Design:
Educational Electronic Multi-Player Games
A Literature Review

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Abstract

Over the past two decades electronic games have become ingrained in our culture. Children's fixation with these games initially alarmed parents and educators, but educational researchers soon questioned whether the motivation to play could be tapped and harnessed for educational purposes. A number of educational electronic games have been developed and their success has been mixed. The great majority of these games are designed for single players; if there is more than one player, the players are usually required to take turns playing. Although learning within a cooperative group setting has been found to be extremely effective, designing educational games to support multiple players working together has received little attention. Using a multi-player game format could provide the motivation that children need to learn and at the same time enhance both the achievement and the social interactions of the children. In order to design multi-player educational games we must understand what motivates children to play electronic games, how to incorporate educational content into electronic games, and how to develop appropriate multi-person educational tasks. An understanding of design issues for multi-user software is also required.

This essay is a literature review that addresses the issues involved in the design of educational electronic multi-player games. The relevant bodies of literature include human-computer interaction, electronic games, educational electronic games, electronic multi-player games, educational non-electronic multi-player games, educational software, and cooperative learning. Two of the most relevant areas of the human-computer interaction literature are Computer-Supported Cooperative Work (CSCW) and Computer-Supported Collaborative Learning (CSCL). All of the bodies of literature are discussed with respect to educational electronic multi-player games, areas where further research is required are noted, and general design guidelines for educational electronic multi-player games are offered.

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Table of Contents

1. INTRODUCTION **1**

2. HCI **6**

2.1 WHAT IS HCI? 6
2.2 HCI FOR CHILDREN 7
2.2.1 Novice vs. Experienced Users *7*
2.2.2 Child-Centered Design *9*
2.2.3 Applying HCI for children to Educational Electronic Game Design *10*

3. ELECTRONIC GAMES **11**

3.1 THE CULTURE OF ELECTRONIC GAMES 11
3.2 MOTIVATION: THE APPEAL OF ELECTRONIC GAMES 13
3.3 EDUCATIONAL ELECTRONIC GAMES 16
3.4 DESIGNING EDUCATIONAL ELECTRONIC GAMES 21

4. DESIGNING EDUCATIONAL SOFTWARE **23**

4.1 DESIGNING FOR USABILITY 23
4.2 QUESTIONING THE PHILOSOPHY OF EDUCATIONAL SOFTWARE 25
4.2.1 Computer Aided Instruction and Intelligent Tutoring Systems *26*
4.2.2 Interactive Learning Environments and Microworlds *26*
4.2.3 Designing Interactive Learning Environments and Microworlds *28*
4.3 APPLYING EDUCATIONAL DESIGN TO GAMES 30

5. COOPERATIVE LEARNING **30**

5.1 GENERAL COOPERATIVE LEARNING 30
5.2 COOPERATIVE LEARNING AND COMPUTERS 35
5.3 COMPUTER SUPPORTED COLLABORATIVE LEARNING (CSCL) 40
5.4 APPLYING COOPERATIVE LEARNING AND CSCL ISSUES TO MULTI-PLAYER GAMES 44

6. MULTI-USER INTERFACE DESIGN AND CSCW **45**

6.1 TERMINOLOGY 46
6.2 OVERVIEW OF CSCW 47
6.3 “BEING THERE” 48
6.4 EXAMPLES 49
6.4.1 GroupSketch (shared-task) *49*
6.4.2 MERMAID (shared-task and person) *50*
6.5 DESIGN CRITERIA 51
6.5.1 Shared-Task Space *52*
6.5.2 Shared-Task and Person Space *52*
6.6 AWARENESS 54
6.6.1 Informal Awareness *54*
6.6.2 Workspace Awareness *55*
6.7 ISSUES FOR SHARED WORKSPACES 56
6.7.1 Feedback *56*
6.7.2 Views *57*
6.7.3 Audio *58*
6.7.4 Video *59*
6.7.5 Colour *59*
6.7.6 Seamlessness *60*
6.7.7 States/Modes *61*

6.7.8 Coordination......61
6.7.9 Number of Participants......62
6.7.10 Functionality vs. Intuitiveness......62
6.8 Challenges and Problems with Groupware......63
6.8.1 Understanding the Nature of Groups and Organizations......63
6.8.2 Evaluation......64
6.8.3 Designer Intuition......64
6.8.4 Introducing Groupware to the Workplace......65
6.9 Applying this research to educational multi-player games......65
6.9.1 Learn from the challenges and problems encountered with groupware......65
6.9.2 CSCW Classification......67
6.9.3 Beyond being there - how can technology enhance the game experience?......67
6.9.4 How are CSCW design criteria and issues impacted by children and game playing?......68

7. ELECTRONIC MULTI-USER GAMES......70

7.1 MUDs......70

8. EDUCATIONAL NON-ELECTRONIC MULTI-PLAYER GAMES......73

9. CONCLUSION......76

9.1 Brief Summary......76
9.2 General Discussion......77

10. REFERENCES......82

1. Introduction

"The fundamental deficiency of the school system is its failure to motivate the youth of the country to want to learn." [introduction, Gordon, 1970]

The state of our educational system is an extremely controversial topic. Some teachers, parents, and educational researchers argue that children are no longer motivated to learn. They contend that rote learning and textbook activities are practices of the past and that it is time to inject new learning structures into the classroom. Educators must question what children are learning and how they are learning it. One question that we might ask is *What role does technology play in the educational process*? Taking one step back, we should first ask *Is technology in the classroom at all*?

Seymour Papert, a researcher of educational computing at the MIT Media Lab, tells a parable in his book *The Children's Machine* [Papert, 1993] about doctors and school teachers who have traveled through time from an earlier century. They have found themselves in modern day operating rooms and classrooms respectively. The parable documents their reactions: the doctors see an environment that has been altered extremely as a result of technological changes, an environment almost entirely unrecognizable. The teachers, on the other hand, hardly notice any differences in the classroom. It is Papert's explanation of what *would* surprise the teachers which so eloquently sets the scene for my paper:

> "The time-traveling teachers of my parable who saw nothing in the modern classroom they did not recognize would have found many surprises had they simply gone home with one or two of the students. For there they would have found that with an industriousness and eagerness that School can seldom generate, many of the students had become intensely involved in learning the rules and strategies of what appeared at first glance to be a process much more demanding than any homework assignment. The students would define the subject as video games and what they were doing as play.
>
> "While the technology itself might first catch the eye of our visitors, they would in time, being teachers, be struck by the level of intellectual effort that the children were putting into this activity and the level of learning that was taking place, a level that seemed far beyond that which had taken place just a few hours earlier in school. The most open and honest of our time-traveling teachers might well observe

> that never before had they seen so much being learned in such a confined space and in so short a time.
>
> "School would have parents - who honestly don't know how to interpret their children's obvious love affair with video games - believe that children love them and dislike homework because the first is easy and the second hard. In reality, the reverse is more often true. Any adult who thinks these games are easy need only sit down and try to master one. Most are hard, with complex information - as well as techniques - to be mastered, the information often much more difficult and time consuming to master than the technique.
>
> "If that argument did not convince parents that the games are not serious, surely a second argument would: Video games are toys - electronic toys, no doubt, but toys - and of course children like toys better than homework. By definition, play is entertaining, homework is not. What some parents may not realize, however, is that video games, being the first example of computer technology applied to toy making, have nonetheless been the entryway for children into the world of computers. These toys, by empowering children to test out ideas about working within prefixed rules and structures in a way few other toys are capable of doing, have proved capable of teaching students about the possibilities and drawbacks of a newly presented system in ways many adults should envy.
>
> "Video games teach children what computers are beginning to teach adults - that some forms of learning are fast-paced, immensely compelling, and rewarding. The fact that they are enormously demanding of one's time and require new ways of thinking remains a small price to pay (and is perhaps even an advantage) to be vaulted into the future. Not surprisingly, by comparison School strikes many young people as slow, boring, and frankly out of touch." [p. 3, Papert, 1993]

In his analysis Papert acknowledges that the largest impact of computer technology on children thus far has been the electronic games that are played outside of school time. And he recognizes that these games can be great sources of learning for children. Many educators and parents don't feel as confident as Papert about the educational value of video games, but they do recognize the overwhelming interest and motivation that children have for these games. There has been a move to capitalize on this interest and motivation by introducing games containing traditional educational content into the classroom.

The majority of electronic games that have made their way into the classroom are single-player games. Although it is common to see children group around their peers when playing electronic games or when playing on the computer in general, there has been relatively little research on designing educational games so that they naturally allow for more than one player. Some video game machines, by having two hand-held controllers, have made some progress in the area of multi-player games but significant possibilities remain. The ability to network computers locally in a classroom, across classrooms, or even across schools means that games could take on a whole new dimension. The concept of educational multi-player games is only now surfacing as a possibility.

Moving from a single-child learning activity to a group learning activity has been heavily researched in the last quarter century under the title of cooperative learning. Generally, it has been found that when children work together there are positive results in both academic achievement and interpersonal relations. These results are observed most often when the group activity is challenging and requires the children to communicate about the task. Such challenge is often found in popular electronic games where communication naturally flows between two or more children working together on a game. Thus the idea of using electronic educational games for group activity emerges as a natural evolution from an existing practice.

The move from single-user games to multi-user games is more complex than it might first appear. Not only does it require considerations about the educational content and its appropriateness for multiple players, but significant design issues arise when technology must be adapted to support a group of individuals rather than a single individual. Establishing network connections among computers and distributed software are only the first hurdles. What is perhaps more challenging is determining how to design distributed games so that they support collaboration and competition among the players. Designing to support awareness of others is not an easy task. For example, questions about who has made which changes to the playing area are critical in game play, not to mention the question of who in fact is playing at all. The latter question would be easy to answer in the case where all the computers are networked in a single classroom, but what about when they are networked across classrooms? Design issues such as these generally fall into a category of research called Human-Computer Interaction (HCI).

There are numerous issues involved in the design of educational multi-user electronic games. A designer of such games would need to ask a number of questions before diving into any

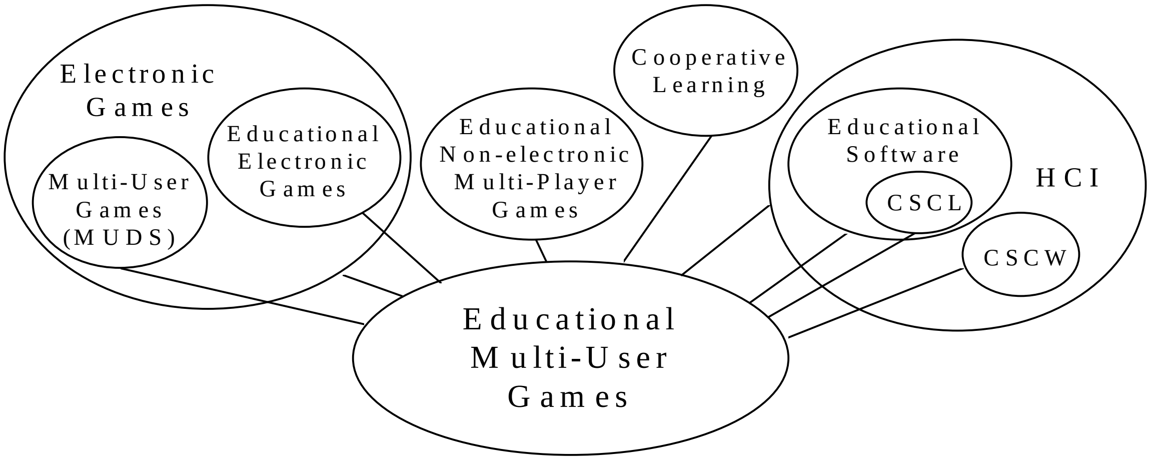

Figure 1 : Literatures contributing to the design of Educational Multi-User Games.

production. These questions should include: What is it about electronic games that makes them so motivational? Does this motivation persist when the games take on an educational flavour? What role does computer technology play in the classroom in general? What design principles exist for educational software? What design issues arise when moving from single-person software to multi-person software? And what educational issues arise when moving from single-person tasks to multi-person tasks?

This essay is a literature review that addresses these questions and other issues involved in the design of educational electronic multi-player games. The relevant bodies of literature include human-computer interaction, electronic games, educational electronic games, electronic multi-player games, educational non-electronic multi-player games, educational software, and cooperative learning. Two of the most relevant areas of the human-computer interaction literature are Computer-Supported Cooperative Work (CSCW) and Computer-Supported Collaborative Learning (CSCL)[1]. See Figure 1.

[1] Both "cooperate" and "collaborate" in the areas of CSCW and CSCL can be defined as "working together".

This survey provides a foundation that I hope will be extremely valuable to any designer wishing to embark on the production of educational multi-player games. The value of this survey, however, is not limited to game designers. For anyone who is interested in children's learning in general, educational electronic multi-player games should not be overlooked. Through using computer games, children can learn about computers. For example, they can learn keyboarding skills and how to use the mouse. Cooperation helps learning. Putting two or more children in front of a computer facilitates learning how to operate the computer through discussion. Cooperation and computer games together promote learning and any learning helps develop skills.

Research being done by the group *Electronic Games for Education in Math and Science* (E-GEMS) has motivated this literature survey. This group is currently in the initial stages of designing a number of multi-player educational computer games and hopes to explore many of the issues that are raised in this survey. The E-GEMS project is a large-scale initiative including computer scientists, mathematicians, educators, teachers, professional game designers and students from the University of British Columbia, Electronic Arts, Queen's University, Apple Canada, several elementary schools, and Science World B.C. The project is aimed at increasing the proportion of children in Grades 4-8 who enjoy learning and exploring concepts in math and science. The goal is to find game formats that are attractive to students and, at the same time, are suitable for learning particular concepts. The E-GEMS research team concentrates on human-computer interaction issues related to learning. Specific projects include research on existing computer games [Klawe and Phillips, 1995; Super *et al.*, 1995], the design of prototype games that incorporate specific mathematical or scientific concepts [Sedighian, 1995; Sedighian and Klawe, 1996], and documenting the different roles children adopt with respect to computer technology [Upitis, preprint; Saxton and Upitis, preprint]. Effects of the collaborative use of computer games [Inkpen *et al.*, 1995a, 1995b], ways to integrate educational electronic games into the school curriculum [Klawe and Phillips, 1995; Upitis, 1996], and gender issues [Upitis and Koch, 1996; Inkpen *et al.*, 1994, Lawry *et al.*, 1995] are also studied.

E-GEMS has adopted a very broad definition of the word “game.” This broad definition will also be used in this survey. Game includes simulation, role-playing, exploration, and creative activities, in addition to more traditional types of games such as *Monopoly*, *Tetris*, *Chess*, etc.

2. HCI

2.1 What is HCI?

The term *human-computer interaction* (HCI) was adopted in the mid-1980s to describe the emerging field of study that focuses on all aspects of interaction between users and computers. This includes, but is certainly not limited to, the design of the computer interface. HCI is concerned with understanding, designing, evaluating and implementing interactive computing systems for human use [Preece, 1994]. It is a highly interdisciplinary area of research; the main contributing disciplines are Computer Science, Cognitive Psychology, Social and Organizational Psychology, Ergonomics and Human Factors.

An underlying theme that has emerged from HCI research is that the users come first. Users should not need to adapt to a system but rather the system should be built to suit the needs of the users and therefore be usable by the users. The concept of *usability* is central to HCI and refers to making systems easy to learn and easy to use. Many researchers have developed comprehensive sets of usability guidelines in order to help designers produce better, more usable systems. Another important concept in the HCI literature is *affordance*. This term has been popularized by Norman [1988] and means that the design of something should suggest (i.e., afford) its functionality.

Given that the users’ needs are paramount, one important aspect of HCI work is to understand the context and the environment in which systems will be used. Two subareas of HCI research that are concerned with specific contexts and environments are Computer Supported Cooperative Work (CSCW) and Computer Supported Collaborative Learning (CSCL). The context of both

CSCW and CSCL is the use of computers by groups of users and, as their names suggest, the environments are the work environment and the learning environment, respectively.

Designing educational multi-player games fits into the broad domain of HCI. The users are children and the goal is to produce usable games that have educational content. The games must be usable in that they must allow for multiple players and that they must be enjoyable to play.

2.2 HCI For Children

Children are certainly humans, but they are humans with needs that are different from those of adults. Establishing an understanding of HCI issues that are specific to children is a neglected area of HCI research. There is without a doubt far more research into designing for adults. One area in the literature that covers learners in general is the area that looks at the needs of the novice user versus the experienced user. Although not all children are novices, it is probably safe to assume that some children are novices and thus this literature may be relevant. I will thus cover the areas of novice vs. experienced users as well as specific issues in child-centered HCI.

2.2.1 Novice vs. Experienced Users

When users are new to an application there are generally two types of learning that takes place: learning the application or task and learning the interface [Trumbly *et al.*, 1993]. This observation applies equally to children using educational software. The two hurdles are learning the interface of the software and learning the educational content. In 1987 Carroll pointed out that most of the user-interface research concentrated on expert users despite the fact that the more difficult issues, namely ease of learning and skill acquisition, arose with novice users [Carroll, 1987 in Trumbly *et al.*, 1993]. Since 1987, more attempts have been made to address the issues of the novice users.

