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INTELLIGENT HUMAN-MACHINE MODELING FOR ENHANCING REMOTE LEARNING ENVIRONMENTS

by

Jason Yeung, BAsC (University of Toronto, 2002)

A thesis

presented to Ryerson University

in partial fulfillment of the

requirements for the degree of

Master of Applied Science

in the Program of

Electrical and Computer Engineering

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Intelligent Human-Machine Modeling for Enhancing Remote Learning Environments

Master of Applied Science, 2005

Jason Yeung

Electrical Engineering, Ryerson University

ABSTRACT

This thesis describes the design and testing of a videoconferencing system for supporting the academic and social needs of hospitalized high school students. The underlying technologies of PEBBLES (Providing Education By Bringing Learning Environments to Students) were incorporated into the High School PEBBLES Prototype (HSPP) with new functionality such as application sharing and a whiteboard.

Laboratory studies were conducted with four groups of high school students in a simulated classroom/hospital environment, assigning them a storyboarding task that encouraged use of the prototype's videoconferencing and application sharing features. The results indicated that the students could work collaboratively through the HSPP, and the students were able to experience presence. Some of the critical requirements for effective presence through videoconferencing were identified.

The systems development approach used in this thesis highlights the value of intelligent modeling of systems in order to meet the specific requirements of the users.

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CHAPTER 1: INTRODUCTION

In 1964 at the New York World's Fair, videoconferencing was unveiled as the replacement for long distance face-to-face meetings by allowing people who were physically and geographically separated to communicate using live audio and video links. It was marketed as being able to eliminate gridlock and enhancing travel experiences for people who lived in cities [1]. The PicturePhone system launched in 1964 used regular telephone lines. It consisted of a 12-button touch tone telephone, a 13.97 cm x 12.7 cm black and white CRT display screen, a camera tube, a loudspeaker, a microphone, and various power and control circuits [2]. The users also had the option of enabling or disabling the video feature.

Since that time, videoconferencing has undergone a significant technological evolution. Audio and video technologies can be controllable and high fidelity or inexpensive and low fidelity, and still function better than the system introduced in 1964. Yet, after over forty years, videoconferencing remains a relatively unused and complicated technology.

Much of the development effort for videoconferencing has focused on business and research applications because of the cost involved in providing high fidelity equipment and connectivity, and the perceived market [1]. Businesses and research institutes are the most capable of investing money to purchase the systems. The most common deterrents to universal acceptance of videoconferencing are still long setup times, poor audio and video quality, and latency [3, 4]. This had led to innovations in high speed broadband networks, conferencing room environments [5, 6], desktop videoconferencing [7, 8], and online conferencing services [9].

There are two main configurations for conventional videoconferencing systems: (1) Dedicated, and (2) desktop. Typical business systems use dedicated videoconferencing rooms that allow multiple users to participate in a single point-to-point videoconferencing session simultaneously. This type of system either uses a camera with a fixed wide-area view of the room, or a camera that has been programmed with preset locations that are most commonly used (e.g., a preset location that zooms in on a speaker's podium). Microphones can be located in the ceiling of the videoconferencing room, placed in the center of a meeting table, or placed close to the video camera (see Figure 1). Speakers are either part of a television screen, located in the center of a meeting table, or mounted around a room. Figure 2 shows an example of a videoconferencing system which uses a table top microphone and TV speakers.

Figure 1: Videoconferencing System with Microphone Attached to Camera

Figure 2: Typical Meeting Setup for Dedicated Videoconferencing Room

In addition, such facilities often require a technician to be on-site to monitor the system. The technician's duties might include manipulating the videoconferencing camera, ensuring sound quality, troubleshooting equipment and connectivity problems, setting up the videoconference, or acting as a moderator when there are multiple participants.

A desktop system consists of a PC with a network connection, inexpensive and low quality speakers, a microphone and a webcam. This type of system is designed to be moderately easy to set up and operate. The desktop system offers a more intimate connection between interlocutors by allowing users to conduct videoconferences from the familiar surroundings of their desk or office environment. However, the camera is rarely able to pan, tilt, or zoom. A local user would need to ask a remote participant to physically manipulate the videoconferencing camera to focus on specific points of interest. Figure 3 shows an example of a typical desktop system setup (PolyCom VSX 3000).

Figure 3: Desktop Videoconferencing System

The problem with these basic systems is that they fail to live up to the expectation that videoconferencing is identical to face-to-face meetings [3]. There are issues related to the complex setup for videoconferences, the ability to share objects (real and virtual), and the audio and video quality makes simpler alternatives (e.g. email and audioconferencing) more appealing [3, 4, 10].

One of the potential applications of videoconferencing that has had limited consideration is education. While there has been some research that examines the use of the videoconferencing in the education, the videoconferencing technology often used is identical to the technology used in business applications.

