners, a domain, and/or a duration over which less-structured goals show greater academic gain in remote CSCL?
- Does enhancing communication within such a less-structured setting influence the size of the gain?

With respect to the gender results, the most important consideration is whether there is a real benefit in different styles of communication and task for different types of learners. One interesting approach to this would be to create an entirely user-configurable learning environment,such that users can choose both how structured their goal is and what type of communication channels they use. Such an open-ended investigation would help define the set of elements within remote CSCL that are valuable across the range of possible learners.

Acknowledgements

This work was supported in part by TeleLearning Network of Centres of Excellence, Project 4.4.

References

[C94] Cohen, E.G. (1994) Restructuring the classroom: Conditions for productive small groups. *Review of Educational Research, 64(1),* 1-35.

[BTR+95] Bricker, L.J., Tanimoto, S.L., Rothenberg, A.I., Hutama, D.C. & Wong, T.H (1995) Multiplayer activities that develop mathematical coordination. In *CSCL'95: First International Conference on Computer Support for Collaborative Learning,* 32-39.

[B94] Bulkeley, W.M. (1994) Gender affects how user sees the computer. In *Wall Street Journal*, Wednesday March 16, B1-B4.

[DHH89] Dalton, D.W., Hannfin, M.J & Hooper, S. (1989) Effects of individual and cooperative computer-assisted instruction on student performance and attitudes. *Educational Technology Research & Development, 37(2),* 15-24.

[GS97] Goldberg, M.W. & Salari, S. (1997) An update on WebCT (World-Wide-Web Course Tools) – a tool for the creation of sophisticated web-based learning environments. In *Proceedings of NAUWeb '97 - Current Practices in Web-Based Course Development*, June 12 - 15, 1997, Flagstaff, Arizona.

[GG95] Griffin, D. & Gonzalez, R. (1995) Correlational analysis of dyad-level data in the exchangeable case. *Psychological Bulletin, 118(3),* 430-439.

[HKM92] Hertz-Lazarowitz, R., Kirkus, V.B. & Miller, N. (1992) Implications of current research on cooperative interaction for classroom application. In R. Hertz-Lazarowitz & N. Miller (Eds.), *Interaction in cooperative groups: The theoretical anatomy of group learning*. New York, NY: Cambridge University Press.

[H86] Hiltz, S.R. (1986) The "virtual classroom": Using computer-mediated communication for university teaching. *J. of Communication, 36(2),* 95-104.

[HZD93] Hymel, S., Zinck, B. & Ditner, E. (1993) Cooperation versus competition in the classroom. *Exceptionality Education Canada, 3(1,2),* 103-128.

[IUK+94] Inkpen, K., Upitis, R., Klawe, M., Lawry, J., Anderson, A., Ndunda, M., Sedighian, K., Leroux, S. & Hsu, D. (1994) We have never forgetful flowers in our garden: Girls' responses to electronic games. *Journal of Computers in Math and Science Teaching, 13(4),* 383-403.

[IM91] Ishii, H., & Miyake, N. (1991) Toward an open shared workspace: Computer and video fusion approach of TeamWorkStation. *Communications of the ACM, 34(12),* 36-50.

[JJS86] Johnson, R.T., Johnson, D.W. & Stanne, M.B. (1986) Comparison of computer-assisted cooperative, competitive, and individualistic learning. *American Educational Research Journal, 23(3),* 382-392.

[JJSR85] Johnson, R.T., Johnson, D.W., Scott, L.E. & Ramolae, B.A (1985) Effects of single-sex and mixed-sex cooperative interaction on science achievement and attitudes and cross-handicap and cross-sex relationships. *J. of Research in Science Teaching, 22(3),* 207-220.

[JMJN81] Johnson, D.W., Maruyama, G., Johnson, R. & Nelson, D. (1981) Effects of cooperative, competitive, and individualistic goal structures on achievement: A meta-analysis. *Psychological Bulletin, 89(1),* 47-62.

[KP95] Klawe, M. & Phillips, E. (1995) Electronic games engage children as researchers. In *CSCL '95,* Bloomington, IN.

[M82] Malone, T.W. (1982) Heuristics for designing enjoyable user interfaces: Lessons from computer games. In *Human Factors in Computer Systems,* 63-68. Gaithersburg, MA.

[MIBK96] McGrenere, J., Inkpen, K., Booth, K. & Klawe, M. (1996) Experimental design: input device protocols and collaborative learning. Technical Report 96-11. University of British Columbia.

[NC93] Nastasi, B.K. & Clements, D.H. (1993) Motivational and social outcomes of cooperative computer educational environments. *J. of Computing in Childhood Education, 4(1),* 15-43.

[OKD96] Oosterholt, R. Kusano, M. & de Vries, G. (1996) Interaction design and human factors support in the development of a personal communicator for children. *CHI'96 Conference Proceedings,* Vancouver, Canada, April 13-18, 450-457.

[P94] Pereira, J. (1994) Video games help boys get a head start. In *Wall Street Journal*, Wednesday March 16, B1-B4.

[P92] Provenzo, E. (1992) The video generation. *The American Schoolboard Journal,* March, 29-32.

[Slav80] Slavin, R.E. (1980) Cooperative learning. *Review of Educational Research, 50(2),* 315-342.

[Slav90] Slavin, R.E. (1990) *Cooperative learning: theory, research and practice*. Englewood Cliffs, NJ: Prentice Hall.

[S91] Soloway, E. (1991) How the Nintendo generation learns. *Communications of the ACM, 34(9),* 23-26.

[W82a] Webb, N.M. (1982a) Group composition, group interaction and achievement in cooperative small groups. *J. of Educational Psychology, 74(4),* 475-484.

[W82b] Webb, N.M. (1982b) Peer interaction and learning in cooperative small groups. *J. of Educational Psychology, 74(5)*, 642-655.

Author's Address

David Graves: E-GEMS, Dept of Computer Science, University of British Columbia, 201-2366 Main Mall, Vancouver, BC, V6T 1Z4.

graves@cs.ubc.ca