Topics found in the literature that deal with novice users are the encouragement of exploratory learning, the use of animated demonstrations to facilitate exploratory learning, matching the user-interface to the user-skill level, and the tailoring of colour, help explanations, and default values to novice users.

Exploratory learning, with respect to application software, refers to learning how to perform a task through exploration of the software using trial and error. This can be contrasted with being taught how to use the software or simply reading a set of manuals that fully covers the operation of the software. Carroll [1990] has shown that exploratory learning may have a positive impact on computer skill acquisition and he says that there are a variety of minimalist training materials that support exploration. These materials result in more successful learning of the target computer systems compared to more elaborate and didactic methods. For example, short incomplete manuals can be more effective than the full “systems-style” versions of manuals [Carroll, 1990].

In more recent literature, it has been suggested that leaving users to explore in an unrestricted fashion is not as effective as partially-restricted interaction. Trudel and Payne [1995] conclude that users do not behave adaptively in that they tend to interact too much, and think too little about their interactions. In an experiment, they gave one group of users a limited number of keystrokes in which to explore a system and a second group unrestricted keystrokes. It was found that the restricted users attained a significantly better understanding of the system’s functionality than did the unrestricted users.

Another method to facilitate exploratory learning has been suggested by Payne *et al.* [1992]. They suggest the use of short animated demonstrations to help novice users in their initial exploration of a system. The animated demonstrations recommended are not task-by-task animations, but rather single animations that serve as an orientation to a system. In a study done with 20 year-old subjects, it was found that the animations allowed the users to draw new inferences beyond what was actually shown in the animation and, further, the animations were useful in suppressing incorrect uses of the system. Animated demonstrations were found particularly beneficial for understanding objects that didn’t quite provide the right affordances [Payne *et al.*, 1992]. One example of such an object was the corner of a window, which when grabbed enables the resizing of the window.

Matching the user-interface to user-skill level has also been suggested as another way to accommodate novice users. Trumbly *et al.*, for example, found that task performance increases and error rates decrease when user interface characteristics are matched to user computer knowledge (e.g., novice interface to a novice user). Examples of interface characteristics include the use of colour, the types of error messages, the degree of help provided, and the use of default values. Research findings indicate that colour can be beneficially employed to highlight or draw attention to special features [Williges and Williges, 1984 in Trumbly *et al.*, 1993]. The use of colour for experienced users, however, is considered to be less important because highlighting is not needed as much [Trumbly *et al.*, 1993]. With respect to help facilities, lengthy explanations have been shown to be useful for novice users while more concise error messages are recommended for experienced users [Shneiderman, 1986 in Trumbly *et al.*, 1993]. And lastly, default values are useful for reducing keystrokes and are especially helpful to novice users because suggested inputs are supplied [Trumbly *et al.*, 1993].

Another interface characteristic that deserves discussion is audio. Earcons are sounds that inform the user about the state of the system. The majority of earcons have been symbolic but interface designers are beginning to explore the use of iconic earcons [Hereford and Winn, 1994]. A symbolic earcon is one in which the mapping between sound and the action is entirely arbitrary (e.g., a beep for a wrong keystroke) [Gaver, 1986 in Hereford and Winn, 1994]. Because of the arbitrariness of symbolic earcons, their affordances are not obvious. An iconic earcon, on the other hand, makes the same sounds as the object it depicts (e.g., a scraping sound for dragging an object across the desktop) [Gaver, 1989 in Hereford and Winn, 1994]. Since the affordances of iconic earcons are more obvious, they will be helpful to novice users.

2.2.2 Child-Centered Design

Children's issues are occasionally documented in the HCI literature.

One difference between adults and children is the mental models that they form. Mental models are formed by users in order to help guide them through attempts to perform tasks and correct errors while using computer software. One particular design strategy is to encourage the correct mental model of the user. This can be accomplished by having the application use a metaphor for something that the user already knows [Flatten *et al.*, 1989 in Trumbly *et al.*, 1993]. A popular metaphor is that of the desktop, but Jones [1990] says that this is not appropriate for children. Interfaces based on the desktop metaphor typically include icons for such things as file folders and in-out trays. But Jones argues that for a child to understand what these items represent, the child will need some knowledge of the office environment, which most children do not have.

Jones performed a user-centered design to determine children-appropriate icons. He asked children of various ages to indicate typical computer activities (e.g., cut, move, copy) by gesturing through glass to a second party. Many children used similar gestures for given activities and so Jones speculated that these gestures could be made into animated icons. For example, to indicate "Send" many children motioned the throw of a ball. To determine static icons Jones had the children draw their notions of classroom realities (e.g., teacher, book). Although Jones did not construct a new metaphor in its entirety, he did set the stage by identifying some child-appropriate icons.

Two other studies that relate to child-computer interaction and are worth mentioning. The first is a study done by Brown and Schneider [1992] in which a direct manipulation interface was compared to a conversational computer interface using elementary school students grades three through six. The children were given basic arithmetic problems. It was found that the direct manipulation interface was more comfortable and enhanced the speed of completing the basic arithmetic tasks. Informal observations showed that students experienced more difficulty and frustration with the conversational computer interface [Brown and Schneider, 1992]. A second study conducted by Inkpen *et al.* [preprint] investigated children's ability to perform a given task using two different interaction styles, namely, drag-and-drop and point-and-click. Results showed that children have more difficulty operating the drag-and-drop type of interaction than the point-and-click interaction.

2.2.3 Applying HCI for children to Educational Electronic Game Design

Exploratory learning is a typical approach for children playing electronic games. This form of learning should be facilitated through the provision of minimal materials. This can already be seen with some commercial games that provide very little in the way of instruction manuals. Animated demonstrations as a means of supporting exploratory learning could be very useful for electronic games. Payne suggests such demos as an orientation to an application. What may be more useful for games would be having demos on a task-by-task basis. This is a form of scaffolding, a technique for supporting learners that is discussed in more depth in Section 4.2.3.

Findings regarding the use of colour, highlighting, detailed help explanations, and default values should be kept in mind when designing games. Using sounds with appropriate affordances is also useful. Sounds that naturally depict an action and that are recognizable by children could reduce children's confusion in games. Determining appropriate icons is also important. Buttons with icons are often found in games and these icons should be meaningful to children. Jones' suggestion of having children design the icons should be considered when designing games. Children prefer direct manipulation to dialogue and so, whenever possible, games should opt for direct manipulation.

3. Electronic Games

3.1 The Culture of Electronic Games

The electronic game culture emerged in the late 1970s. It started with the birth of arcade style video games such as *Pong* and *Pac Man*, spread quickly to the home market with video game machines such as the Atari, the Intelivision, and the Nintendo, and then spread equally as fast into the computer game domain when PCs began appearing in homes in the early to mid 1980s. Each of these three platforms, the arcade machine, the home video machine, and the computer have retained their original format but have been "upgraded" with newer and faster models as technology has evolved over time. As the models have gotten faster with more advanced hardware, the complexity of the games they support has increased dramatically.

The electronic game culture, however, is defined not so much by the various platforms and the many video games available, but rather by the interaction that people, particularly children and adolescents, have with these games and around these games. At the beginning, this interaction was often categorized as an addiction that had similar symptoms to other addictions: compulsive behavioural involvement, lack of interest in other activities, association mainly with other addicts, and (for school children) failing grades due to diminished school activity [Soper and Miller, 1983]. One extreme reaction to these symptoms when they first emerged were laws banning the play of video games. In Dacono Colorado, for example, such a law was enacted to prevent schoolchildren from skipping classes and hanging out in a local store playing video games [Nolte, 1984].

The great appeal of electronic games has not diminished since Soper and Miller reported their findings in 1983, however, a somewhat more balanced and scientifically-based understanding of the appeal and its consequences has replaced the hyped reaction of educators and parents from the early 1980's. Griffiths and Hunt [1995] conducted a study in the U.K. in 1995 to ascertain the prevalence and the demographics of computer game playing among adolescents. The study included 387 adolescents (12-16 years) and the format was a questionnaire which established, among other things, the time spent playing computer games, the reasons why the adolescents first started, why they play now, and negative consequences of play. Some of the more interesting findings include: some adolescents do spend a considerable amount of time playing computer games and others don't - approximately one third of the adolescents play every day and the same proportion plays once a month or less; 7% of the sample play for at least 30 hours per week; and 11% of the sample claimed they currently play computer games because they cannot stop. So although addiction remains a factor in the electronic game culture, it far from characterizes the entire population.

The misconception that playing electronic games is an anti-social activity has been dealt with in the recent literature. While some children do prefer to play alone, many children prefer to play while others are present. Girls are in fact more likely to play if there is the possibility of interacting with others while they play [Inkpen *et al.*, 1994]. And boys do play collaboratively and are often involved in game-playing parties and every-day conversations about games [Lawry *et al.*, 1995; Saxton and Upitis, preprint]. Both of these findings support the claim that for many children playing electronic games is not an anti-social activity.

The demographics of the electronic game culture reveals a gender imbalance. The Griffiths and Hunt study [1995] found that although both males and females play computer games, males play significantly more regularly than females. Parents and teachers confirm that girls are less interested in video games than boys [Provenzo, 1992]. This can be explained in part by the electronic games themselves. Oosterholt *et al.* [1996] report that boys are interested in games with high scores and winning whereas girls are more interested in creative games and specifically dislike fighting-style games. It has also been argued that girls prefer games that involve a complex web of relationships and situations [Saxton and Upitis, preprint]. The content and goals of the games, however, can only explain some of the gender imbalance. The differences in the way that boys and girls are socialized contributes significantly to this imbalance as well [Inkpen *et al.*, 1994]. Consider Nintendo games. Provenzo [1992] found that gender bias and gender stereotyping were widely evident throughout these games. He found that of the 47 top-rated video games, only seven did not have violence as their major theme. And the covers of these top-rated games portray a total of 115 male and 9 female characters. Further, 13 of these 47 games have scenarios with women kidnapped or having to be rescued as part of the game.

3.2 Motivation: The Appeal of Electronic Games

Clearly there must be something very enticing about electronic games. What is it that motivates these players to come back for more? Heavy players have described the activity as exciting, exhausting, fun, or stressful [Soper and Miller, 1983]. What is it about the games that makes them exciting, fun, and even stressful?

There appear to be a number of theories about the motivation to play electronic games. Walker de Felix and Johnson [1993] suggest that it is the structure of video games that make them captivating, more so than their specific content[2]. They include the following four characteristics of structure: dynamic visuals, interaction, presence of a goal, and rule-governed. Nawrocki and Winner [1983] suggest that the key to motivation is winning while remaining challenged. And lastly there is Malone's [1981] theory, which is undoubtedly the most referenced in the literature.

[2] Content and structure have been investigated by Nystrom [1975 in Walker de Felix and Johnson, 1993] in an educational context. Nystrom pointed out that the content of curriculum is not as potent to learners as the structure.

Malone defines the motivation to play electronic games as an intrinsic motivation. An activity is intrinsically motivating if people engage in it "for its own sake," and not to receive some external reward such as money or status. Malone, predominantly in the research for his PhD dissertation, found that intrinsic motivations for playing are the challenge, fantasy, curiosity [Malone, 1981], and control [Malone and Lepper, 1987] that electronic games afford. Each of these four categories is described in turn below.

According to Malone [1981], challenging games must provide goals that the players are uncertain of attaining. Goals should be personally meaningful and they should be obvious or easily generated. The game should also provide performance feedback on how close the user is to achieving the goal. The uncertainty of reaching a goal can be achieved in a number of ways. An outcome can be made uncertain through the use of variable levels of difficulty that are determined automatically, chosen by the player, or determined by an opponent's skill. Uncertainty can also be introduced through hidden information and randomness. Lastly, Malone says uncertainty can be achieved through multiple-level goals such as score-keeping or timed responses[3]. With respect to score-keeping, Nawrocki and Winner [1983] found that individual scoring showing personal progress in arcade video games was more effective than permanent scores that indicate best players overall. It is questionable, however, whether this finding would hold true for a game located in a classroom where the sense of peer competition would have a significant influence.

Fantasy is Malone's [1982] second heuristic for intrinsically motivating games. He describes a system with fantasy as one that evokes mental images of physical objects or social situations that are not actually present. He says that fantasies should appeal to their target audience or games should provide several fantasies so that different people can select fantasies that are personally appealing. In addition to being emotionally appealing, fantasies should act as metaphors for things with which the user is already familiar. Sound, which can perhaps be categorized as an element of fantasy, has also been found to be a motivational factor. For example, it has been reported

[3] A timed-response goal describes a situation where the goal is not only to complete a task, but to do so as fast as possible.

anecdotally that people's scores on video arcade games decrease when the sound is turned off [Buxton, 1989 in Hereford and Winn, 1994][4].

Curiosity, Malone's third heuristic for intrinsically motivating games, can be achieved by providing an optimal level of informational complexity. This means that the environments should be neither too complicated nor too simple with respect to the user's existing knowledge. Malone says that they should be novel and surprising but not completely incomprehensible. Ways to reach this goal include the use of audio and visual effects as decoration and to enhance fantasy, the use of randomness to add variety but not unreliability, and the use of appropriate humor. Curiosity can also be achieved by having the interface capitalize on the users' desire to have "well-formed" knowledge structures. The interface should introduce new information when users find that their existing knowledge is incomplete or inconsistent.

Control is another element required for an intrinsically motivating game [Malone and Lepper, 1987; Gentner, 1990]. Children's belief in their own control is positively correlated with academic achievement [Crandall *et al.*, 1965, in Gentner, 1990]. Games offer a mixed locus of control in the sense that some actions are initiated by the user and other actions are initiated by the computer [Gentner, 1990]. According to Malone and Lepper [1987], it is the perception of control rather than actual control that is most important. They argue that a perception of control depends on the extent to which a player controls the likelihood of an outcome occurring and this can be produced through responsiveness and the provision of explicit choices. They further note, however, that providing too many choices can cause the player to devalue the importance of choice and to experience frustration instead of satisfaction.

Some might argue that the ultimate motivation with electronic games - one that encompasses challenge, fantasy, curiosity, and control - is *mastery*. Weinbren [1995] succinctly describes it in the following phrase: "the point of the game, what keeps the boy playing, is the promise - the intimation that with enough energy, enough focus, and enough lives, he might master this machine" [p. 405]. Griffiths and Hunt [1995] in their demographic study in the U.K. also

[4] This could be more related to sound as a temporal cue, than a motivational cue.

concluded that males play video games to master the games and for competition. They did, however, find that females prefer less aggressive and less demanding games and so whether mastery is as significant an issue for females as it is for males is unknown. One possibility is that boys only recognize mastery by winning, whereas girls are satisfied when they understand enough to know what the game is about.

As mentioned previously, Malone's theory regarding motivation and games is undoubtedly the most respected theory. This is probably because he performed very in-depth research on the topic of motivation and electronic games. Other theories seem almost anecdotal in comparison and do not have the same foundation. Games have changed dramatically, however, since the late 1970's and early 80's when Malone did the majority of his work. It is probably time to revisit the work he has done using more modern games.

3.3 Educational Electronic Games

It is no secret that motivation is one of the keys to education. Thus, it is a logical step to try to take advantage of the intrinsically motivating nature of electronic games by using this medium for educational purposes rather than simply for pure entertainment[5]. The idea of producing educational games is certainly not new; it was one step behind the advent of electronic games themselves [Malone, 1981, 1982; Gentner, 1990; Nawrocki and Winner, 1983; Lepper and Chabay; 1985; Reynolds and Martin, 1988]. Educational games, sometimes called "edutainment" [Lepper and Chabay, 1985], represent the fastest-growing type of software [*Consumer Reports*, 1995]. So now, approximately one decade after the emergence of edutainment, the pertinent question would seem to be: how do we design games for education? What is more often tackled in the literature, however, is: have educational games been successful? I will thus start with the second question and then move to the first.

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[5] Not only have educators noted the intrinsic motivation inherent in games, so has the HCI community [Pausch *et al.*, 1994]. Some researchers argue that the motivating aspects of games could be used as a paradigm for general user-interface design while some argue that they cannot. Neal (1990), for example, argues that the graduated challenge aspect of games could be used in applications through the provision of multiple levels of interaction. This can be contrasted with the majority of applications which have at most novice and expert levels. Thomas and Macredie (1994), opponents to using game features, cite reasons which include the deep cultural division between work and recreation.

Success is a broad term and could be assessed or measured in various ways with respect to educational electronic games. Much of the work on the evaluation of games has been anecdotal, descriptive, or judgmental [Randel *et al.*, 1992]. As a result, there are often very sweeping statements assessing the success of educational games without providing grounded reasoning, scientific or otherwise. These statements generally indicate that the success has been mediocre. For example, Brody [1993] stated that “the marriage of education and video-game-like entertainment has produced some not-very-educational games and some not-very-entertaining learning activities” [p. 52]. Another example of a general assessment is that “programs that fail tend to fall short in either educational content or entertainment value, or simply do not meld the two in an engaging package” [p. 764, *Consumer Reports*, 1995]. While these types of statements and the literature from which they come do convey some information, they do not provide concrete measures for success and so their value is questionable.