For example, the RACOL Project, which aims to connect teachers and students separated by vast geographical distances, uses a “standard” setup for videoconferencing [11]. The project employs a mix of desktop videoconferencing stations and videoconferencing rooms. The RACOL Project is part of a province-wide initiative to link all schools, hospitals, and government offices together via a high speed broadband network called Alberta SuperNet [12, 13]. RACOL has been successful in connecting the

province's schools remotely, but only mainly because it used a wide variety of videoconferencing technology. Large sums of money were invested in acquiring all the technology such as interactive whiteboards, large televisions, sophisticated sound equipment, and a special feedback system for every student's desk [13].

The above example highlights using typical professional videoconferencing technology in an educational environment successfully. However, there are certain considerations that need to be examined. A fixed wide area view of a classroom gives the impression that the user is an external observer instead of an active participant. A complex videoconferencing system also requires a great deal of time to setup properly. This duty is one that teachers would find cumbersome in addition to their usual teaching duties. Also, careful planning is required for optimal placement of the technology [5].

Students' needs are also different from those of business professionals. The interactions in a business setting are predominantly of a professional nature, but students' interactions are mostly of a social nature. They are also quite visual, often creating and sharing quick notes and sketches.

An example of videoconferencing technology integrated into a classroom to meet social needs is PEBBLES (Providing Education By Bringing Learning Environments to Students). It is an interactive videoconferencing system that is designed to support children who are unable to attend class regularly. PEBBLES is unique in that it combines traditional videoconferencing technology with simple robotics to create a more interactive and natural experience with an emphasis on social interactions. A more detailed description of PEBBLES can be found in Chapter 2.

In this thesis, I investigate the development and effectiveness of a videoconferencing system, based on the design of PEBBLES, designed to support the education and communication tasks of high school students. This new design incorporates many of the strengths of the PEBBLES system, but has modifications that are geared towards enabling collaborative work in a high school classroom environment. The overall goal of the system is to provide high school students with an effective presence in their classrooms from a remote location, and as result of their presence, they will be able to function productively.

1.1 Objectives and Scope of Thesis

The primary objective of the research described in this thesis is to examine how presence factors implemented through a High School PEBBLES prototype (HSPP) affect the ability of high school students to experience telepresence, and to accomplish typical tasks required of high school students. I will be examining the effects of the HSPP on students' abilities to carry out social and academic tasks, the sense of presence experienced by hospital and classroom students, and changes in behaviour and attitudes from interacting through the HSPP. Presence is a subjective experience defined simply as the sense of "being there" [14].

Determining the effects of the HSPP with high school students will determine what steps need to be taken in future developments of the HSPP to ensure its effectiveness for any learning environment. This is important because previous studies with PEBBLES have only involved classrooms at the elementary school level. Limited trials with high school students [15] have shown that they are hesitant to use the current

version of PEBBLES. Some of the concerns were with regards to the appearance of the system, audio problems, and problems with sharing work [15, 16].

Additional concerns are that the current version of PEBBLES is too large and cumbersome for the typical high school classroom. The rotary schedule of high school students requires them to move to different classrooms throughout the day. Transporting the current version of PEBBLES in a similar fashion would be too awkward because of the crowded conditions in the hallways between classes. In addition, the provincial government of Ontario has mandated a maximum average class size of 22 high school students per class [17]. However, since the cap is on average class size, individual class sizes can vary. A 2004/2005 survey by a parents' group found that 68% of the compulsory classes exceeded the government's cap [17]. This places restrictions on the size of the HSPP since space is a valuable resource in the classroom.

A secondary objective of the research is to determine what elements can contribute to an effective videoconferencing system that supports the academic and social needs of high school students. By observing their behaviour in a collaborative environment, we will be able to identify what type of functionality is required to allow high school students to not only take an active role in their classroom from a remote location, but to make the videoconferencing experience as seamless as possible, thereby preserving a good sense of presence, for the remote student and the students in the classroom.

The research presented in this thesis does not suggest a new method for measuring presence, nor does it recommend how presence should be measured. It adopts common principles that have been established from previous presence research to gauge

sense of presence in a qualitative manner. The features of presence that are central to this thesis are social presence, engagement, convenience, and user impression on task success (see Chapter 2 for further explanation of presence). Analyses of questionnaire data and videotapes of the usability studies are performed in order to assess these presence features with the high school system developed in this thesis.

Despite the impact of audio and video quality on users' impressions of videoconferencing, the research in this thesis does not attempt to develop new codecs or transmission schemes to improve the audio and video fidelity. Instead, we use off-the-shelf components that are readily obtainable. This is in the interest of making the HSPP more accessible by using technology that is more recognizable.

The work presented in this thesis is not intended to enable a designer to build a completely new and different videoconferencing system. The HSPP is an extension of the current version of PEBBLES. It uses the elementary school version of PEBBLES as a foundation and incorporates aspects of other videoconferencing systems to enhance its utility for high school students such as a whiteboard application, an application sharing feature, and an Internet connection.