Although much of the literature covering the effectiveness of educational electronic games is of an anecdotal or descriptive nature, there is some literature that documents formal studies which assess the success of these games. In these studies the measure used for success is well defined. Success is measured with respect to traditional classroom education [Lepper and Chabay, 1985; Butler, 1988; Randel, 1992]. For a game to be considered successful, it must be at least as effective as traditional classroom education. This threshold for success, however, may be inappropriate. It certainly is appropriate if games are to replace traditional classroom teaching, but if games are to be used as a supplement to classroom education, then the threshold could be too high. Some games could perhaps act as a “stand-alone teacher” for a particular subject area and a particular grade level. For example, some would argue that *Carmen Sandiego* (described later in this section) could be used to teach world geography facts. Students using the game may have an opportunity to learn the same kinds of information as students using only a textbook. Other games, however, while containing educational content, primarily serve as motivators that are not meant to be used in a stand-alone manner. For example, a Newtonian microworld[6] which doesn’t give exact physics equations motivates an understanding of physics, but used alone would

[6] See Cockburn and Greenberg [1995] for an example of a Newtonian microworld. Microworlds are described in Section 4.2.2.

probably not provide sufficient material for students to do well on a physics test. In addition, children may be willing to play educational games outside of school hours in lieu of watching T.V. or playing non-educational games. In this case isn't it sufficient that these games have some educational value even if they don't meet the above threshold? It is most likely the case that the threshold has been chosen because it is the most concrete comparison with educational value that can be made easily. The distinctions of whether games are to be used in a stand-alone manner or integrated into the curriculum and whether games are to be used in school or outside of school have not received sufficient attention in research to date.

Butler [1988] and Randel *et al.* [1992] have both conducted literature reviews on the effectiveness of educational games and simulations[7] using the threshold of traditional classroom teaching as a measure of success. Butler's findings are quite broad and he doesn't provide the source for his findings. The findings of Randel *et al.*, on the other hand, are more specific and they provide the source and the methodology that was used in reaching their conclusions. As a result of these differences, I have more confidence in the findings of Randel *et al.*, than in those of Butler and so I am reporting their findings separately. Butler found that when games are used:

1. students generally acquire at least equal knowledge and intellectual skills as they would in other learning situations,
2. information is learned faster than in other methodologies although the amount learned is not significantly greater than with other methods,
3. students of low academic ability often improve their academic performance because of greater interest,
4. problem solving ability increases,
5. students will be motivated to participate in the activity, but their interest in the subject may not be improved, and
6. the tendency for students to attend school regularly increases.

[7] Simulations model a process or mechanism relating input changes to outcomes in a simplified reality that may not have a definite end point [Randel *et al.*, 1992]. Simulation games are a subset of games.

Randel *et al.* performed a very strict review of studies reported in the literature and ignored the results of those studies for which the methodology was determined not to be scientific. They included studies based on games that were both electronic and non-electronic[8]. 68 studies were examined directly or indirectly (through reviews conducted before 1984). A summary of their findings is found on page 269 of their article and is reproduced almost verbatim here:

1. 38 (56%) studies found no difference, 22 (32%) found differences favouring simulations/games, 5 (7%) favoured simulations/games, but their controls were questionable, 3 (5%) found differences favouring conventional instruction.
2. Seven out of eight studies involving math found that the use of games is superior to traditional classroom instruction for improving math achievement. The one study in physics was also favourable. Subject matter areas where very specific content can be targeted and objectives precisely defined are more likely to show beneficial effects for gaming. Games may also be effective in drill and practice situations with numerous highly related instances.
3. The greatest number of studies on simulation/gaming is in the area of social sciences. The majority of these studies (33 out of 46) showed no difference in student performance between games/simulations and conventional instruction.
4. Five out of six studies demonstrated that games can teach language arts effectively, particularly when specific objectives are targeted.
5. Social science simulations/games tend not to use a computer, while math, physics, and language arts games tend to use a computer.
6. Simulations/games show greater retention over time than conventional classroom instruction.
7. In 12 out of 14 studies, students reported more interest in simulation and game activities than in more conventional classroom instruction.

In general Butler's and Randel's findings indicate that games and simulations can be equally as good or better than traditional classroom teaching.

[8] For a more detailed discussion on the use of non-electronic games in the classroom, see Section 8.

The fact that some of the literature reports the success of educational electronic games in an anecdotal or ad hoc manner and others use more formal methodology results in some disagreement in the literature on the effectiveness of games. Perhaps the best example of this is the literature covering the game *Where in the World Is Carmen Sandiego* produced by Brøderbund. This game has been a very enduring, commercially successful game [*Consumer Reports*, 1995] that is widely used to teach geography to elementary school students [Gentner, 1990]. In this game players assume the role of a detective and attempt to solve a series of international crimes. In order to solve the crimes the players have to figure out a number of geography clues that include the names of countries, their capitals, their flags, their monetary units, and their major religions. Brody [1993] says that the motivating aspects of video games are replaced in educational games such as *Carmen Sandiego* by gimmicks, artificial lures, and contrived hurdles. Here the fantasy is tacked on whereas in a "pure" video game, the knowledge acquired is part of the fantasy. Brody offers a somewhat negative opinion that in *Carmen Sandiego* "the learning of factual information becomes important in the same way that it would if highway toll takers made everyone perform an arithmetic problem or recite a line of Shakespeare before being permitted to continue driving" [p. 55].

Gentner [1990] and Wiebe and Martin [1994], unlike Brody, document more positive reports about *Carmen Sandiego*. Gentner describes the game as an educational simulation that functions primarily as a motivation for learning other information. Wiebe and Martin selected *Carmen Sandiego* for a study because they felt that it had many components of a well-designed computer-based educational package. The purpose of the study was to investigate how a commercially-prepared computer geography adventure game impacted students' recall of geography facts and students' attitudes toward studying geography. The study revealed that there are no significant differences between the children who played the game and children who drew maps and played non-computer games with the same geography facts found in *Carmen Sandiego*. Thus the researchers concluded that non-computer games and activities can be equally as beneficial as computer games for learning geography facts and for improving student attitudes. This, of course, doesn't indicate how games in general (computer and non-computer) compare to traditional classroom education.

Klawe and Phillips [1995] specifically question whether the standard of success should be traditional classroom teaching. They suggest that playing electronic games on their own is generally not sufficient and recommend non-electronic activities in addition to game play. Klawe and Phillips found that pencil and paper activities that supported game activities stimulated students to explore the electronic versions of the games and the educational content more fully. They concluded that these activities facilitate reflection and the ability to transfer the learning to other contexts.

3.4 Designing Educational Electronic Games

Having found that educational games have been perhaps moderately effective at imparting learning, it is still unclear why some games are effective while others are not. Lepper and Chabay [1985] posed a number of questions regarding the effectiveness of intrinsic motivation in educational electronic games. These questions probably hold part of the key to understanding what makes an effective game, but unfortunately most of the questions remain unanswered. The unanswered questions include: Are game-like elements that have been added to the software distractive? Do they impair learning or do they enhance children's attention to the material presented? With respect to design, Lepper and Chabay also posed some very poignant questions: Is there an optimal level of control between the computer and the student and if so, what is it? When a student makes an error on a problem, how should the computer respond? Besides providing information, corrections, suggestions, and hints, what type of non-didactic information should the computer provide in the way of goal setting, progress marking, encouragement, exhortation, commiseration, and praise? These questions require further research.

Despite the fact that many questions remain unanswered in our understanding of educational games, new design guidelines for these games continue to surface in the literature. Malone's [1981, 1982] heuristics of challenge, fantasy, curiosity, and control[9] continue to appear in more recent articles covering educational games and game design. Other guidelines for design have been documented by Reynolds and Martin [1988], Brody [1993], Quinn [1994], and Kelly and

[9] These heuristics are described in Section 3.2.

O'Kelly [1994]. They include: provide a clearly stated educational objective and content; provide prompt feedback on performance and progression; provide gaming interactions that facilitate the mastery of the objective; provide mechanisms for correcting errors and improving performance; provide positive reinforcement that is appropriately timed; provide underlying pedagogical support; and map learning activities to interface actions and map learning concepts to interface objects. In addition, Sedighian and Klawe [1996] argue that educational games should be designed to promote reflective cognition of the players. Details of their design strategy can be found in Section 4.2.3.

Quinn [1994] not only provides guidelines for the design of educational games but goes one step further and presents a methodology for their design. He advocates a model of design called the "cognitive apprenticeship" model by Collins, Brown and Newman [cited in Quinn, 1994] that incorporates modeling, practice, scaffolding, and release. In this model a desired behaviour is modeled for students after which practice opportunities must be provided. Scaffolding support is provided in the form of simplified versions of the problems, by having some of the task already accomplished, or by providing tools that support the difficult portions of the task[10]. Release occurs as more and more of the complete task is placed under the control of the student. He extends this base model to include situated, constructive and reflective tasks. A situated task is one that is motivating and meaningful for the students and relevant in a context of real practice. Activities are constructive in the sense that learners build their own understanding of the knowledge rather that accept an external mode. Lastly, reflective instruction occurs when students have the opportunity to consider the understanding they are developing and the process of application they are following.

The work by Malone, Quinn, and others listed above indicates that significant thought has been allocated to the design of educational games. The design issues that have been documented here don't seem specific to single-player games even though they were developed around single-player games. Although they may require some modifications, they certainly represent a good starting point for the design of multi-player games.

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[10] A more detailed description of the scaffolding technique can be found in Section 4.2.3.

4. Designing Educational Software

When considering the design of educational games it is worthwhile to look at general educational software design issues and techniques. We discover that the success of educational software has been relatively unimpressive [Robertson, 1994]. We must ask ourselves why this is the case and what can be done to resolve it. There are two levels to approaching and understanding this issue. At a fine-grain level, we must look at problems with the usability and design of current educational software. For a more coarse-grain approach, we must look broadly at the philosophy of educational software in general. Both of these are valid approaches to improving educational software and its design. I will cover them each in turn.

4.1 Designing for Usability

The poor success of interactive software is not limited to educational products, but has equally been the case for workplace products [Robertson, 1994]. In the domain of workplace software a number of usability guidelines as well as usability design and testing techniques have been developed over the last decade with the aim of improving the success of workplace applications. Given that the use of these techniques has resulted in improved success for workplace products, the temptation is to directly use these techniques for the development of educational software as well. However, Robertson [1994] says that because these techniques were developed based on workplace and consumer applications it is difficult to apply them directly to educational software.

Robertson [1994] examines traditional usability design guidelines and usability testing methods and suggests that these need to be revamped for educational software. For example, user-centered design is a popular approach in designing for usability. It is an approach which views knowledge about users and user’s involvement in the design process as central concerns [Preece, 1994]. Robertson argues that this approach is not feasible for children because it would be difficult to bring children into the software developers’ workplace or to place the developers into the children’s classroom. “Performance testing”, which is often used synonymously with “usability testing”, is an example of a usability testing method. This testing determines whether a system meets a pre-determined, quantifiable level of usability for specific types of users carrying out specific tasks [Preece, 1994]. Robertson questions whether there exists any subset of educational software that might benefit from performance testing with the possible exception of drill-and-practice programs.

Robertson provides her own usability guidelines for educational software which she acknowledges are preliminary and exploratory. They are as follows:

1. Design teams should be multi-disciplinary. Robertson suggests that by bringing together the disciplines of education, child psychology, human factors, software design, and teacher experience, each of the disciplines will be well-served. She agrees that this approach, because it does not use children, is not as desirable as user-centered design but it is more practical.
2. Each member of the design team should have his or her own requirements for the software and should attend to those requirements throughout the design.
3. Because using children as team members is probably not feasible, each adult team member should become "user-centered". By this she means that the team members should attend to the language, physical, social, and cognitive needs of children.
4. While design team members should perform usability testing throughout the design, actual children should also be part of the testing process.

The E-GEMS team is multi-disciplinary and to a large extent follows Robertson's guidelines. One notable deviation from her guidelines is that children are included as team members in the E-GEMS group. E-GEMS has established relationships with several public schools in Vancouver and students from these schools are involved as researchers in the E-GEMS project [Klawe & Phillips, 1995]. The role of the students includes maintaining computer log books, testing prototype and commercial games, maintaining "bug" sheets, and weekly class debriefing and sharing sessions. At these sessions the children provide very valuable feedback to researchers such as game aspects and activities that are liked, disliked, too easy, too challenging, etc. In addition, the children's computer log books provide very valuable written feedback. Involving the students as researchers in the team results in a participatory form of research that has proven to work very effectively.

For usability testing methods Robertson recommends child surveys, heuristic evaluations, teacher surveys, and think-aloud protocols. Surveys are self-explanatory[11]. One thing to note, however, is that designing surveys for children can sometimes be tricky and so surveys should be prototyped first. For example, surveys often include questions for which a Likert scale[12] is used to provide the response. Typical options on a Likert scale are: disagree, disagree mildly, indifferent, agree mildly, and agree. The differences between these options are often not understood by elementary children. One possible solution that has been found to work with children at the grade 4-5 level is to use the following options: NO, no, maybe, yes, YES. Heuristic evaluations are general examinations of a system or prototype by reviewers who are guided by a set of high-level heuristics which guide them to focus on key usability issues of concern [Preece, 1994]. Think-aloud protocol is a special type of verbal protocol in which the user verbalizes thoughts while using the system [Preece, 1994]. This can help designers understand confusing and inconsistent aspects of a system.

Understanding how the design of software for adults parallels or contrasts with the design of software for children is very important. The goal for children's software should be to take advantage of or re-use as many as possible of the techniques and the methodology that have been developed for adult software. Robertson's paper is the only material that I found on this subject. Further research is required.

4.2 Questioning The Philosophy of Educational Software

Designing usability guidelines is certainly a practical approach because these guidelines will, at some level, improve the design process for educational software. The assumption is, of course, that a better design process will produce better software. This is most surely the case. Or is it? Papert [1980, 1993] and others that have commented after him would say that although guidelines may lead to a marked improvement of educational software, they do not address the

[11] There is a large literature covering the design of surveys.
[12] A Likert scale is a multipoint rating scale that measures the strength of a subject's agreement with a clear statement.

real problem with educational software. The problem is not so much in the specific design of a piece of educational software but rather in the educational philosophy on which educational software and school, for that matter, are built[13]. In order to understand this it is first necessary to take a brief look at the history of educational software.

4.2.1 Computer Aided Instruction and Intelligent Tutoring Systems

Educational software first emerged in the late 1960's and 1970's in a format called Computer Aided Instruction (CAI). CAI refers to programming the computer to administer the kinds of exercise traditionally given by a teacher at a blackboard, a text-book, or a worksheet [Papert, 1993]. Intelligent CAI or what is more commonly known as Intelligent Tutoring Systems (ITS) are successors to CAI. These allow one-on-one tutoring with individualized instruction. The difference between CAI and ITS is that ITS is based on an explicit model of tutoring and an explicit model of domain knowledge which enables the system's response to be more flexible to the student [Soloway & Bielaczyc, 1995]. Meta-analyses of CAI showed that it produced a 30% speed-up in learning time and 10% improvement of student scores. The findings for ITS were an order of magnitude improvement on scores and a reduction of time-on-task[14] [Soloway & Bielaczyc, 1995].

4.2.2 Interactive Learning Environments and Microworlds

CAI and ITS are similar to each other in that they are low-interactivity systems and their basic goal is to teach content. The claim is, however, that these educational systems are too limited in scope: they only teach specific content knowledge and skills. In fact, critics frequently ask whether these systems do anything at all to justify the cost of computers. The most hardened skeptics describe the computer as "a thousand-dollar flash card," and what it does is "drill and kill" [p. 41, Papert, 1993]. Papert himself says that "the most common use of the computer in education has become force-feeding indigestible material left over from the precomputer epoch" [p. 53, Papert, 1980]. Because of their limited scope, CAI and ITS have only been moderately

[13] This parallels software designed for the workplace. Better usability does not imply a "better application" if the software is for something that is not needed or that is counter-productive.

[14] Soloway & Bielaczyc do not clarify whether "speed-up" and "reduction of time-on-task" are the same. I would assume that they are at least related.

successful. Soloway & Bielaczyc [1995] say that in order to meet the needs of the 21st century, educational software needs to broaden its scope and look at issues of how-to-learn, communication, inquiry, reasoning, and metacognitive skills.

Papert was the first to address the scope issue in the late 1970's. His solution went beyond finding the ideal format for educational software. He questioned the whole philosophy of teaching. Papert adopts "Piagetian learning" which is a natural spontaneous learning of people in interaction with their environment. He contrasts this to curriculum-driven learning characteristic of traditional schools. This contrast can also be classified as *constructionism* versus *instructionism* [Papert, 1993]. Papert says that it is precisely the computer that will enable education to shift from instructionism to constructionism. The computer can open up microworlds that otherwise wouldn't be available to students. For example, a Newtonian physics microworld could allow students to manipulate physical laws, such as gravity, and observe the resulting behaviour on the objects in the microworld [Cockburn and Greenberg, 1995]. Microworlds facilitate exploration and learning by doing. In Papert's vision, instead of the *computer being used to program* the child, as in CAI and ITS, *the child programs the computer*. Through programming the child "both acquires a sense of mastery over a piece of the most modern and powerful technology and establishes an intimate contact with some of the deepest ideas from science, from mathematics, and from the art of intellectual model building" [p. 5, Papert, 1980].

The microworld that Papert developed was a Turtle World based in Logo [Papert, 1980] which is a programming environment accessible to young children. Papert described the Turtle World as an incubator, a place, and a province of Mathland where certain kinds of mathematical thinking could hatch and grow with particular ease [p. 125, Papert, 1980]. In this microworld, the child, even at preschool ages, is in control. The child programs the computer. Papert uses the word *syntonic*[15] to describe the learning that the Turtle World facilitates. Syntonic learning can be contrasted to dissociated learning, which is what takes place even today in the traditional classroom [Papert, 1980].

[15] Webster's definition of syntonic is: in emotional equilibrium and responsive to the environment.

It is instructive to look at two examples that show the power of the Turtle microworld. The first exemplifies syntonic learning. When a child cannot figure out why the turtle is not doing what the child expected, the child is able to act out the motions of the turtle to see where the instructions for the turtle are wrong. In this way, the Turtle microworld is body syntonic. The second example shows how the microworld facilitates a deeper sense of learning. Papert says that a child's typical reaction to a wrong answer is to try to forget it as fast as possible. By contrast, in the Logo environment the child is not criticized for an error. In fact, the process of debugging is a normal part of the process of understanding a program and the child is encouraged to study the bug rather than forget the error [Papert, 1980].

Microworlds represent the third format of educational software to emerge. They differ greatly from CAI and ITS mostly because of the educational philosophy that they espouse. Soloway *et al.* [1994] describe the difference as a shift from user-centered design to learner-centered design. One of the byproducts of this shift is that learner-centered systems are highly interactive. Soloway *et al.* [1994] have grouped these systems under the heading of Interactive Learning Environments (ILEs).

4.2.3 Designing Interactive Learning Environments and Microworlds

Scaffolding[16] is a technique that is used for designing ILEs and microworlds [Soloway *et al.*, 1994, Graci *et al.*, 1992]. It is a means of supporting the learner such that more support is provided initially, but as the learner acquires the necessary knowledge and skills, the support fades, leaving the learner in control. This is analogous to construction scaffolding. One method of providing scaffolding is through a graded sequence of microworld instances [Graci *et al.*, 1992]. These instances are achieved by gradually providing subsets of functionality to the users. Functions that are unavailable at a particular instance are entirely invisible to the learners, not just grayed out as is common with menu options that are not available. Graci *et al.* note that this form of scaffolding is very important because it permits a balance between goal-directed learning and discovery learning. They compare the importance of functionality hiding in microworld educational practice to information hiding in the field of software engineering.

[16] Scaffolding is first mentioned in Section 3.4.

Soloway *et al.* [1994] propose a more comprehensive model of scaffolding called the TILT Model (Tools, Interfaces, Learner's needs, Tasks). The model uses specific scaffolding strategies that are appropriate for the special needs of the learner. For "tasks" a coaching scaffolding technique is recommended that will help students acquire knowledge and the specific practices of a task domain. For "tools," adaptable tools provides the scaffolding. Lastly, for "interfaces," the interface must provide the use of different media and modes of expression.

Scaffolding is important because it directs the learning process. Another important strategy for the design of educational interactive software is that interfaces promote active reflection on the part of the learner [Sedighian & Klawe, 1996; Trudel & Payne, 1995; Holst, 1995; and Golightly, 1995]. It has been suggested that easy-to-use or intuitive interfaces, such as direct manipulation, are sometimes in fact too easy. While these interfaces are appropriate for workplace or productivity software, they may be inappropriate for educational software. Students, when using direct manipulation, are often able to complete tasks without being aware of the educational aspects of the tasks.

Golightly [1995] suggests that more difficult interfaces may lead to greater mental effort by the learner in planning the operations necessary to achieve a goal. This increase in mental effort leads to a different problem-solving strategy than is evident with easy interfaces. In Golightly's particular experiment, the difficult interface resulted in a "look-ahead" problem solving style where as the direct manipulation interface led to a "trial-and-error" style. Holst [1995] reported a number of positive findings with respect to difficult or awkward interfaces. She found that when information was not provided on the main screen, it forced students to actively seek the information at times when the knowledge would be of significance to them; that the lack of visual access to the object configuration at the time when students had to make a move encouraged the students to remember the configuration for themselves; and that when more keystrokes were required to make a move or to recover from a move, that students reflected longer before making the move initially. Trudel and Payne [1995] suggest that imposing constraints (such as limiting the number or rate of interactions) will encourage reflection during exploratory learning. Sedighian and Klawe [1996] provide an interface strategy for promoting reflective cognition. It is based on three interface elements: A) an educationally appropriate representation, B) an interaction protocol that naturally shifts children's attention from intuitive interaction to one that focuses on the structure and operation of the representation, and C) a gradual elimination of feedback and/or components of the representation so that children are required to assume increasing cognitive responsibilities. Note that C) is a particular form of scaffolding.

4.3 Applying Educational Design to Games

Robertson's [1994] guidelines should be tested and used. One modification to these guidelines that might be useful would be to include game designers in the design teams. These guidelines should work equally as well for educational games as for educational software in general.

Designers will need to pay special attention to the framework of the game they're designing. Although most "pure" electronic games probably fit into the ILE category, it is easy to see that by adding educational content they could easily slip into the CAI or ITS categories. Designers, especially if they have an educational background, will need to resist the temptation of falling into CAI or ITS. Scaffolding techniques should be considered for the design of games. Recall that Quinn [1994] suggested a design model for educational games that incorporates modeling, practice, scaffolding, and release (see Section 3.4 for more details). Lastly, interface strategies that promote active reflection by the students should be employed.

5. Cooperative Learning

5.1 General Cooperative Learning

Research in cooperative learning should be considered when contemplating multiple children working together in an educational environment, whether it be in general tasks or specifically in the use of an electronic game. Cooperative learning refers to "classroom techniques in which students work on learning activities in small groups and receive rewards or recognition based on their group's performance" [p. 315, Slavin, 1980]. The cooperative learning literature provides a rich understanding of how children learn together and covers topics such as motivation, self-esteem, academic performance, social development, and interpersonal functioning.

Cooperative learning is an old idea in education [Slavin, 1980] that has been given a significant amount of new attention in educational research over the last quarter century. Although there has been much written about cooperative learning, I have chosen to base my coverage on two recent literature reviews on the topic, one by Hymel *et al.* [1993] and another by Cohen [1994]. These reviews provide an overview of the current understanding of cooperative learning.

A common theme in cooperative learning research is the impact of different learning structures on areas such as academic achievement, motivation, and social behaviour. The three types of classroom learning structures that are examined are competitive, individualistic, and cooperative. The following descriptions of these structures are summaries from those in Hymel *et al.*:

1. In a ***competitive*** learning environment success is defined on a relative basis and rewards are distributed unequally based upon relative performance. Competitive situations involve what is called negative *goal interdependence* (defined below) among students, in that only one or a few students can actually reach the goal of high marks or being "correct" or the "best".

2. In ***individualistic*** learning structures there is no *goal interdependence* between students since students work on their own material at their own pace, regardless of the progress of other students, and success is not judged relative to the performance of others.

3. In ***cooperative*** learning structures students work in collaboration with one another to achieve their learning goals. Thus, there is *positive interdependence* among classmates, with each student achieving his/her own learning goals and outcomes only if other students in the group also achieve their goals. Learning is structured in such a way that students within a cooperative work group share responsibility for the learning task.

A number of definitions are required for the above descriptions and for the discussion that follows:

- ***Positive goal interdependence*** means that individuals perceive that they can achieve their goal if and only if the other individuals with whom they are cooperatively linked also achieve their goals [Cohen, 1994]. No goal interdependence simply means that individuals perceive achievement of their goal as independent of the other group members achievement.

- ***Positive resource interdependence*** exists when individuals can only achieve their goals when other group members provide needed resources [Cohen, 1994].

- ***Positive reward interdependence*** exits when rewards for the group as whole are based on the performance of each individual member [Cohen, 1994].

- ***Individual accountability*** is based on the fair and equitable distribution of labour or effort and the independent evaluation of learning for each group member, i.e., each student in the group must both contribute his/her equal share of work to the project and be responsible for learning the assigned material [Hymel *et al*., 1993].

One main focus of the Hymel *et al.* paper is the impact of cooperative versus competitive learning experiences on children's social development and interpersonal functioning. A number of studies that have addressed these outcomes have looked at relations among heterogeneous populations of children, especially children who differ in racial or ethnic background or in terms of academic or physical handicaps. Mainstreaming is the philosophy that heterogeneous groups of children should not be segregated in their learning environments. It is partially built on the notion that if these different populations of children are put in close proximity to one another, positive interrelations will result. Research shows, however, that proximity is a necessary but not a sufficient factor. Proximity of heterogeneous children can have positive or negative results with respect to interpersonal relations depending on the learning structure used. Cooperative environments have been found to foster positive interdependence among students which generally results in more positive interpersonal relations and attitudes. Competitive and individualistic learning situations, on the other hand, which foster negative interdependence and no goal interdependence respectively, have been found more likely to result in negative interpersonal relations and attitudes.

Clearly it is important that social gains are not at the expense of academic progress. Thus Hymel *et al.* also address the academic outcomes of the different learning structures on both achievement and motivation. Studies show that cooperative learning situations are generally more successful at improving student achievement and academic performance than individualistic and competitive environments. Hymel *et al.* note, however, that not all studies have demonstrated superior academic outcomes in cooperative learning situations. They say that positive academic outcomes are mostly evident when the cooperative learning situations are structured in such a way that emphasizes both group goals and individual accountability among students.

Hymel *et al.* report that few studies have looked at the direct impact of cooperative learning on motivation. What has been found is that the motivational outcome is highly related to the success of the learning situation. Successful cooperative learning situations can be an ideal context for developing positive perceptions of competence in all group members whereas group failure, on the other hand, may be no more likely to enhance student motivation than competitive situations. Hymel *et al.* report a number of factors associated with cooperative learning environments that should enhance motivation: students in cooperative learning groups report more intrinsic reasons for doing schoolwork whereas students in individualistic learning situations report more extrinsic reasons; students have a greater sense of personal control than students in individualized environments; cooperative learning environments can foster a positive sense of self in children and result in improvements in some aspects of self-esteem; students in cooperative learning environments were found to be more likely to exhibit desirable school behaviours, to display less difficulty following directions, to have less difficulty understanding assigned tasks, and to spend less time waiting for teacher assistance.

Based on their review, Hymel *et al.* concluded that there are five necessary elements which must be present in order to achieve a successful cooperative learning environment: positive interdependence, face-to-face interaction, individual accountability, social skills training, and group evaluation opportunities. With respect to the last two items, it was found that cooperative learning situations will not work if children, who are generally socially unskilled, are not trained to cooperate. They suggest that training be an ongoing job for the classroom teacher and that it can be accomplished through actions such as praising both prosocial and cooperative behaviour. In addition, they concluded that it is important for children to be given opportunities to evaluate how their group is functioning and discuss ways in which the group interaction could be improved.

Cohen [1994] reviews the same literature as Hymel *et al.*, but assesses it from a different vantage point. She moves away from the debates about rewards, interdependence, and individual accountability, which characterize the majority of research in cooperative learning. Instead, her focus is on tasks and interaction in cooperative learning. By shifting the focus she hoped that "new light will be shed on some old problems" [p. 4].

Cohen notes that the volume of interaction has often been used as a metric to attempt to predict learning in collaborative environments, but that sometimes it accurately predicts learning and other times it does not. She proposes that the reason for this discrepancy is based on the assigned group task itself. She distinguishes between true group tasks and tasks that could be done as individuals, which have the character of collaborative seatwork. She further distinguishes between tasks which have fairly clear procedures and thus may have "right-answers," and tasks that she calls "ill-structured problems." She concluded that the total amount of interaction should be far more critical for achievement gains when there is an ill-structured problem that is a true group task than when the task is more clear-cut and could be carried out by individuals. Stated in another way, given a problem with no one right answer and a learning task that will require all students to exchange resources, achievement gains will depend on the frequency of task-related interaction.

The amount of interaction among students is determined by task instructions, student preparation, and the nature of the teacher's role. Cohen says that the interplay of these variables that is appropriate for supporting interaction in more routine learning tasks may result in overly constrained interaction in less structured tasks where the objective is conceptual learning.

In reviewing the literature, Cohen found that if individual accountability is maintained in some fashion, reward interdependence does not appear to be necessary for achievement when students are motivated to complete a challenging and interesting group task that requires everyone's contribution for a good outcome. This contradicts Hymel *et al*.'s findings that individual accountability and positive interdependence are both necessary conditions for learning gains. Cohen says that the latter proposition applies more specifically to collaborative seatwork and routine learning.

In summary, Hymel *et al.* concluded that cooperative learning environments can lead to positive social development and interpersonal relations and they also enhance achievement and motivation. Cohen concluded that when using the cooperative learning structure, it is important to understand the learning objective: if learning is for understanding and involves higher order thinking, then tasks and instructions which foster maximum interaction, mutual exchange, and elaborated discussions will be more beneficial than tasks and instructions which constrain and routinize interaction.

5.2 Cooperative Learning and Computers

Computer use has been found to influence students' motivation and perseverance which, in turn, can influence learning [Krendl and Lieberman, 1988]. When we add to this the increasing presence of computers in the classroom and the resurgence of research in cooperative learning, it is hardly surprising that using computers for cooperative learning has surfaced in both the literature and in classrooms. The joining of computers to cooperative learning seems to have come about primarily for pragmatic reasons. It is often the case that children using computers tend to gather in social groups of two or more [Strommen, 1993]. This behaviour is very much analogous to the behaviour of children when they group around their peers playing electronic games [Lawry *et al.*, 1995]. Strommen says that this finding coupled with the fact that school budgets can rarely provide enough computers for children to each have their own has led to cooperative learning methods for teaching with technology[17]. He calls this a “marriage of convenience that has produced highly fruitful offspring” [p. 46]. Current research indicates that computer environments do in fact appear to facilitate cooperative learning [Nastasi and Clements, 1993].

It is important that we don’t slip into incorrect assumptions when considering collaborative learning using computers. Recall that cooperative learning is more than putting students in groups. Dockterman [1991] says that when students are forced to share a limited resource, which occurs frequently with computers, it is often assumed that a collaborative experience results. The findings of Hymel *et al.* [1993] about reward structure, interdependence, and individual accountability and the analysis of Cohen [1994] on task and interaction need to be equally accounted for when cooperative learning is taking place with the support of computers. In addition, children’s roles as collaborators using a computer need to be understood. Cole [1995] points out that it is often assumed that the child manipulating the mouse is controlling the group activities at the computer. What occurs frequently in practice, however, is that the child who is controlling the mouse ends up simply taking directives from the other group members.

There are a number of topics in the literature that surround the use of computers for cooperative learning. These topics include: the comparison of cooperative learning with computers to cooperative learning without computers, how the outcomes of cooperative learning classroom structures are affected by computers, and comparisons of cooperative learning using different kinds of applications. This research, while important, represents basic use of computers for cooperative learning and does not acknowledge the full potential of computers. An area of research called Computer Supported Collaborative Learning (CSCL) has recently emerged that attempts to integrate computers more thoroughly into cooperative learning. Below I will briefly cover the basic research of cooperative learning using computers as well as some of the CSCL literature.

[17] What Strommen does not clarify, however, is whether the social grouping of children around computers could actually be a direct consequence of limited resources rather than a separate fact. One could ask whether kids would group if abundant resources were available.

Nastasi and Clements [1993] ran a study in which children performed both a task on computers and a similar task without computers. They found that even when instructed to collaborate, students working on the noncomputer version of the task spent less time working collaboratively than when they had the opportunity to work with computers. According to Nastasi and Clements, this indicates that computers facilitate collaboration and that computers raise social interdependency in learning environments. It may actually be the case, however, that computers *force* collaboration rather than *facilitate* it. The computer task may be structured in such a way that only one student can have access at a given time and so the students either have to decide who will work when or if they will have to work on the whole task together rather than dividing the task. The non-computer complementary task, on the other hand, may not have the single-person access restriction of a computer, thereby eliminating the need for collaboration. Nastasi and Clements do not address this possibility. Lastly, Nastasi and Clements found that as children cooperate in certain computer environments their motivation and positive social interactions increase.

It is important to note that we still do not have a full understanding of novelty effects [Krendl and Lieberman, 1988]. When studies, such as the one documented above, do show results in favour of computers, can we know how much of this effect is related to the novelty of using computers? As the spread of computers reaches the majority of homes and many schools, it is clear that computers are not quite the novelty they were in 1988 when Krendl and Lieberman, among others, questioned the novelty effect. Despite the spread of computers, however, computers are not fully integrated into most classrooms; computer usage is not as regular, say, as using the blackboard or writing in a notebook. The extent and the impact of the novelty effect is certainly an interesting issue for further research.

A number of studies have been run to compare the competitive, cooperative, and individualistic learning structures that are heavily compared in the regular cooperative learning literature. A few of these are documented below.