The end product of this thesis is a videoconferencing system that has undergone an initial evaluation to examine whether features of the HSPP are usable by and effective for high school students. The HSPP presented in this thesis is by no means a definitive final blueprint for High School PEBBLES. It is intended instead that this body of research will in turn serve as a foundation and compass for the future development of the HSPP and any similar videoconferencing system.

1.2 Outline of Thesis

This thesis is organized as follows:

Chapter 2 reviews the relevant literature and background materials. Relevant topics include presence and telepresence, measuring presence, videoconferencing technology, design considerations, and applications. A description of the elementary version of the PEBBLES videoconferencing system is also presented.

Chapter 3 presents a description of the HSPP. The electrical and communication characteristics of the system are given. In addition, a description of the physical design is provided.

Chapter 4 describes the methodology used in the studies to achieve the research objectives. The development and deployment of the HSPP is discussed.

Chapter 5 presents the results of the studies. The results provide an analysis of data obtained from pre-study and post-study questionnaires, video recordings, and interviews with the study participants.

Chapter 6 provides a discussion of the implications of the results for the design and study of presence and videoconferencing to support high school students.

Chapter 7 concludes the thesis and offers recommendations for future directions for the HSPP.

CHAPTER 2: LITERATURE REVIEW

The concepts of presence and telepresence are central constructs in videoconferencing, and represent the main theoretical model of this thesis. In sections 2.1 and 2.2, models of presence and telepresence, and presence measurement methods are reviewed and related to the developments in this thesis. Having effective presence is an important determinant of people's success in communicating via videoconferencing systems. Measuring presence is important in this thesis because some measure of presence is required in order to ascertain whether or not the system is performing as desired by supporting user's communication needs.

There is a vast literature on videoconferencing technology and its applications. In section 2.3, the literature on past current, and future developments of videoconferencing technology will be presented to explain the technical foundation of the HSPP. The underlying technologies that support videoconferencing such as video and audio processing and connectivity are discussed. The role of technology in mediating telepresence is examined using some practical examples with a particular focus on educational implementations.

Section 2.4 provides examples of more modern videoconferencing systems that have been developed. This section also provides a discussion on design considerations for videoconferencing systems which can affect a user's sense of presence. The relevant technical terms are also reviewed.

Finally, section 2.6 provides a detailed description of the existing PEBBLES designed for use in hospitals and elementary schools, and from which the HSPP borrows some of its design considerations.

2.1 Presence and Telepresence

Presence is one of the key factors in determining the success of videoconferencing. Lack of sufficient amounts of presence combined with the technical difficulties of videoconferencing hardware are the main reasons for its failure to become a mainstream technology.

One of the simpler definitions for presence is the sense of “being there” [14, 18, 19]. However, this is a very abstract definition and difficult to measure. Many researchers have attempted to refine this definition with more concrete constructs. [20] acknowledges the role of technology when defining presence as “the perceptual illusion of non-mediation”. This means that a user of a technology that is providing a presence experience ultimately becomes so engrossed with the experience that the user is unaware of the technology [20]. Other researchers also suggest that presence can be affected by many different psychological and technological factors, and is difficult to measure objectively because it is experienced as a subjective phenomena [14, 18, 20-22].

Telepresence, as an extension of presence, refers to the experience of presence when people are physically separated, and communication is mediated by technological intermediaries such as the telephone or videoconferencing. [23] defines telepresence as when people experience a distant location as if they had been transported there even though they have not. The experience of presence now requires mechanisms to support the illusion of a person being there because in reality they are not.

The phenomenon of telepresence can be a common and frequent experience for people. For example, it is possible for people to experience telepresence by listening to a piece of music because they can imagine being physically present before the performers,

or people can daydream that they are vacationing at an exotic location far away from their present location. The terms presence and telepresence are used interchangeably throughout since the focus is on computer-mediated presence, specifically videoconferencing.

Researchers [22] attempted to determine which technological and psychological factors influenced presence by providing users with drastically different presence experiences (mediated with technology). In their study, one half of the study participants viewed a 3-D IMAX movie while the other half viewed an old sitcom on a small black and white television set. Based on their responses, the researchers identified seven dimensions to presence: Immersion, parasocial interaction, parasocial relationships, physiological responses, social reality, interpersonal social richness, and general social richness. Of these seven dimensions, immersion, parasocial interaction, interpersonal social richness, and general social richness are applicable to PEBBLES. Immersion refers to a user's sense of involvement or engagement with the mediated environment. Parasocial interaction refers to interacting with people in the mediated environment. Interpersonal social richness refers to a user's perception of communication cues during interactions. General social richness refers to quantitative and qualitative aspects of interactions (e.g. responsive/unresponsive, engaging/boring).

The aforementioned model of presence illustrates the multidimensional approach that is adopted to measure presence. Researchers need to decide which dimensions are relevant or appear to be more significant. Often, they use models of presence that include social presence (i.e. interacting with distant people and objects) and technical presence (i.e. seeing and hearing distant people and objects in high fidelity).

[18] suggests a subjective viewpoint of presence with three dimensions to presence: (1) Personal presence, (2) Social presence, and (3) Environmental presence. Personal presence is based on a person's subjective understanding of why they exist in the presence environment. This understanding depends on how closely the presence experience mimics the real world. For example, a simple flight-simulation video game would create a lower degree of personal presence than a sophisticated flight simulator used to train airline pilots. Social presence stems from interactions with others entities (real or virtual) during the presence experience which serve to convince somebody that they are present. Similarly, environmental presence is based on how the presence environment reacts to an individual during the presence experience. For example, a simulated beach environment would leave footprints in the sand where the person has already treaded.

[24] proposes a more technical model; that there are three determinants of presence: (1) Extent of sensory information (number of bits per feature), (2) Control of sensors relative to environment, and (3) Ability to modify physical environment. NASA's Mars rovers [25] are good examples for explaining this model. Extent of sensory information can be measured by examining the resolution of the cameras. With a large number of pixels per picture, the scientists are able to see small features in greater detail. This is similar to being able to move closer to an object to examine its finer details. Control of sensors can be measured by the flexibility of the sensors. Scientists can explore beyond the landing site because the controllable camera is mounted to the rover which can roam about the planet surface to get different vantage points. This is similar to being able to listen to another discussion in a room by walking towards another group of

people. Ability to modify physical environment is determined by the availability of devices for manipulating objects. The Mars rovers are equipped with tools for extracting soil samples from the landscape. This is similar to being able to move items around in a room. Enhancements made to these determinants can improve sense of presence because they enhance the ability to interact with a remote location.

These presence models are appropriate for virtual reality or simulated environments. However, they are not suitable for videoconferencing applications because manipulating the environment and performing physical tasks are not possible. Videoconferencing requires a model of presence associated with supporting communication and intellectual tasks.

There is a model of presence that is more appropriate for describing presence in the context of videoconferencing and communication, incorporating aspects of social interaction and fidelity. [20] presents a model of presence that uses six conceptualizations: Presence as Social Richness, Presence as Realism, Presence as Transportation, Presence as Immersion, Presence as Social Actor Within Medium, and Presence as Medium as Social Actor.

Presence as social richness refers to the quantity and quality of social factors such as gestures, facial expressions, eye gaze and body position. This is most evident in a face-to-face social setting or videoconference where people can discuss a variety of topics. Depending on the participants and the topics (e.g. they like the person, they are interested in the topic), the participants may indicate varying levels of engagement through body position, gestures, tone of voice, and expressions. As a result, the participants may believe that they have a presence with the other person because they are able to notice if

the other person is taking an active interest in the discussion (e.g. deliberate gestures, appropriate reactions). Videoconferencing systems enable a user to be able to detect changes in tone, and see gestures, positions, and expressions.

Presence as realism refers to the degree a medium can reproduce an object, person, or event that is close to the real thing. Realism can be further divided into social realism and perceptual realism. Social realism refers to how plausible a sequence of events appears to the person observing them. Perceptual realism refers to how plausible the objects and people are. This is more applicable to virtual reality systems or computer simulations than videoconferencing systems. For example, a computer game could recreate the events surrounding World War II. It would possess social and perceptual realism if it depicted events and central persons with historical accuracy.

Presence as transportation refers to a set of three notions of transportation: “You are there”, “It is here”, and “We are together”. “You are there” implies that the user is transported to a different place. “It is here” implies an object is transported to the user from a different place. “We are together” implies that two or more users have been transported to a common environment.

An example of presence as social richness and transportation is a game played via simple text chat [26]. The players share a common social environment (the game and its rules) and they can establish trust with each other as result of their common ground (transportation) and their social banter (social richness). In a videoconferencing application, the “you are there” notion of presence as transportation occurs when a user may be watching another person give a presentation. Videoconferencing enables the user to temporarily believe that she has been transported to the same room as the presenter.

Presence as immersion refers to immersing the senses into an artificial world and blocking out the real world. The person believes that the virtual world is real, making this notion of presence similar to the notion of presence as realism described previously. Virtual reality systems using head-mounted displays, headphones, and haptic feedback are examples of this type of presence because they replace sensations from the real world with sensations from a computer-generated environment.

Complete sensory immersion is not a requirement for presence. [24] suggests that sufficient presence can be provided by stimulating only a few of the senses rather than all of them. Psychological immersion is sufficient as well. [27] reports that people playing violent video games can become so psychologically immersed that their brains function as though they are actually experiencing everything in the game. For videoconferencing, presence as immersion can occur depending on the type of equipment used by the system. A simple PC-based videoconferencing system would immerse the senses to a lesser degree than a more complex videoconferencing system using elements of virtual reality. The simpler system requires the user to consciously focus on their monitor and ignore objects and events in their immediate surroundings. The more complex system may be more effective at both sensory and psychological immersion if it automatically blocked all external stimuli, making the user only aware of the computer-mediated environment.