In 1984, Strein and Kachman ran a study to explore the effects on children's cooperative behaviour of participation in mildly competitive, cooperative and individualistic computer games. Although statistical significance was not achieved in this study, there were strong trends indicating that cooperative games did increase cooperative behaviour whereas competitive games lowered this behaviour. All the children played the same basic game, but with minor differences for the different learning structures. For the cooperative version of the game there was only a single score given and the feedback provided emphasized teamwork. In the competitive version individual scores were given for each player and the feedback was directed towards a single player. The individualistic version was identical to the competitive version except that the child played the game alone. Explanations by the authors for the lack of statistical significance include that the game itself wasn't adequate to represent the three different type of work tasks and that the length of the treatments was too short. While the authors' explanations are probably correct, the fact that statistical trends were reached suggests the power of team versus individualized scoring and feedback. One could hypothesize that if the task in the game had been a true cooperative task as described by Cohen [1994], then this coupled with team scoring and feedback might have achieved a statistically significant outcome.

A study by Strommen [1993] also makes a comparison between children playing cooperative and competitive games on a computer, but this study specifically looks at the role of the instructions given to the children. In the cooperative game two children played together against the computer and in the competitive game, the children played against each other. Strommen didn't give the children any instructions on how they should play the game and he found that children in the cooperative condition had more correct answers. The only strategies that he could significantly relate to obtaining the correct answers were ones in which children worked together. An interesting finding is that the children in the competitive condition also used these strategies but much less frequently. This study suggests that even though children may not be specifically trained in cooperative strategies and methods, the use of a properly designed application can produce both an increase in the motivation of the children and positive and effective cognitive activity as well. This finding goes against Hymel *et al.*'s conclusion that children need to be trained socially for cooperation.

Many studies of computers and cooperative learning have also been done using CAI. For example, Yueh and Alessi [1988] found in their study on cooperative learning using CAI that the combination of group and individual rewards produced higher achievement and increased peer-tutoring. They also tested the impact of group composition on performance. The general cooperative learning literature has found that medium-ability students will learn more in groups of all medium-ability students than in groups of mixed ability. In their study using CAI, however, Yueh and Alessi weren't able to determine whether group composition had any impact. Stephenson [1992-93] looked at the role of the instructor on subjects who worked individually and in pairs using CAI. He found that instructor interaction could have a positive effect on achievement when subjects worked individually whereas when subjects worked in pairs, instructor interaction had no effect on achievement. He concluded that many of the social functions that were performed by the instructor were taken over by the dyad partner.

As was mentioned in the section on educational software, many educational/computer researchers such as Soloway believe that CAI does not tap into the full potential of computers for learning. They suggest that Interactive Learning Environments (ILEs) are what we should be designing if we expect that computers will be more than just expensive flash cards. Nastasi and Clements [1993], in their analysis of a number of studies, have tried to understand the differences in collaboration within these two different educational computer environments. They compare Logo, a microworld environment that fits into the ILE category, with CAI. I explore some of their findings below.

Nastasi and Clements found that both environments, CAI and Logo, can provide opportunities for the enhancement of children's motivation to direct their own learning. This type of motivation is indicated by such behaviors as independent work, self directed problem posing, persistence, and expressing pleasure at learning. The environments, however, provide these opportunities in different ways. In CAI it is through automatic external feedback that is provided by the computer; in Logo it is through intrinsic means in that the evaluation of success is done by the students themselves or in consultation with the teacher.

Nastasi and Clements investigated the conflicts or disagreements between partners during their collaborative problem solving. They found that although Logo and CAI generated the same amount of conflictive interactions, students working in Logo were more likely to resolve these conflicts successfully. Further, students working in Logo frequently used cognitively-based strategies such as providing a rationale for the proposed solution to resolve cognitive conflicts. The CAI group, on the other hand, relied more frequently on social negotiation such as turn taking. This finding can probably be linked back to Cohen's analysis of task and interactions. In CAI and Logo the volume of interactions are the same, but the ill-structured nature of the Logo task predicts a more successful resolution of conflict. This in turn may explain why interactions during the resolution of an ill-structured task are predictors of achievement and learning.

It is necessary to note, however, that Krendl and Lieberman [1988] found slightly conflicting outcomes to Nastasi and Clements. They report that teacher mediation, more so than peer collaboration, predicted the success of Logo learning. Unlike Nastasi and Clements, they found that peer collaboration itself tended to exist on an extremely superficial level such as students organizing themselves in a turn taking modes instead of working together in a truly collaborative way. Krendl and Lieberman further found that the transfer of problem-solving and planning skills from the computer application to other tasks was limited. In fact, it was the role of the teacher that determined the transferability of thinking skills and not peer collaboration. Lastly, it was the high-ability students who were found most able to make this transfer.

5.3 Computer Supported Collaborative Learning (CSCL)

What has mostly been discussed thus far is what could be called *cooperative learning using computers*. The thrust of this research is mainly on the cooperative learning component and computers are somewhat tacked on to the end. For example, using CAI for an individual student versus a pair of students or setting up a video game that provides team feedback instead of individualized feedback makes the computer into a tool that at best permits some collaboration. Riel [1992] says that although the benefits of cooperative learning environments have been established, the transformation of traditional classrooms into the social organization that permits cooperative learning has proven to be a complex task. Adding the computer into the task does not reduce the complexity. This probably explains why early attempts at collaborative learning using computers have made the computer's role secondary. There is an area of research, however, that is trying to push the frontier of cooperative learning using computers. This area is called Computer Supported Collaborative Learning (CSCL) and as its name suggests, the computer plays a prominent role in the collaborative learning process and is not simply tacked onto the end.

As previously mentioned, CSCL is a part of the much broader HCI literature. In fact, CSCL fits under the umbrella of Computer Supported Cooperative Work (CSCW), which is itself under the umbrella of HCI. CSCW investigates what are called groupware applications. This name reflects the fact that these applications do not support individuals but rather they support group interactions in some manner, whether it be face-to-face or asynchronously (see Section 6 for more information on CSCW). CSCL is a more focused study of the use of collaboration technology than CSCW in that it deals specifically with an educational domain [Koschmann, 1992]. In CSCL, the group is a specific group, i.e. a group of learners, and so the requirements for the applications go beyond simply supporting communication.

Koschmann *et al.* [1993] divide CSCL applications into two groups: applications designed for use within the classroom and those designed for communication across classrooms via wide-area networks. Both groups of CSCL applications tend to emphasize access to learning materials as opposed to delivery of instruction.

Tele-task forces [Levin, 1992] and *Learning Circle* [Riel, 1992] are two examples of CSCL applications over wide-area networks. *Tele-task forces* are described by Levin as ad-hoc groups of people that come together for a particular task, and then disband when the task is completed. The groups interact over the network, working collaboratively and drawing on different types of expertise. The *Learning Circle* attempts to apply classroom cooperative learning procedures across classrooms, and is composed of a small number of classrooms that interact electronically to accomplish a shared goal. Each classroom in a *Learning Circle* is a team that contributes to the overall end product [Riel, 1992]. Although cooperative learning across networks shows a great deal of potential, further research is still required. Levin [1992] identifies four key areas that are crucial for the development of effective computer-supported learning environments which are based on such electronic networks:

1. The need for new forms of interaction to support distributed communities of learners.
2. The importance of mediators in these networks.
3. The need for computer-based tools for these mediators.
4. The opportunities that computer-based networks provide for integrating the world of learning and the world of work.

CSILE (Computer Supported Intentional Learning Environment) represents an example of a CSCL application that is run within a single classroom [Scardemalia, 1995]. The *CSILE* setup consists of student computers attached via a local area network to a *CSILE* server which maintains a shared workspace. It was the first network system to provide general support for collaborative learning and inquiry activities in school environments. The core is a student-built database in which the main objects are notes characterized by type, authorship, attributes and permission rules. Labels can be embedded within any notes and links between labels and notes or two notes can be created by the students. It is easy for students to post comments on other students' ideas and authors are actually notified when comments are made on their notes. Thus, if an idea is used or expanded by someone other than the author, the author will still maintain the "ownership" of the idea.

A number of very positive results have been noted since the inception of *CSILE* nine years ago. I will mention two. One is that *CSILE* students improved significantly in problem solving and recall. And a second positive outcome is that *CSILE* promotes a culture of understanding which encourages teachers to continue to learn and encourages children to expand beyond the traditional class material.

Resnick [1992, 1996] extends the "collaboration" in CSCL to include not only learning *through* collaboration but learning *about* collaboration. He uses *Logo, an extension of traditional versions of Logo, to exemplify this extended collaboration. Resnick argues that while *Logo can be used to learn *through* collaboration by having children working together on projects, what is more striking is that it enables students to design, observe, and experiment with collaboration on the screen. *Logo, unlike regular Logo, has thousands of turtles. One behaviour is programmed by the user and all turtles exhibit that one behaviour. What results is a sort of "turtle collaboration." Resnick says that one reason it is important for students to explore turtle collaboration is because people seem to have difficulty reasoning about interaction and collaboration. So although this may not be considered to be a collaborative activity[18], the goal is to promote active reflection on collaboration itself.

While many researchers are enthusiastic about CSCL, many are also aware that CSCL systems are not the solution to all educational problems. Solomon [1992], for example, says that the factors which determine whether a CSCL system is successful are far more complex than the design of the technology itself. She argues that learning requires mindful engagement that is controlled by the learner and that computers can start a chain reaction thereby affecting the nature of the whole learning environment. But whether the learning environment is actually affected by the computer depends on factors which concern the orchestration of the whole learning environment - the curriculum, the activities that students engage in, students' perceptions of the learning goals in the classroom, their social interactions, the teacher's behaviour, and more. Soloman also argues that genuine interdependence is required for computers to support collaboration. Soloman's observations are pushing the frontier of cooperative learning. In the same way that educational researchers observe that simply putting children in groups is not sufficient to result in cooperative learning, Soloman recognizes that having technology that supports collaborative tasks is also not sufficient for CSCL systems to be successful.

Despite the enthusiasm of many researchers, the acceptance of CSCL by educators has not been one of raging enthusiasm. Batson [1992] identifies that this is partially explained by our inability to compare CSCL to the traditional classroom. He says that "comparing the traditional classroom to a CSCL setting involves attempting to pair dozens of variables, any one of which could bring

[18] It might more accurately be termed coordinated parallel activity.

about significant changes in teaching and learning and many of which can't be compared because it [sic] has no counterpart in the traditional classroom" [p. 26]. Moran and Klem [1992] attribute the mediocre enthusiasm to the fact that we have ignored the effects of the new technology on teachers. They correctly note that if the new technology affects the teacher, such an effect will itself affect the learning that takes place in the classroom. Batson [1992] speculates that ultimately the future of CSCL may be determined simply by teacher preference, so if CSCL systems are going to be viable, teachers need to play a more significant role in the CSCL process.

5.4 Applying Cooperative Learning and CSCL Issues to Multi-Player Games

Games can be competitive, cooperative, or individualistic. Most multi-player arcade and video games fall into the competitive category. In these games there are usually at most two players who play simultaneously or take turns. Multi-player games for the computer also tend to be competitive but almost always involve turn-taking since until now the computer has only allowed one instance of each input device (i.e., one mouse, one keyboard, one trackball, or one joystick).

The benefits of cooperative learning have been established and therefore when educators consider the development of educational multi-player games, the cooperative approach should not be overlooked. The same complexities and difficulties that arise when moving from a traditional classroom, which has many competitive elements, to a cooperative structure will most likely arise when moving from individualistic single-player games and competitive multi-player games to cooperative multi-player games. The task or activity in a cooperative game will have to be designed such that there is individual accountability and positive interdependence. In the case of games it may be that the understanding of individual accountability needs to be reworked to reflect children's intrinsic motivation when playing. Individual accountability for games must recognize that some children will want to continue playing and may not want to allow the other members time to play. The design of the game must be structured so that each player is able to achieve their own goals without an over-enthusiastic group member taking over the control.

Cohen's work regarding the nature of the cooperative task should also be taken into consideration when designing cooperative games. If the task is a true group task that is ill-structured, then the game must facilitate communication and interaction. In addition, if the task truly requires collaboration by all group members in order to be completed, then additional reward interdependence is not needed.

Research done in the area of CSCL can also be applied to the design of multi-player games. Techniques that have been used to facilitate collaboration across networked computers could be used for collaborative games as well. For example, a game that required the transfer as well as the archival of information could take advantage of the *CSILE* infrastructure.

6. Multi-User Interface Design and CSCW

The idea of computers supporting collaboration is well established. Over the last decade there has been an increasing demand for collaborative computer usage in the workplace. People are requesting tools and technology that allow multiple users to work together independent of their location; users can be in the same room, on the same floor, in the same building on a different floor, or in a different country. The nature of the computer supported collaboration is varied. It ranges from people wanting to have the sense that they share personal space, such as an office, to wanting to work simultaneously on the same entity, such as a document or visual presentation. Designing technology to support such tasks has revealed significant HCI issues. The need for multi-user interface design guidelines and techniques that support shared spaces has been recognized.

The importance of such interfaces is perhaps best illustrated through the use of examples. Consider two people working together on editing the same document. Appropriate interfaces and protocols are required so that one user knows what part of the document is being edited by the second user in order that overwriting one another's work doesn't take place inadvertently. The computer needs to convey to each user what the other user is doing in a meaningful yet unobtrusive way. Another example is two people located in different buildings who are working together on a project. In order to facilitate both spontaneous and planned face-to-face communication, their offices may be linked with both audio and video connections. Interfaces to support interaction protocols are needed so that these links can be used effectively for collaboration while maintaining the privacy of the individuals.

Considerable research on multi-user interfaces and shared spaces has been documented in the field of CSCW (Computer Supported Cooperative Work). This work falls within the broader body of HCI literature. It is extremely important to consider the work that has been done in the area of CSCW when considering multi-user interfaces for any type of application, whether it be a game application or otherwise. I will outline some of the issues that have arisen in the CSCW research and I will then make some observations as to how these extrapolate to multi-user educational games.

6.1 Terminology

It is instructive to first define CSCW and some of the common terms found in the CSCW literature.

groupware: Groupware is software that explicitly supports group work. It is a technically-oriented label meant to differentiate "group-oriented" products explicitly designed to assist groups of people working together from "single-user" products that help people pursue their isolated tasks [Greenberg and Bohnet, 1991].

CSCW: Computer Supported Cooperative Work is the scientific discipline that motivates and validates groupware design. It is the study and theory of how people work together, and how the computer and related technologies can or do affect group behaviour [Greenberg and Bohnet, 1991].

media-space: A media space is a system that uses integrated video, audio, and computers to allow individuals and groups to work together despite being distributed spatially and temporally [Gaver *et al.*, 1993].

telepresence: Telepresence is the use of technology to establish a sense of shared presence or shared space among geographically separated members of a group [Buxton, 1992].

shared-person space: Shared-person space in telepresence is the collective sense of co-presence between/among group participants [Buxton, 1992]. Tele-conferencing is one type of shared-person space [Buxton, 1992].

shared-task space: Shared-task space is a co-presence in the domain of the task being undertaken [Buxton, 1992]. This is also referred to as *tele-data* [Greenberg and Bohnet, 1991] and shared workspace [Ishii *et al.*, 1993].

6.2 Overview of CSCW

CSCW systems can be classified by two parameters: the mode of interaction they support and the location of the users. The mode of interaction is either synchronous or asynchronous. In a synchronous system the users are interacting at the same time (i.e., interactively); in an asynchronous system, the users use the system at different times (or at the same time but not in an interactive manner). With respect to location, users are either in the same space, which is often referred to as co-located or local, or they are in different spaces, which is often referred to as remote. This leads to a four category classification system which is shown in the table below. This table is found in [Shneiderman, 1992].

	Same Time	***Different Times***
Same Place	Face-to-Face (classrooms, meeting rooms)	Asynchronous interaction (project scheduling, coordination tools)
Different Places	Synchronous distributed (shared editors, video windows)	Asynchronous distributed (e-mail, bboards, conferences)

Table 1 CSCW four category classification system.

Shared-person and shared-task spaces fit into this classification. Sharing a task can be a part of any of these four categories. To see that this is true, it is only necessary to imagine working on a shared document. One could be working on the document at the same time or at a different time than a colleague who is sitting either in the same room on in another room. Shared-person space refers to the sense of copresence and therefore applies to same time categories. Of course if the users are already in the same place there is no need for the system to support the shared-person space. Thus shared-person space fits into the same time/different place category.

CSCW systems support either shared-person spaces, shared-task spaces, or both. Because the main focus of this paper is the collaborative play of electronic games, systems that only support shared-person spaces are not of interest. The electronic game itself represents a shared-task space. Thus, the issues for strictly shared-person systems will not be given significant coverage here.

6.3 "Being there"

One of the main goals of CSCW systems is to emulate face-to-face communication and achieve a sense of being there. The goal is to design systems that provide the same contextual richness which exists naturally when people work face-to-face on non-computer supported shared tasks such as a whiteboard. Hollan and Stornetta [1992] have effectively argued the extreme position that we should not necessarily try to emulate face-to-face communication, or *being there*, when we design computer supported communication. We should instead design communication systems that are *beyond being there*, or better than being there. Stated in other words, the goal should be to design systems so people at a distance are not at a disadvantage to those who are present. For people at a distance not to be at a disadvantage, local people must use the system as well. The only way that local people will choose the system is if it offers more than meeting face to face. The latter is considered by Hollan and Stornetta to be the litmus test of a system. The features that a new communication medium could take advantage of in order to meet this challenge are: the ability to support asynchronous communication; the ability to support anonymous communication; and the ability to automatically archive communication. One such form of communication that meets this litmus test is e-mail.