An example of where the notions of presence as realism, transportation, and immersion can all occur is an IMAX movie showing a bird's eye view of a flight over a mountain range. The images are experienced from a first-person perspective so that the viewer believes that he is actually in the environment seen on the movie screen experiencing the action (realism). The viewer can experience the sensation of flying,

forgetting that they are sitting in a theatre watching a movie on a screen and listening to sounds produced from speakers (transportation), because the bobbing camera motion is similar to the head motion that occurs from soaring and gliding, and he therefore becomes psychologically immersed in the movie experience (immersion).

Presence as social actor within medium refers to the imaginary social connection that forms between an actor in a television program and a viewer regardless of whether or not the character being portrayed by the actor is fictional or not. The viewer may not be intimately familiar with the character on the television screen, but the actor's performance (via gestures, casual speech and tone of voice) is good enough to give the audience the impression that they are well acquainted. This example only applies to a one-way communication channel. For videoconferencing, a counter-example might be when a remote lecturer is giving a presentation and completely ignoring the audience. The audience might form poor impressions of the remote lecturer because she is not acknowledging their presence.

Presence as medium as social actor refers to attributing human qualities to objects which are not normally thought of as being human. The object is inadvertently granted lifelike or even human qualities because the individual that interacts with the object believes that it operates in a way that sufficiently mimics sentient behaviour. An example of this type of presence often appears in science fiction content. Androids and computers exhibit human-like characteristics such as coherent speech, emotion, and physical movement, and the human characters interact with them as though they were actual humans. The ASIMO [28] robot developed by Honda Motor Co., Ltd. is a real-life example of presence as medium as social actor. It is treated as a sentient individual

because it has a humanoid form, is capable of walking, and can “speak” [28]. Other examples include Sony Corporation’s AIBO [29] and QRIO [30] (see Figure 4) robots which can react to people with life-like motion and sounds, MIT’s Kismet [31] robot which can express a variety of emotions depending on external stimuli, and Osaka University’s Repilee R1 [32] android which has the appearance of a young woman.

Figure 4: Sony Corporation’s QRIO Robot [30]

The RAGE [33] robot developed by Berkeley Labs (see Figure 5) is an example of a videoconferencing robot that exhibits some degree of human behaviour. The robot consists of the usual video camera, monitor, microphone, and speakers. In addition, the robot operates wirelessly, is capable of roaming about on four individually driven wheels, and is equipped with sensors for collision avoidance. These additional features create the illusion that the robot possesses some degree of intelligence, and does not require a human operator (which it does).

Figure 5: Berkeley Lab's RAGE Robot [33]

Presence as medium as social actor is also reported for the PEBBLES system after it is in operation in a classroom for a sufficient amount of time [34]. PEBBLES is a videoconferencing system that uses simple robotics and is designed to give hospitalized students a presence in their usual classroom. The students in the classroom begin to treat the PEBBLES unit as a physical surrogate for the hospitalized student not only because their face is clearly visible, but because the unit is also capable of mimicking enough human responses to give the illusion that the hospitalized student is physically present in the classroom.

The notions of presence as social richness, transportation, and immersion are also exhibited by PEBBLES. The hospitalized student believes that she has been transported into the classroom because of the social interactions with other students and teachers, and the simple robotics allows the student to view different areas of the classroom with the videoconferencing camera. For these reasons, this model of presence is an appropriate one for the HSPP to be likened to as well.

2.1.1 The Role of Technology in Telepresence

Telerobots are mobile remote-controlled robots that allow a human operator to establish a presence in another location. They are used for a variety of applications. Remote-controlled robots are ideal for exploring dangerous areas or places such as undersea and space exploration [25, 35], bomb disposal [36] and nuclear power plant maintenance [37] where it would not be safe or economically-feasible to send a live person [23, 38]. For this reason, they are usually equipped with video cameras to get information about the location. For example, the telerobots used for search and rescue after the World Trade Center disaster [39] were operated wirelessly and fitted with two-way communication devices to communicate with any survivors found in the rubble. This resulted in the survivors having a greater impression of the presence of the rescuers since they could communicate with them in real-time.

Telerobots similar to the RAGE robot have applications in simpler situations. The iRobot-LE [40] robot was designed to allow people to monitor their homes over the Internet with a mobile rover capable of climbing stairs. Similarly, the iRobot CoWorker [41] allowed an office worker to telecommute using a mobile rover that allows him to see, hear and interact with others working in his office. However, these robots were not fitted with a display showing the remote user, resulting in lower presence since people had the impression they were speaking with a talking box on wheels rather than communicating with a live person.

Other applications for telepresence are telemedicine and remote testimony. Telemedicine is a promising application for telepresence. A less experienced doctor may be able to consult a more-experienced doctor or a specialist who is unable to be

physically present with that doctor [42]. Also, a remote doctor may be able to visit patients and make simple diagnoses[43]. Remote legal testimony was demonstrated in the US trials for the prisoners at Guantanamo Bay as they were deemed too great a security risk to physically transport to the courtroom [44]. Remote legal testimony could also be used to obtain crucial testimony from key witnesses who may be afraid of endangering themselves by appearing in public. This enabled justice to be carried out normally since people in the courtroom would have the impression that the witness had a presence in the courtroom.