6.4 Examples

Before proceeding with general design criteria for CSCW systems, it is instructive to highlight two specific examples. *GroupSketch* exemplifies a shared-task application and *MERMAID* exemplifies a media-space that supports both shared-task and shared-person spaces.

6.4.1 *GroupSketch* (shared-task)

GroupSketch [Greenberg *et al.*, 1992] is a groupware system that provides small groups of two to approximately eight people with remote real-time access to a shared-drawing space. It is a minimalist multi-user sketchpad that occupies the entire computer display. It is WYSIWIS (what you see is what I see), and it allows users to draw, type, erase, and gesture simultaneously in the communal work surface, supporting interactions similar to those occurring in the face-to-face process. It also allows for the saving and restoring of the image.

Each participant using *GroupSketch* has a labeled cursor and a unique caricature displayed outside the border of the writing/drawing space. There are four action modes, namely pointing, drawing, listing, and erasing, and the cursor automatically changes form depending on the mode. For example, the cursor becomes pen-shaped when a user begins to type. The mode is indicated by the input. For example, to draw, the mouse is used with the left button depressed. All different forms of the cursor are extra-large in size; they are 64bit by 64bit instead of the regular 16bit by 16bit. This permits better visibility and coordination of participants' activities. There is no social protocol enforced for the interaction; the coordination is left entirely to the participants. There is a fully duplex audio channel enabled and the system provides instantaneous shared views of the display.

Reported observations of *GroupSketch*:

- It is very easy to learn.
- It is effective
- Increasing the number of participants in an open floor policy increases parallel activity but also decreases focused attention.

- Movement of a participant's cursor synchronized with the participant's voice provides the greatest sense of tele-presence.
- The shared work surface captures participants' attention and focused interaction.
- Participants desire greater functionality.
- Intermixing listing and drawing (text and graphics) occurs frequently and naturally.
- Vertical orientation of the work surface removes the physical limitations of the table top.
- Saving only one image is not enough.
- The work surface is too small.
- The worst part of it is trying to draw with a mouse.

GroupSketch was designed based on six criteria formulated by Tang; its success is largely attributed to adhering to these criteria. Tang's criteria can be found in Section 6.5.1.

6.4.2 *MERMAID* (shared-task and person)

The *MERMAID* (multimedia environment for remote multiple attendee interactive decision-making) system is a desktop conferencing system that provides both multimedia communication and presentation [Watabe *et al.*, 1991]. Its goal is to provide widely dispersed group members with an environment at their desks for holding formal or informal multi-party conferences.

MERMAID provides four modes for floor passing (passing control from one participant to another). One of the four modes is free mode in which all the participants can simultaneously manipulate the shared window. In the other three modes[19], there is one floor holder and the designation of user to floor holder position is more regimented. A floor holder controls the manipulation of the shared windows and can perform such operations as opening and closing shared windows, loading documents to the shared windows, scrolling documents, hand-drawing, and scanning documents.

[19] These three modes are designation mode, baton mode, and first-come-first-served mode. In the designation mode, the chairperson of the meeting always selects the next floor holder. In the baton mode, the former floor holder designates the next floor holder, which is analogous to passing a baton during a relay race. In the first-come-first-served, there is a request queue and the floor is passed in the order of the requests in the queue.

The main windows included in *MERMAID* are:

- Shared window for shared tasks.
- Personal window is a form of electronic notebook similar to the shared window except that the contents are not seen by all participants.
- Video window can display either one other participant or display all four parties simultaneously by dividing the video window. This window is often used for presenting objects and it can be extended to occupy the whole screen space.
- Status window contains status information such as who has the floor for manipulating shared windows, the duration of the conference, etc.

Reported observations of *MERMAID*:

- Voice was the easiest and most commonly used medium for communication. When more than four people join a conference and participants do not already know one another's voices, there was some difficulty in determining who was speaking.
- Participants found that video images of participants' faces on workstation screens enhanced the visual effectiveness of conferences.
- Different modes of floor control were used depending on the respective rank of the participants. If the participants were peers, then a free mode was used. If participants were of different ranks, then floor control which gave the person of higher rank the control was usually selected.

6.5 Design Criteria

A number of design criteria or guidelines have surfaced in the CSCW literature. I include two sets of guidelines below. The criteria by Tang [cited in Greenberg *et al.*, 1992] are specifically for shared-task spaces and have been frequently referenced in the literature. The criteria by Sasse and Fentem [1994] cover both shared-task and person spaces. These criteria are new to the literature.

6.5.1 Shared-Task Space

Tang's criteria were derived from observations that he made during his ethnographic study of eight short, small-team design sessions. The six criteria are found below. This table is found in Greenberg *et al.* [1992] and is condensed from Tang's doctoral thesis completed in 1989.

Design Criteria	Reasons
1. Provide ways of conveying and supporting gestural communication. Gestures should be clearly visible, and should maintain their relation with objects within the work surface and with voice communication.	• Gestures are a prominent action. • Gestures are typically made in relation to objects on the work surface. • Gestures must be seen if they are to be useful. • Gestures are often accompanied by verbal explanation.
2. Minimize the overhead encountered when storing information.	• Only one person usually records information. • Other participants should not be blocked from continuing private or group work while information is being stored.
3. Convey the process of creating artifacts to express ideas.	• The process of creation is in itself a gesture that communicates information. • Speech is closely synchronized with the creation process. • Artifacts in themselves are often meaningless.
4. Allow seamless intermixing of work surface actions and functions.	• A single action often combines aspects of listing, drawing and gesturing. • Writing and drawing alternates rapidly. • Actions often address several functions.
5. Enable all participants to share a common view of the work surface while providing simultaneous access and a sense of close proximity to it.	• People do not see the same things when orientation differs. • Simultaneous activity is prevalent. • Close proximity to the work surface encourages simultaneous activity.
6. Facilitate the participants' natural abilities to coordinate their collaborations.	• People are skilled at co-ordination communication. • We do not understand the co-ordinating process well enough to mechanize it.

Table 2 Tang's design criteria for a shared-task space.

6.5.2 Shared-Task and Person Space

Sasse and Fentem [1994] performed a small exploratory study with a multimedia conferencing system. Based on observations, structured interviews, and returned questionnaires from this study as well as knowledge from the HCI and ergonomics literature they composed a list of design recommendations which include:

1. *Independence*: The input mechanisms for each media that are being used simultaneously (e.g. workspace and audio) should be as independent from one another as possible. This would provide a stronger link for the users between the input devices and their effect.
2. *Reception feedback*: The participants in a conference should be able to tell how well the output from their media input devices is received by the other remote participants.
3. *Participant and speaker information*: To aid participants, especially in conferences consisting of more than one unfamiliar person, it should be salient who is speaking at any one time.
4. *Seamlessness*: There should be window seamlessness and event-capture seamlessness. A system is window seamless if it is possible to grab other windows, move them into the shared workspace, and modify/annotate them using the whiteboard. A system is event-capture seamless if it is possible to capture conference events in any format that the user requires such as full video, printout, etc.
5. *Video-window management and content*: There should be management of windows so that the screen doesn’t become cluttered with windows.
6. *Shared workspace functionality and flexibility*: The workspace should provide as much or as little functionality as the user can cope with or desire. The functionality would be available in a modular form where all modules are mutually compatible.
7. *Media integration*: All of the media should share one interface.
8. *Communication should be real-time and synchronized*.
9. *Workspace awareness*: The most recent additions/changes from other participants should be made more salient to the user.

6.6 Awareness

Designing for the awareness of others is a common theme throughout both Tang and Sasse and Fentem's guidelines. Building awareness into cooperative systems represents the need to replicate the contextual cues and richness that are available when people have traditional meetings or conferences and/or work on traditional work surfaces. For example, consider Sasse and Fentem's guideline to include participant and speaker information. This information allows users to be aware of who is participating in the collaboration. Clearly this information would not be necessary if the collaborators were co-located because it is visually and audibly obvious who is participating and who is talking.

Cutwin *et al.* [1996a] categorize awareness into *informal awareness* and *workspace awareness*. They define informal awareness to involve knowing who's currently around, whether they're available or busy, and what sort of activity they're engaged in. Workspace awareness, on the other hand, involves knowing where in the space others are working, what they are doing, and what changes they are making.

6.6.1 Informal Awareness

Media spaces are one way of providing distributed groups with informal awareness of each other [Greenberg, 1996]. Users can select offices and common areas at remote sites, and view them through continuous video. Examples of such systems are *Portholes* [Dourish and Bly, 1992], *VOODOO* [Li and Mantei, 1992], and *RAVE* [Gaver, 1993]. The set of issues that this type of system has to deal with include privacy and bandwidth.

While audio-video connections provide a sense of shared presence, they can also pose a serious threat to the privacy of the individuals using them. Both the *VOODOO* and the *Portholes* systems have video connections directly into the users' offices. This enables users to glance into their colleagues' offices to see if they are there or to establish a connection for communication. Although this functionality is extremely useful, it is clearly gained at the expense of privacy. *VOODOO* addresses the privacy issue in two ways. First it allows the user to explicitly set a level of accessibility so that the user decides when and when not to permit interruptions. It also enforces reciprocity in the video and audio channels. It does so under the premise that in an open office, viewing and listening is reciprocal. The developers for *RAVE* have taken a slightly different approach. They have kept one-way connections because of the advantages that they provide. For example, glances provide awareness without actually engaging or interrupting one's colleague. Notification that a colleague is glancing is given, however, in the form of an auditory cue as described previously. Similar to *VOODOO*, *RAVE* allows the user to explicitly set their accessibility. In *RAVE*, however, accessibility can be set differently for different colleagues or co-workers.

The high bandwidth that video demands is another concern with media space systems that provide informal awareness. Even compressed video demands too much bandwidth for everyday use [Greenberg, 1996]. Greenberg [1996] notes that although *Portholes* [Dourish and Bly, 1992] partially solves this problem by periodically transmitting small video snapshots instead of a video stream, it still requires people to have video cameras attached to their workstations and a willingness to leave them turned on.

Greenberg [1996] presents iconic *presence indicators* as an alternative to video. These indicators show who is around and the likelihood of their availability. These peepholes simply check who is logged on to a system and provide slightly different iconic representations if a user is logged on or not, and if logged on, for the activeness of a session. The system provides functionality such as notification when a particular user's session becomes active.

6.6.2 Workspace Awareness

Workspace awareness involves knowing who, how, and where others are interacting in the workspace. The table below shows a set of elements that Cutwin and Greenberg [1996] consider to be part of workspace awareness. Questions that a participant might ask themselves during a shared activity are included in the table. Clearly, if a participant could pose these questions then the system should be designed in such a way that the answers are readily available to the users.

Element	Relevant Questions
Presence	Who is participating in the activity?
Location	Where are they working?
Activity Level	How active are they in the workspace?
Actions	What are they doing?
	What are their current activities and tasks?
Intentions	What will they do next? Where will they be?
Changes	What changes are they making, and where?
Objects	What objects are they using?
Extents	What can they see? How far can they reach?
Abilities	What can they do?
Sphere of influence	Where can they make changes?
Expectations	What do they need me to do next?

Table 3 Elements of workspace awareness. This table has been taken from Cutwin and Greenberg [1996].

Some of these elements have been addressed by workspace awareness techniques and others require further research. The section that follows covers some of these techniques.

6.7 Issues for Shared Workspaces

There are a number of techniques used to maintain workspace awareness and issues involved in the design of shared workspaces. Techniques include feedback, views, audio, video, colour, and seamlessness. Issues that are important regarding shared workspaces include states/modes, coordination, the number of participants involved, and functionality versus intuitiveness.

6.7.1 Feedback

Feedback is covered by Tang's third item and Sasse and Fentem's second, third, and ninth items. Feedback is a mechanism by which a user is made explicitly aware of an action undertaken or a change to the current state that the user has made. For example, in most word processors when a user selects text for cutting the text becomes highlighted so that the user is made explicitly aware of the exact text that has been selected. In a multi-user system feedback of an action must be provided to all users in the shared workspace, not just to the user who performed the action [Morris *et al.*, 1992]. Although this might seem obvious, early cooperative systems did not broaden the understanding of feedback in this way. One example of such a system is Cognoter [Tatar *et al.*, 1991]. Morris *et al.* note that it is not always obvious where the best location or format for the feedback might be.

Feedback plays a role in common views which are described next.

6.7.2 Views

One way to increase collaborator awareness is through the provision of different views of the workspace. A *common* view or WYSIWIS (what you see is what I see) is an important feature that was missing in some of the first shared-task space systems [Greenberg and Bohnet, 1991]. The importance of such a view is covered in the fifth criterion in Tang's list of six criteria. A common view enables all the participating users to orient themselves in the same direction towards the work surface so that all the users see the same thing. This view can also be called an *observation* view [Baecker *et al.*, 1993].

While having a common view is necessary for workspace collaboration, it is not sufficient. The shared workspace is often too large to fit into the whole screen and so participants may need to work in different sections of the workspace. Thus strictly WYSIWIS interfaces present problems of screen real estate management and distraction [Gibbs, 1989]. As a result there has been a move to relaxed-WYSIWIS interfaces. Cutwin *et al.* [1996b] note that supporting awareness is more complex for these interfaces.

One example of relaxed-WYSIWIS is the *gestalt* view introduced by Baecker *et al.* [1993]. This view presents a condensed image of an entire document as well as all collaborators' positions and text selections in the document. Cutwin *et al.* [1996b] provide a similar view called a *radar* view which adds information about other people's interaction to a basic overview. The overview already provides a spatial representation of the workspace and the radar view adds information about where others are working and what each person can see. This is accomplished by marking view outlines and showing fine-grained location by including miniature telepointers that represent each participant's mouse cursor. The radar view also supports awareness of activity since it shows movement of and changes to artifacts in the workspace.

Another relaxed-WYSIWIS view introduced by Cutwin *et al.* [1995] is called the *what you see is what I do* (WYSIWID) view. This view shows only the immediate context around another user's cursor, which is a subset of that user's view. The view stays centered around the user's cursor and the background is panned when that user moves the cursor.

Usually a common view is an available option in relaxed-WYSIWIS interfaces. This allows a user to "latch-on" to the view of a second user enabling the first user to follow in detail the actions of the second user. This is somewhat analogous to a user looking over the shoulder of a second user.

6.7.3 Audio

Audio can be either speech or non-speech. It has been found that speech audio adds significantly to the collaboration process [Greenberg and Bohnet, 1991; Gaver *et al.*, 1992]. As an example, the movement of the cursor synchronized with a participant's voice in *GroupSketch* provided the greatest sense of tele-presence [Greenberg *et al.*, 1992].

Non-speech audio has also been found to increase collaborator awareness. For example, Hereford and Winn [1994] noted that audio clues allowed participants working in a collaborative simulation system to diagnose problems and monitor the whole system as well as their own individual portion of the system. Hereford and Winn said that in general, the collaborators exhibited an awareness and interest in the whole system rather than just the system component designated to each of them individually.

Gaver *et al.* [1992] note that there are a number of advantages that nonspeech audio has over graphics, text or speech. The following advantages are given: sounds can be heard without requiring the kind of spatial attention that a written notification would; non-speech audio cues often seem less distracting and more efficient than speech or music; sounds can be acoustically shaped to reduce annoyance; and finally, caricatures of naturally-occurring sounds are a very intuitive way to present information.

6.7.4 Video

It is natural to assume that using video for shared-person spaces is beneficial. The intuition that video adds a sense of presence to telecommunications stems from its ability to add facial expressions and gestures to standard audio-only conversations [Brinck and Gomez, 1992]. Sasse and Fentem [1994] note that the video-channel does appear to play a significant part in increasing the "satisfactoriness" of a conference.

Video can be also used to support the performance of a task [Buxton, 1992]. This usually occurs when only one user is performing a task and the collaborating users are watching and perhaps providing help. Here the video is showing the actual task space. It is more often the case, however, that video is used in addition to having a shared-task application such as an editor or whiteboard. So the video is really adding a sense of shared-person space to the shared-task space. Thus we have the integration of the spaces.

The relative merits of audio and video for creating a shared presence is a well discussed topic [Greenberg and Bohnet, 1991; Gaver *et al.*, 1992]. The consensus seems to be that allowing people to see one another does not add significantly to the process of collaboration. In other words, visual information has no significant effect on the dynamics of conversation. Buxton [1992] found that when visual attention was directed at the computer screen, the speech and non-speech audio established a shared space which was more effective than the highest fidelity video display. However, tasks that involve conflict, bargaining and negotiation are affected by face-to-face visual communication [Gaver *et al.*, 1993].

6.7.5 Colour

Colour can be used effectively to promote collaborator awareness. One example is the shared editor *SASSE* [Baecker *et al.*, 1993]. Each of the authors maintains a unique colour for the life of the document, and thus all document updates can easily be associated with a particular author. In addition, colour makes it easy to discern where in a document the different authors are working. Baecker *et al*., however, do not clarify how many different authors the shared editor supports and whether an author always uses the same colour for different documents. This could be important if groups create a number of documents over time. *SASSE* also provides the use of telepointers. Although Baecker *et al.* [1993] doesn't mention it specifically, I assume that the telepointers for each of the authors take on these same unique colours. So as well as being able to locate where a particular author is working, it is also possible to distinguish which author is pointing something out in the document for the other authors to focus upon.