Technology plays a crucial role in telepresence because it affects the notions of presence as social richness, immersion, realism and transportation, and acts as a conduit for the senses of seeing and hearing. For example, videoconferencing systems are designed to make users believe they are together at a common location, that the technology stimulates the senses of seeing and hearing sufficiently to give the impression that the technology is transparent and that the other person is with them allowing them to interact freely.

[38] presents a “barometer for presence fidelity” to illustrate how different mediums compare in instilling a sense of presence. In order of increasing presence, there is hearsay, printed matter, video, interactive software, virtual reality, telepresence, and actual presence. It is interesting to observe that the barometer ranks visual media (i.e. printed matter) above aural media (i.e. hearsay). This strengthens the point that videoconferencing can create a greater sense of presence than audioconferencing because it has the visual component.

Human-computer interaction becomes equally important as human-human interaction. Users are challenged to consider what kind of behaviour they should be exhibiting during a videoconference because they are interacting with a computer as well as attempting to communicate with another person using the technology. In addition, there are unconscious expectations and learned social structures such as turn-taking behaviour imposed by the communication tasks that are limited or interrupted by the technology. This can then weaken the illusion of presence enough to interfere with users achieving success with their remote communication tasks, or users must modify their learned behaviour and task expectations to accommodate the technical limitations.

[45] noted that the development of computer supported communication created a new communication medium that required users to re-examine rules for intonation, turn-taking, and question style. The acceptance of the telephone created its own form of communication despite centuries of face-to-face conversations [46]. Prior to the telephone, it was nearly impossible to communicate with somebody that you could not see without exchanging letters. Being able to hear a person's voice and carry on a conversation with them in real-time may have been unsettling at first, but the telephone eventually became a common fixture in almost every developed society and people developed conventions on acceptable telephone behaviour. Similarly, the proliferation of videoconferencing will make it appear natural and seamless, and eventually participating in a videoconference may seem as natural as talking to somebody face-to-face [47].

The ability of a communication media to support a sense of common ground between interlocutors is necessary so that they can understand each other [48]. Common ground is closely linked to the notion of presence as transportation in the sense that the

parties involved believe that they are together. Different communication media possess different characteristics which can contribute to a sense of common ground (and in effect, presence). [48] identifies the key characteristics of communication media as: Copresence, Visibility, Audibility, Cotemporality, Simultaneity, Sequentiality, Reviewability, and Revisability.

Copresence means that the parties exist in the same physical environment (i.e. same room) and have access to the same physical objects. Visibility and audibility mean that the parties can see and hear each other. Cotemporality means that any messages exchanged between the parties are immediately received or with negligible delay. Simultaneity means both parties can send and receive messages simultaneously. Sequentiality means that the order of turn-taking can be maintained when determining which party should be sending messages. Reviewability means that the parties have the ability to review the other parties' messages at a later time (e.g. a transcript of an conversation). Revisability means that the parties can check and revise their messages before they are sent. These characteristics as they apply to various communication media are summarized in Table 1.

Table 1: Characteristics of Various Communication Media That Contribute to Common Ground [48]

Medium	Copresence	Visibility	Audibility	Cotemporality	Simultaneity	Sequentiality	Reviewability	Revisability
Face-to-face meeting	•	•	•	•	•	•		
Telephone			•	•	•	•		
Videoconference		•	•	•	•	•		
Two-way text chat				•	•	•	•	•
Voice mail			•				•	
E-mail							•	•
Letter (post)							•	•

From Table 1, we can see that videoconferencing is similar to face-to-face meetings (lacking only copresence), has the property of visibility that telephone conversations and text chat do not, and has a large number of characteristics not possessed by non-synchronous communication media (voice mail, e-mail, letter). This begs the question: Why is videoconferencing not more popular? The answer lies in the fact that Table 1 does not give a sufficiently detailed picture of the characteristics of videoconferencing. The cotemporality of videoconferencing is not guaranteed, and the visibility and audibility of videoconferencing may not always be satisfactory.

As mentioned earlier in this section, there are concerns with signal latency and video and audio fidelity which have a negative impact on the acceptance of videoconferencing as a commonplace communication medium. Also, there is the misconception that videoconferencing is identical to face-to-face meetings, but as shown in Table 1, copresence is lacking in videoconferencing which requires a different perspective, just as telephone conversations are different from face-to-face meetings.

[3] proposes several factors which would help boost the appeal of videoconferencing. Lower bandwidth costs, cheaper technologies, and the offering of video-based services (e.g. signing for hearing impaired, weather forecasting, movie times and trailers) are some of the more immediate factors that could make videoconferencing more acceptable. In the longer term, fuel shortages and a shift from conference rooms to desktop videoconferencing would also be beneficial for the proliferation of videoconferencing technology. However, this still does not address support for the communication and behavioural differences that users experience because of the technology and medium.

As mentioned previously, videoconferencing lacks the copresence characteristic that face-to-face meetings have. As a result, asymmetries exist between the two communication media [49]. The most apparent asymmetries that cannot be easily remedied by technology are mobility and control. Users may wish to move about a room to examine certain objects in closer detail. While there are some systems that are capable of locomotion [33, 40, 41], there are size and safety concerns because the user of such a mobile system may not have complete awareness of the system in relation to the remote environment. For example, the videoconferencing camera of a roving system cannot inform a user if he is about to roll over somebody's foot because it is not pointing at the ground immediately in front of the system's wheels. Instead, he must rely on the system's collision detection mechanisms, if applicable.

Users may wish to manipulate and move objects around a room. The desire to control physical objects is typically mediated through a person at the remote location. The addition of a robotic manipulator would allow the user to accomplish this, but such a

system would require high precision and continuous feedback to ensure appropriate force is being applied by the manipulator. For example, the user would not want a robotic manipulator to crush a brittle object, but would want it to apply sufficient force to grip a variety of objects without slipping. This affects a user's perception of presence through immersion because the user's sense of touch is stimulated.

2.1.2 Telepresence Technology and Education

Telepresence has applications in a teaching or learning environment where a teacher and student may be separated by a large distance. This type of learning system is already used for a large number of distance learning programs offered by colleges and universities. A simple search for "distance education university videoconferencing" using Google yields over 570,000 results. These distance education programs are directed towards people who would like to further their education, but because of time constraints or personal obligations, it is impractical for them to commute to and from the school [50].

Distance education for high schools can be problematic though because the students are not necessarily attending school voluntarily. As a result, the students may lack motivation to complete work or participate in class, and may even cause disturbances in normal classroom activities. [51] investigated a situation in a high school where students were allowed to attend classes remotely through the FirstClass conferencing system, a server-based instant messaging system that allows users to send and receive files. The students and their parents were content with the freedom and independence that was afforded to them by using this system. The teachers lauded the program as being a good alternative to expulsion and there was greater social interaction compared to home schooling.

However, the program was plagued with several problems ranging from students frequently using profanity to truancy and missed deadlines resulting in performance (grades or marks) degradation. Interviews with teachers, students, and the guardians of the students revealed that all participants (teachers, students and guardians) experienced frustration and disorder in the beginning of the program. This was partially due to teachers finding it difficult to adjust their teaching styles to accommodate the new medium and partially due to discomfort with the technology.

Another reason for the student's frustration was that the students either received insufficient supervision, or that they were not motivated enough to concentrate on their distance education. It is conceivable that the students lost interest more quickly when faced with a "talking head" rather than an interactive classroom experience [52]. The situation finally improved with a combination of increased student-teacher interaction and greater parental involvement and supervision. In the end, the program only lasted one school year before the school administrators decided to terminate it citing an excessive time investment required to operate the distance learning program efficiently.

The above example shows how teachers' impressions on videoconferencing systems can affect their acceptance in classrooms. Teachers are busy with managing the academic well-being of their students, and forcing technology upon them that requires them to alter their teaching approach, or invest additional time to learn how to manage the technology only causes them to form negative opinions of videoconferencing technology. This is considered in the design of the HSPP developed in this thesis

A study of virtual learning groups found that 26.3% of the behaviour exhibited by the groups was classified as social [53] and that social interaction contributed to the

satisfaction of the students, and gradually allowed their relationships to become less formal and more relaxed. [54] proposes that it is the responsibility of designers to design systems that ensure users remain alert, motivated, and accountable for their actions. The videoconferencing system should behave as a conduit rather than perform all the tasks that a user would normally do.

This raises an important issue. There is a need to change the way social interactions occur regardless of how user-friendly the hardware and software for the system might be. In the case of the virtual schooling program, the teachers and the students failed to adapt early in the program but gradually became acclimatized to the new learning environment. However, the system designers also failed to acknowledge the importance of existing work processes and behaviours, and create a design that could take advantage of those existing processes.

It is possible for communication technology solutions to become more comfortable for users in relatively short periods of time. [55] describes a long-distance audio/video connection between two laboratories where employees at both locations had little to no difficulties in adjusting to the new link between the two facilities. In fact, the link was frequently used for spontaneous social interactions even though its significance was most evident in professional group discussions and presentations.

There have been studies indicating a positive correlation between the level of social presence and motivation [18, 56]. This begs the question: Does greater motivation brought about by a greater sense of social presence lead to a greater chance for success? The safe answer would likely be, “it depends”. There has been much debate over whether or not there is a positive correlation between presence and task performance. The link

between success and social presence has yet to be definitely proven. The advocates believe that performance improves by increasing the level of social presence either through increased realism or greater interaction with the environment [57, 58]. The naysayers would point out that there are several experiments that sought to win the argument but have failed [19, 56, 59] since presence had no significant effect on performance.