6.7.6 Seamlessness

The seamless integration of the task space and the person space is one of the most important attributes of any telepresence system. This is because in true face-to-face interaction, these spaces are naturally integrated and the goal is to make the telepresence system as natural as possible [Buxton, 1992]. The typical approach to providing video images is either tiled windows or overlapping windows[20]. These visually separated windows impose seams between faces and tasks [Ishii and Arita, 1991]. Below I highlight two techniques that have been developed to address seamlessness.

A multi-user interface design technique called *ClearFace* is proposed by Ishii and Arita [1991] as a solution to these imposed seams as well as the lack of screen real estate. In *ClearFace*, translucent live face windows are placed over a shared-drawing window. This represents an attempt to provide a smoother transition between face-to-face conversation and shared-drawing activity which is essential for the seamless support of dynamic interaction in design sessions. Several layout strategies were tried: fixed location windows and movable and resizable windows. Because users hesitated drawing over the faces, it was found that the movable and resizable

[20] Tiled video windows are placed outside the workspace such that the video images can each be seen in their entirety. Overlapping video images, on the other hand, are placed on top of one another and/or on top of the workspace such that only a portion of the image is visible. The user must click on an overlapped window in order to make the image fully visible. The advantage of tiled windows is that all images can be seen. The disadvantage is that there is significantly less screen real estate available for the workspace. With overlapping windows it is just the opposite. Although the workspace can use more of the screen, the window images may not always be visible and/or may block the workspace, which can be distracting.

window strategy was best. Experiments confirmed that there is little difficulty in visually separating the overlaid video layers (face and drawing surfaces). This ability of human perception is accounted for by the theory of selective looking.

A second technique for seamlessness called *ClearBoard* is proposed by Ishii *et al.* [1993]. *ClearBoard* is based on the metaphor of "talking through and drawing on a transparent glass window." *ClearBoard* allows users to draw on and gesture directly over the screen surface and provides a common drawing orientation to the users.

6.7.7 States/Modes

Tang in his fourth guideline talks about a kind of seamlessness that differs from the one mentioned above, namely, the seamless intermixing of work surface actions and functions. This limits the need for states or modes. In addition to the reasons listed for this guideline, using modes or states can sometimes add to a user's cognitive load because (s)he has to remember which mode or state (s)he is in. This problem is increased when there are multiple users.

An example of how states can be problematic was documented by Pedersen *et al.* [1993] for the design of *Tivoli*, an electronic whiteboard. An important design issue for *Tivoli* was the means by which to enable different users to use the board. It was decided that the board would support three different pens and that different states were necessary. The two states were "pen state" and "system state." Something that belongs to a given pen's state, such as the selection of objects by that pen, could not be operated on by a different pen. Another example is that a pen could not erase the actions of a different pen. This design conflicted with the designer's goal of making the board act as a regular whiteboard. In the latter case, a user can easily erase or modify objects drawn by a different user.

6.7.8 Coordination

User coordination is a very important issue when there is more than one user. Designing for coordination often comes down to two choices: embedding support for a protocol within the software or leaving it to social interaction [Gibbs, 1989]. Tang recommends the latter in his sixth guideline, stating that our understanding of the coordinating process is not sufficient to mechanize the process. Morris *et al.* [1994] adds that imposing coordination through some form of floor control policy is a technological solution to the problem of coordinating action, not a user-centered one. Rigid floor control policies remove control from the user which can lead to dissatisfaction with the system.

GroupSketch [Greenberg, 1992] adheres to Tang's recommendation and experimental observations indicate that users are able to successfully coordinate themselves. *MERMAID*, on the other hand, implements a number of floor passing protocols, one of which is the free mode while the others are more regimented. Watabe *et al.* [1991] reported that under experimental conditions the regimented protocols seemed to be used effectively. One could question whether cultural differences come into play in this controversy over implementing rigid protocols. The Watabe *et al.* experimentation was conducted in Japan, where the rules for the respect of superiors are strongly entrenched in the culture. Perhaps in that environment, having the system support these rules is appropriate.

6.7.9 Number of Participants

The support of a larger group size seems to be an unresolved issue in CSCW. There are a number of problems that arise when the number of participants goes beyond approximately four. Observations of *GroupSketch*, for example, found that while increasing the number of participants in an open floor policy increases parallel activity, it also decreases focused attention [Greenberg *et al.*, 1992]. With respect to voice, observations of *MERMAID* found that when more than four persons join a conference and participants do not already know one another's voices, there was some difficulty in determining who was speaking. The use of video also poses design problems because the images of each participant takes up a significant amount of screen space [Ishii and Arita, 1991].

6.7.10 Functionality vs. Intuitiveness

There is a fine line between functionality and intuitiveness. It is often the case that increasing functionality results in a less intuitive system. One of the conclusions regarding the interface design for *Tivoli*, for example, was that the designers had erred in favour of increased functionality over intuitiveness [Pedersen, 1993]. Greenberg and Bohnet [1991], on the other hand, reported that computer literate users desired increased functionality in *GroupSketch*. Sasse and Fentem [1994] suggest in their sixth guideline that workspaces should provide an amount of functionality that is appropriate to the users' abilities and desires.

The balancing act between a simple, intuitive application and a functionally-rich and complex application is a debate that is not unique to multi-user applications. One would assume that the right balance is probably application and user dependent whether it be multi-user or single-user.

6.8 Challenges and Problems with Groupware

6.8.1 Understanding the Nature of Groups and Organizations

We interact with other people continually and usually rather effortlessly, but designing computer support for collaboration is very difficult because we have to actually understand how groups and organizations function. Grudin [1991] describes this as the paradox of collaboration. And he argues that it is this lack of understanding of group behaviour on the designers' part which is largely to blame for the general failure of groupware. Grudin [1994] lists eight current problems with CSCW applications. The first five address a lack of understanding of the work environment and the last three address a need for changes in the development process. I paraphrase them as follows:

1. Often the people who use the application are not the ones who benefit from the application - e.g., employees keeping an electronic calendar so their boss can schedule meetings with them.
2. It is difficult to get enough people to use the system to make the system work. (The critical mass problem.)
3. Groupware often interferes with the subtle and complex social dynamics that are common to groups.
4. Groupware is sometimes designed for the way processes are supposed to work (according to a procedural guide for example) rather than the way they actually work in practice.

5. Infrequently used features need to be better integrated with more frequently used features and thus made less obtrusive.
6. It is very difficult to evaluate multi-user applications and so we don't often learn from our mistakes.
7. Designer intuition doesn't work well for multi-user applications.
8. The introduction of groupware into the workplace has not been careful enough.

A more in-depth discussion of items six through eight follows.

6.8.2 Evaluation

It is very difficult to evaluate multi-user applications and so we don't often learn from our mistakes. Morris *et al.* [1992] note that there is no widely accepted methodology for evaluating synchronous multi-user systems where the users are geographically separated. They discuss how the single-user evaluation techniques of software logging, video and audio recording required adaptation for use in a multi-user environment.

6.8.3 Designer Intuition

The design methodologies that were developed for use with single user systems are often inadequate for studying group situations. In a groupware system each user must interact with both the system as well as the other group members who are also interacting with the system; hence, groupware design encounters all the interface design challenges of single-user applications and more [Morris *et al.*, 1992; Grudin, 1994].

An example of the failure of designer intuition was reported by Tang [cited in Greenberg *et al.*, 1992]. He found that the conventional intuition of small group activities was that these activities consisted primarily of creating and storing a drawing artifact. His ethnographic study showed, however, that this type of activity only took up 25% of the group's time, whereas expressing ideas took up approximately 50% and mediating interaction roughly 25%.

Poor designer intuition has also lead to a number of systems that were guided by technological, not user-centered considerations [Morris *et al.*, 1992].

6.8.4 Introducing Groupware to the Workplace

Groupware has not been introduced carefully into the workplace. One solution Grudin suggests for this problem is the addition of groupware features to already existing and accepted applications. He says that it is common for a shared editor, for example, to fail because the users don't want to give up using their favourite word processors.

6.9 Applying this research to educational multi-player games

Clearly CSCW research has an important role to play in the design considerations for multi-player games. To benefit from CSCW research it is necessary to understand how multi-player games in an educational environment differ from applications that are studied in a CSCW context. We have to ask what can be learned from the challenges and problems that have been documented about groupware. And we have to look at design issues for CSCW applications and ask whether they will be applicable to multi-player games.

The similarity between general CSCW applications and educational multi-player games is obviously the use of technology to support group interactions. The differences are the users, the genre of applications, the environment, and the intention of the users. These are listed below:

	CSCW	**Educational Multi-Player Games**
users	adults	children
applications	productivity office applications	games
environment	workplace	classroom, home
users' intentions	complete a task	learn skills, concepts, or facts

Table 4 Differences between CSCW and educational multi-player games.

6.9.1 Learn from the challenges and problems encountered with groupware

According to Grudin [1994], the failure of groupware can largely be attributed to designers' lack of understanding of group behaviour in the workplace. This finding is extremely valuable for multi-player game designers even though the environment under consideration is different. Designers should strongly consider a number of questions before launching into large implementations. At the broadest level the question would be: what is the nature of group behaviour and dynamics when children are playing games? At a fine level we have the following questions: If a game doesn't specifically require turn-taking, how do children coordinate themselves for turn-taking? What different types of roles do children assume in the classroom and how does this impact their behaviour when playing games? How does children's actual behaviour within a game relate to expected behaviour? If expected and actual behaviour differ, which should be incorporated into the design?

Incorrect designer intuition will also be an issue for multi-player games. Many designers of successful single-user workplace applications built multi-user applications based on their own intuition and failed. It is probable that designers, who often focus on a single type of application, will build multi-user games based on intuition derived from that one type of application. Thus intuition will be based on single-user games, non-game groupware, or workplace applications. Unfortunately, unless designers of these multi-user games take into account *all* of these areas and others, such as children's group behaviour, then the intuition will prove to be insufficient just as it was for CSCW applications.

The lack of evaluation tools for multi-user applications may also play a role with multi-user games. However, I suspect that the difficulty in evaluating educational games as a whole (computer, non-computer, single-player, and multi-player) and their role in the classroom will probably continue to dominate the evaluation dilemma.

The introduction of multi-player games into the classroom will have to be done more carefully than the introduction of groupware into the workplace. Given the entertainment aspect of games, the students will not be hard to sell on the idea of using electronic games. The teachers and parents, on the other hand, may not only be skeptical about using the game paradigm but also about using and managing the technology itself. This teacher skepticism has been seen with the use of CSCL systems in the classroom. In short, significant support for teachers is required if these games are going to be viable.

6.9.2 CSCW Classification

The 2 x 2 classification of CSCW based on time and location (see Table 1) is incomplete when considering the use of computers by children in the classroom. The underlying assumption of the same time/same place category is that each participant has his/her own computer. While this assumption may be appropriate for adults in the workplace, it does not apply to children in the classroom. As was documented in the section on CSCL, same time/same place interaction often involves multiple children working on a single computer. This is a whole area of groupware that needs further investigation. The work by Inkpen *et al.* [1995a] and Bricker *et al*. [1995] that documents the use of multiple mice on a single computer which enables two students to share a single machine recognizes the need for research in this area. In the system designed by Inkpen *et al.* only one mouse is active at a given time and a mouse passing protocol is used to transfer control between users. Bricker *et al.* document a system in which multiple mice are active at one time but each mouse has distinct objects on which it can act. The addition of users sharing a single computer leads to at least a 2x2x2 classification of (*same time, different time*) x (*same place, different place*) x (*shared computer*, *separate computers*).

6.9.3 Beyond being there - how can technology enhance the game experience?

The notion of *beyond being there* documented by Hollan and Stornetta [1992] can also be applied to multi-player games. Using technology simply to mimic multi-player co-located situations is only a preliminary goal. Such a goal is worthwhile because it will enable game playing among distributed children who would not otherwise be able to play together. It will make it possible to bring together children who don’t know one another. But a larger goal, one that would make multi-player games *beyond being there,* is also possible. The goal is to design multi-player games to support features that make these games attractive alternatives to both non-computer games and electronic single-player games for co-located children. Thus if co-located children choose to use the multi-player games over the other alternatives, then the players who are distributed will not be at a disadvantage. Features or capabilities that could make the games more attractive include: ability for asynchronous play (e.g. e-mail chess), provision of anonymity (which may be desirable for shy children), ability to maintain a permanent record of the game interaction (which is the largely attractive feature for MUDs[21] games), ability to experiment with different turn-taking policies, and perhaps even the ability to switch between different cooperative learning structures.

6.9.4 How are CSCW design criteria and issues impacted by children and game playing?

Children

Here we must revisit the need for HCI for children. Techniques that support cooperation and promote awareness for adults may not work in the same manner for children. It is easy to guess that using different colours to represent different participants will likely work as effectively for children as it does for adults. (In fact using different colours for participants mimics the differently coloured playing pieces in board games.) It is extremely difficult to predict, however, whether more complex interaction techniques such as the radar view by Cutwin *et al.* [1996b], would work with children. Children's spatial skills may not be developed sufficiently to understand this form of overview representation. As another example, states/modes are difficult enough for adults to keep straight and would likely be more difficult for children. Yet another example is the transparency technique in *ClearFace*. Would children have the ability to distinguish between the facial images and the drawing surface onto which they are overlaid? The fact is, we just don't know the answers to these questions. These techniques and design guidelines need to be explored using children as subjects. We also must be careful not to limit ourselves to techniques that are proven to work for adults. Children are better at some things than adults (e.g., patterning, exploration, learning languages, etc.). It is possible that some techniques that have failed on adults or techniques that haven't even been tried on adults may work for children.

Game Playing

Not only do each of the CSCW design criteria and techniques need to be reassessed with respect to children, but also with respect to the context of game playing. One would expect that designing for collaboration in the office has both similarities and differences to designing for collaboration within a game.

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[21] MUDs are multi-user text-based games played over the Internet. See Section 7 for further information.

I found one example of a cooperative game that was documented in the literature. De Koven and Radhakrishnan [1990] designed a distributed game for which they considered two different control passing protocols: opportunistic control and a serialized token-passing mechanism. The opportunistic protocol basically meant that no control was imposed and any player could take control when they felt like it. The serialized token-passing control meant that only the player with the token could act and after acting was expected to pass the token to the pre-defined next player. If the player did not wish to act, then (s)he would simply pass the token. In order to complete the game, it was necessary for each player to act at some point; one player could not hold the token and complete the game by (her)himself. The designers chose the token-passing protocol because they felt that the opportunistic protocol might have imposed a competitive pressure on the players but the authors also admitted that it was chosen because it could be integrated easily into their distributed system.

De Koven and Radhakrishnan found that the players did not adapt well to the token-passing protocol. The players needed to be reminded to pass the token and having the token made the players feel as though they needed to act even if a more optimal strategy would have been for the player not to act and to simply pass along the token to the next player. Token passing was not conducive to the spontaneous participation of a player. De Koven and Radhakrishnan concluded that an opportunistic control mechanism, based on the current state of the board, would have been more suitable for their game.

De Koven and Radhakrishnan also encountered the same workspace overview issues that have been encountered in the CSCW literature. Each player in the game was only shown their own quadrant of the playing surface. It was found that the cognitive overload was reduced for the players when they were allowed a pen and paper to draw out the whole playing board so that they could get the global picture. Although having the global picture was not strictly necessary for the game, the players obviously felt a need for it. Thus the designers concluded that a well designed user interface that provides a global view of a distributed problem in an easily perceivable way could reduce the cognitive overload. It should be noted, however, that using a pen and paper to draw the global picture may be a better learning (and cooperative) activity than merely being able to see it on the display.

In the instance of the particular game documented above, the findings regarding floor control policies and global overviews indicate that the design of multi-player games has similarities to and can benefit from CSCW research. But it may also be the case that some of the CSCW design guidelines and techniques may not be appropriate for a gaming environment. Take the guideline of awareness as an example. In CSCW applications, the need to provide collaborator awareness and workspace awareness is paramount. For games, however, the degree of awareness will most likely depend on the nature of the game being played. Part of the challenge in a game may be to figure out what the other player has done, so receiving full feedback may not be desirable.

7. Electronic Multi-User Games

Issues related to electronic multi-user games are not well represented in the literature. I speculate that the reason for this is that the great majority of multi-user games are commercial games that run on video game platforms (e.g., Nintendo). The design of these games are generally not covered in research papers or monographs. One category of multi-player games that does get some coverage is MUDs, which are in the public domain.

7.1 MUDs

MUDs traditionally refer to multi-user role-playing fantasy games that are electronic adventures run over large networks[22]. They are multi-user in that as many as 100 players can simultaneously roam the fantasy world together [Kelly & Rheingold, 1993]. Given that MUDs run over global networks, players from all over the world are meeting daily in these fantasy lands. Resnick [1992] says that MUDs go beyond traditional adventure games in two important dimensions. The first is that MUDs allow collaboration. The second difference is that they allow the players to invent and

[22] Actually the term MUD is now used to refer to more general forms of multi-user domains, i.e., not necessarily found on the standard type of fantasy adventures.

build the world in which they are roaming. Kelly & Rheingold state that “the game is to create a cooler world than you had yesterday” [p. 70]. Resnick argues that although existing MUDs were not designed as learning environments, “the MUD concept offers rich opportunities for learning” [p. 36].

MUDs have proliferated since the original MUD was created and put on the Internet in 1980. It was created by two British college students who were fans of the fantasy role-playing board game *Dungeons and Dragons*. They called it MUD for Multi-User Dungeons [Kelly & Rheingold, 1993]. Since then, about 200 similar games have surfaced and there may be as many as 200 undocumented games out there as well [Kelly & Rheingold, 1993]. Some of the current generic names for MUDs are Muses, TinyMUDs, and MOOS, depending on the programming language used or the type of game played [Kelly & Rheingold, 1993]. MOOs are MUDs that are written in object-oriented programming languages. Muses and TinyMUDs are socially oriented MUDs. Beegle [1995] groups MUDs into three loose categories: Combat, Social, and Story MUDs. Combat-MUDs make heavy use of coded commands by which participants engage in regular combat. Social-MUDs provide a means for people to meet and visit in a social setting. And Story-MUDs serve as environments for role-playing and the cooperative telling of stories set in fictional worlds.

The great majority of MUDs do not involve fancy graphics or colour; they are text-based games. To navigate the fantasy world the player must read descriptions and specify directions, movements, and actions for their character by typing them in. Similarly, to talk with another character, the player must type in the dialogue. For example, entering the command “look” will produce a description of the room in which the character is currently located. MUDs, however, are not all text based. Habitat, for example, was one of the first multi-user role-playing games to introduce graphics. The game was extremely popular during the early 1990s in Japan but did not achieve the same success in the US, where it had been developed [Johnstone, 1995]. Perhaps the decline in enthusiasm in the US can be explained by the restriction that graphics put on the creativity of the players. Because the game did not come with a graphics toolkit, all new region generation and object creation had to go through the game developers [Morningstar and Farmer, 1991]. Thus players were not able to participate in the invention of the fantasy world in the same way that they could in text-based MUDs.

The majority of MUDs players are males in their early 20s [Kelly & Rheingold, 1993; Johnstone, 1995], so it is not surprising that violence and obscenity is prevalent in these virtual worlds. The MUD Cyberion City was developed at MIT in response to all of the “slash and hack” universes [Kelly & Rheingold, 1993]. This MUD outlaws killing altogether and has gathered a huge following of elementary and high-school students. On an average day approximately 500 kids will roam and build in Cyberion. By 1993, kids had built more than 50,000 objects, characters and rooms [Kelly & Rheingold, 1993]. The educational value for children is real. This MUD fosters creativity, not to mention that it has taught some players how to type [Kelly & Rheingold, 1993]. Beegle emphasizes the role of storytelling in MUDs. She says that “players who use them have the opportunity to create realities in text, the same way one would when writing a novel or play” [p. 26]. Thus for kids, MUDs could perhaps be considered like an interactive creative writing exercise done in cooperation with children from all around the world. Now this is fun learning!

MUDs have an enormous appeal for many. The fact that the great majority of MUDs are text-based means that many players are willing to forego the visual appeal of typical electronic games for the ability to play multi-user highly interactive and highly creative games. This leads to the question of whether graphics are truly necessary? Should research resources go into creating better graphics or should they go into improve the means by which players communicate and interact? The developers of Habitat suggest that the latter is of more importance:

> “The essential lesson that we have abstracted from our experiences with Habitat is that a cyberspace is defined more by the interactions among the actors within it than by the technology with which it is implemented. While we find much of the work presently being done on elaborate interface technologies - DataGloves, head-mounted displays, special-purpose rendering engines, and so on - both exciting and promising, the almost mystical euphoria that currently seems to surround all this hardware is, in our opinion, both excessive and somewhat misplaced. We can’t help having a nagging sense that it’s all a bit of a distraction from the really pressing issues. At the core of our vision is the idea that cyberspace is necessarily a *many-participant environment*. It seems to us that the things that are important to the inhabitants of such an environment are the capabilities available to them, the characteristics of the other

people they encounter there, and the ways these various participants can affect one another. Beyond a foundation set of communications capabilities, the details of the technology used to present this environment to its participants, while sexy and interesting, are of relatively peripheral concern" [p. 274, Morningstar & Farmer, 1991].

8. Educational Non-Electronic Multi-Player Games

The idea of using games in the classroom is not solely based on the motivational features of electronic games and their potential to convey educational material. Using games in the classroom predates personal computers and video-game machines altogether. Non-electronic educational games were introduced into the classroom in the 1960s in a cloud of controversy similar to the current controversy over the use of electronic games in the classroom[23]. The debate centered around the incompatibility between education as a serious pursuit and games that were not serious but fun [Gordon, 1970]. As we contemplate the use of computer games, we seem to be revisiting the exact same debate. It is worthwhile to discuss briefly some of the findings regarding non-electronic games.

Gordon [1970] defines a game to be "any simulated contest (play) among adversaries (players) operating under constraints (rules) for an objective (winning)" [p. 8]. Educational games fall into two basic structures: board games and role-play games [Gordon, 1970]. Board games are familiar to most. *Monopoly* represents a typical board game in which pieces are moved around the board in a manner determined both by the role of the dice and other factors within the game. Gordon describes an educational board game for the elementary level called *Neighbourhood* which has similarities to the game *SimCity*. In *Neighbourhood* students develop a geographical area, shown as a grid, by putting down tokens representing people, factories, stores, and cultural centers. The students have to deal with increasing populations and geographical obstacles and thereby learn about the process of development.

[23] Games, or course, predate classrooms altogether. Using games to teach skills at an elementary level most certainly pre-dates the 1960s although it is not made clear in the literature.

Role-playing is used primarily in games that teach processes involving negotiation, bargaining, and compromise. This type of game usually only requires written materials in the form of a scenario and profiles. An example of an educational role-playing game is one where students play the roles of buyers and sellers, each with their own individual goals, and in doing so learn about the principles of supply and demand. Another example is a game in which students play roles of historical people in an attempt to understand the issues and process involved in a historical situation. Aransky & Klarin [1987] suggest that role playing games are used mostly at the secondary level.

As with computer games, motivation was a significant factor for introducing educational games into the curriculum. Gordon [1970] says that packaging, or method of presentation, is a critical factor in capturing attention and thereby motivating students. She argues that educational games are essentially a method of packaging concepts. Gordon lists a number of reasons why games are so motivating. These reasons include that games: require active participation; provide intrinsic and prompt feedback; are goal-directed and provide closure once the goal is achieved; provide uncertainty and open-endedness with respect to the eventual outcome; provide reality, relevance, and role imitation; provide interaction and peer learning; provide competition and cooperation; and they allow equal opportunities for all students regardless of their ability which in turn increases the self image of students. All of these motivational factors can apply equally to electronic multi-player games.

Games are not only motivational but have significant benefits attributed to them. According to Gordon [1970] games convey information and permit the transfer of knowledge. Games foster a flexible approach to problem solving, improvement of problem-solving abilities, and the students’ ability to perform analysis and synthesis. Games also result in improved verbal, interpersonal, and socialization skills. Lastly, Gordon argues that role-playing games increase students’ comprehension of role and of process and their ability to judge the effectiveness of actions within a process.

Educators who have come after Gordon, such as Magney [1990] and Aransky & Klarin [1987], do concur with Gordon on the general benefits of games. One difference, however, is that they suggest the information gain from games is not consistently better than that from the traditional classroom. Magney notes that while games aren't always better, they also aren't always worse. Aransky & Klarin argue, however, that games are considerably inferior to some other educational methods for the transmission of factual knowledge.

Educators strongly agree that games should be integrated into the traditional curriculum and not take it over completely. Gordon, for example, says that games serve as "useful springboards for further study" [p. 40] when students are not already motivated to learn. Aransky & Klarin suggest that game methods serve as a kind of transition between the sphere of play and that of straightforward teaching. I have argued that it is the integration of electronic games into the classroom that should be investigated as well.

It is interesting to note that Gordon in her book *Games for Growth* [Gordon, 1970], heavily concentrated her coverage of games on role-playing games which she felt were most useful for the social sciences. She felt that the potential of games was highest in the social sciences because games could provide laboratory experiences that were otherwise difficult to create. In pure science fields such as physics, we are now using computers to provide such laboratory experiences. This indicates that computers have broadened the spectrum of material that can be learned in a game format.

Understanding the background of game usage in the classroom is important. It provides a context in which to base the consideration of electronic games. In particular, the documented advantages of educational games, which have mostly been multi-participant games, validates research in the area of educational electronic multi-player games.

9. Conclusion

9.1 Brief Summary

Electronic games are here to stay. They take on a number of forms: arcade games, video games, and computer games that are played on stand-alone computers, as well as games that can be played over computer networks such as the Internet. Many children and adolescents are extremely motivated to play these games and happily spend their free time attempting to master the games. Some educators feel that the content of these games has educational value. Others are skeptical about the content of “pure” electronic games but acknowledge that the motivational game format could perhaps be the perfect packaging for otherwise mundane educational content. The idea of using games to package content predates electronic games altogether. Board-style games as well as role-playing games have been used in classrooms for decades and have proven to be instrumental in motivating children to learn.

Some research on educational electronic games has been conducted and the results are mixed. The success of the games seems to depend on the nature of the game, the nature of the educational content, and how the game compares to traditional classroom education. It has been argued that the goal should be to integrate electronic games into the classroom curriculum. Games should not necessarily be considered as stand-alone teachers.

All educational games researched thus far have been for single players. Multi-player games seldom surface at all in the research literature and educational multi-player games are even rarer. Moving from individual learning activities to group learning activities has been thoroughly documented in the cooperative learning literature and in general has been found to be very successful, both academically and socially, given a properly structured cooperative task. Thus the justification for research in multi-player games is well founded.

One important issue is how to design educational multi-player games. Determining tasks and activities that are appropriate for groups of children is only one aspect of the design. Aspects of single-player games that will be equally beneficial for multi-player games are fantasy, curiosity, and control. With respect to the educational aspect of design, scaffolding has proven to be a useful technique for educational software. An element that has been found to be of significant importance for distributed multi-player games is communication. This is a whole new feature for games that must be incorporated into the design. Although significant research has been documented within the HCI literature on facilitating communication and awareness of others, it is not clear which of these methods are appropriate for children or for games.

9.2 General Discussion

The objective of this review has been to investigate a number of literature areas in order to establish the issues involved in the design of educational electronic multi-player games. To conclude the review I will make some general comments regarding the literature itself, highlight some base issues that need to be resolved if these games are going to be viable, and lastly offer a set of design guidelines.

General Comments

Even though CSCL is considered a branch of CSCW, the two bodies of literature seem to be quite distinct, almost entirely separate. I expected the ties between CSCL and CSCW to be more thoroughly explored in the literature. The obvious questions seem to be: Which issues in CSCW are relevant to CSCL? Which issues aren't relevant? and Why? CSCW is a more mature field than CSCL and it would seem natural that one of the first objectives of CSCL would have been to benefit from all of the research that has been done in CSCW by analyzing which issues are the same and which are different. The differences found would then be the launching points for new research. One example that was previously mentioned was the extension of the CSCW classification. The classification for CSCL must account for multiple users working simultaneously on the same machine. This represents a whole new category for CSCL that is in need of research.

A common theme found in the literature for educational games, both electronic and non-electronic, as well as educational software in general is that these games and software are considered successful only if they are equally as effective as traditional classroom education. This measure is used because it seems to be the only concrete measure available. But it is somewhat of a cop-out. Firstly, by setting up two options for comparison, it entirely ignores any possibility for integration. Where are the studies that compare the traditional classroom against a classroom that integrates educational software (games and non-games) into the classroom? Klawe and Phillips [1995] document one such study and the positive results of integration, but I found no other studies. Integration could take the form of using the educational software and then performing more traditional activities around the knowledge that is built by using the software. A second problem with this measure is that it makes the assumption that the traditional classroom evaluation is in fact the desirable form of evaluation. Even when educational software is being studied, the evaluation of what is learned is done using traditional forms of evaluation such as pen and paper tests.

Issues that Need to be Addressed

Can we use CSCW design principles for multi-player games? The answer must be yes, at least partially. What aspects of CSCW can be used? Awareness has been mentioned as one principle that may or may not be applicable depending on the nature of the game itself. Awareness can be linked to Malone's heuristics of curiosity and fantasy. If players' actions add to the curiosity and the fantasy as in MUDs, then full awareness of other players may not be desirable. The deciding factor will most likely be the degree of collaboration required within the game. If a great degree of collaboration is required then awareness would be more pertinent than if little collaboration is required. An example of a game requiring significant collaboration would be a multi-player version of the game *The Incredible Machine*, which is currently being developed by Sierra for the World Wide Web. In this game, there is a shared surface on which objects are placed and sometimes hooked together in order to create a machine that fulfills a predetermined goal. To play, the players would need to see the entire playing surface and so it would be similar to a shared-whiteboard. Techniques to establish where other players are in the surface and what changes they are making would be necessary. In games such as MUDs, it is not necessary to actively collaborate in order to play the game. They can be individualistic games in which many can play. For a player who prefers to collaborate with fellow players in the construction of artifacts or in the roaming of the game space, awareness would probably be useful. On the other hand, for a player who builds his/her own artifacts (maybe on top of another player's artifact or from scratch) constant awareness of others may be distractive. Other CSCW issues that will require some investigation include coordination, the number of participants that can be supported, and the role of video images within games.

Gender is an issue that was touched upon briefly in this report. I noted that the electronic game culture was gender biased in that males play games more often than females. It is also the case that males and females prefer different styles of games. This knowledge regarding gender differences is extremely important when considering the use of educational electronic games in the classroom. It has been said that the educational system in general is geared more towards the needs of males than females. Clearly, if the introduction of electronic games into the curriculum increases this disparity between the two genders, then we are in trouble. This means that significant research is required to understand the needs of females with respect to educational games. How and what motivates males is at least somewhat understood or at least predictable given the number of games that are targeted at males and that have been commercially successful. The same cannot be said for females. Although some research is being done in this area, significantly more remains to be done. Research has found, for example, that girls often need to have a "space" created for them before they will attempt a game or even approach a computer in general. When computer usage in a classroom is dominated by males, girls will tend to lose interest entirely unless the teacher intervenes to set aside time specifically for the girls [Upitis and Koch, 1996]. For on-going research on electronic games and gender see Upitis [1996], Upitis [preprint], Upitis and Koch [1996], and Saxton and Upitis [preprint].

An understanding of children's behaviour when they play electronic games together is required. Although this was already mentioned, it is so crucial that it is worth highlighting again. The main reason for groupware failure was that it didn't recognize the needs of individuals who work together. In order for multi-player games to be successful, they will need to support the group behaviour of children. Group dynamics and individual behaviour will have to be understood in the context of different types of games - collaborative, competitive, and individualistic.

Guidelines for Designing Educational Multi-Player Games

Based on the literature reviewed, I am able to suggest a set of rough guidelines for the design of educational multi-player games. These guidelines represent a starting point from which educational game designers should work. These guidelines will surely benefit from iterative testing:

- *Provide for challenge, fantasy, curiosity, and creativity*. The first three are included in Malone's heuristics for intrinsically motivating electronic games. Creativity has been found to be a desirable characteristic especially for girls. It has also proven to be a successful component of MUDs. Although these elements have not been explored specifically for educational multi-player games, there is no reason to expect that they will not be equally important here.

- *Design the task carefully*. If it is a cooperative task, then findings in the cooperative learning literature regarding interdependence, individual accountability, and the importance of using an "ill-structured" task should be considered. It is crucial that the design allow playing opportunities and learning for all players. Having said this, it is also important not to over constrain the interaction. The design should allow the children to coordinate their activities as much as possible.

- *Allow learner control*. Control is Malone's fourth heuristic for intrinsically motivating games. Control of learning is also an important element covered in the cooperative learning literature. For the educational components of the game, scaffolding can be used as a means to gradually pass control to the learner.

- *Allow for communication possibly through multiple modalities- audio, video, text messages*. Communication was found to be one of the highly motivating features of MUDs. Cohen found that the amount of interaction among learners for an ill-structured problem determined the success of the cooperative learning activity. Hymel *et al.* further found that one of the requirements for cooperative learning was to work face-to-face. Collaboration does not have to be synchronous and the support needed for asynchronous collaboration is different from that for synchronous collaboration. If any real-time collaboration is required, then audio is a base necessity. If asynchronous collaboration is adequate, then text messages may suffice. It may be important to consider the use of video, depending on the nature of the game. Techniques for incorporating video images such as *ClearFace*, could possibly be employed.

- *Provide instant update of the game space.* This is especially important when audio is used. If the game space doesn't match the current communication, it is extremely confusing and therefore frustrating for players.
- *Provide for awareness through the use of various views and colour*. This is specifically for games requiring collaboration in the game space.

Developing educational electronic multi-player games is a new idea. Their success is not guaranteed, but they do hold significant promise. What is certain, is that the design of these games will benefit from understanding issues that have arisen in related areas of research. Integrating these games into the home and the classroom may enable children to play together and learn in ways that are radically different from traditional classroom and home learning. It would be interesting to observe Papert's time-traveling teachers were they to stumble across a classroom in which children are engaged in multi-player electronic games. I suspect that these teachers would see an environment altered by technology in which highly motivated children were interacting and learning with their fellow classmates, schoolmates, and global peers.

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