[59] suggests, however, that poorer performance on solving mathematical problems was due to anxiety caused by the continuous presence of an observer which could have been alleviated by inserting periodic breaks, similar to taking breaks in natural settings. This is understandable because the participants in the experiment were unfamiliar with each other. For the purposes of this thesis, it is assumed that presence and performance are linked since collaborative work by nature depends on having group members present to collaborate with.

2.2 Measuring Presence

While there is some agreement in the literature that the simplest definition of presence is “being there,” there is a lack of agreement on standardized methods for measuring it, mainly due to the differing opinions of how presence is interpreted [60, 61]. There have been a variety of suggested methods for measuring the degree of presence in computer-mediated environments. As seen in section 2.1, there is a lack of consensus on a universal definition of the concept of presence. As a result, there is a lack of consensus on how presence should be measured.

It has been suggested that presence be determined through subjective measures, and objective measures [14, 20]. Subjective measures are useful since the experience of

presence is based on recounting experiences and opinions of the people who experience that presence. Subjective measurements are taken by asking for user's opinions on their preferences, and attitudes and reactions towards specific technologies or activities. Objective measures are useful because they appear to have validity and can sometimes be easier to obtain than subjective ones [14]. These measurements can include measures of the psychological and physiological reactions of the participants to the telepresence experience and tasks.

Questionnaires and surveys employing subjective measures appear to be commonly employed in presence research, and preferred research instruments for measuring presence since they are relatively inexpensive to setup, deploy, and analyze. A survey of various questionnaires administered for measuring presence [62] reveals that they measure different factors associated with presence such as the quality of the medium, the degree of participation, and the degree of control over the remote environment. For example, a questionnaire designed by [63] attempted to determine the degree of presence in virtual reality environments based on four factors: (1) Involvement, (2) Sensory Fidelity, (3) Adaptation/Immersion, and (4) Interface Quality. Some of the questions asked how much influence a user had over certain events, how engaging the experience was, and to what degree the user interface interfered with the presence experience. However, it has been criticized for being too subjective and having low reliability [19] because it focuses too much on the respondents' opinions of how well they performed in the virtual reality environment.

Questionnaires are usually administered immediately after the presence experience to minimize the chances of the measure interfering with the experience. The

disadvantages of administering a questionnaire after the experience are that participants tend to remember only the conclusion of the experience rather than the experience as a whole [21], the results may lack validity if the sample size is not large enough [64], and different questionnaires regarding the same presence experience may produce different results [65]. These disadvantages make it seem that questionnaires are a poor measurement tool. However, they are a relatively inexpensive and simple method to obtain a small amount of quantitative data [19].

Another technique for gathering subjective data is the qualitative observations of a researcher. The observations may provide rich detail that quantitative measures cannot provide (e.g. gain an understanding of why a certain behaviour occurred). This is similar to conducting a small-scale ethnographic study because the observations are usually about relating behaviour to events which most questionnaires cannot address. However, there are some important disadvantages that must be carefully considered and addressed by researchers. These include biases introduced by the researcher and the difficulty associating qualitative observations with the quantitative observations. Also, qualitative observations are more difficult to generalize and validate because of the possibility of skewed or biased observations.

An example of the possibility of skewed observations was an experiment where individuals were asked to experience a virtual reality environment and indicate when they were no longer experiencing telepresence by informing a researcher [61]. In this experiment, the subjects were essentially given two simultaneous roles of experimental participant and observer. Even though the reporting task was simple, their sense of presence may have been diminished because they had to interrupt their activity and

remember to inform the researcher. It is possible that their subconscious prevented them from fully experiencing telepresence because they had to remember to perform a task that was external to the presence experience.

While some researchers purport that objective measures are not useful in measuring presence, others suggest that they can be useful in some cases [62]. Objective measures consist of measures that occur without user intervention. Examples include changes in blood pressure, heart rate, eye movement, and respiration rate. These measures are usually taken from users during their presence experience because researchers want to capture real-time data. The main advantage of taking objective measures is that the user (usually) cannot consciously manipulate the measurements, and there is no reliance on users' memories when asked to recall certain events that occurred during the presence experience. For example, [66] conducted an experiment that measured changes in heart rate in response to being exposed to a deep pit in a virtual reality environment. The researchers found that subjects experienced a higher heart rate when they experienced being beside the virtual pit than when they experienced being inside a simple virtual room, and the results were well correlated with the subjects reported sense of presence.

The difficulty with obtaining objective measures is that the measuring equipment usually intrudes into the experience, potentially interfering with task performance and user satisfaction. For example, if an individual was connected to an EEG machine to measure brain wave activity, the individual would likely be distracted by the probes and cables regardless of how immersive the experience was. This may have prompted the

suggestion that “there is currently no evidence that physiological measures correlate well with presence” [22].

Some researchers attempt to combine objective with subjective measures to determine presence. In a study by [67], subjects were asked to view a movie and manipulate a slider according to the subjects’ own sense of presence. The slider output was a quantitative objective measure of the subjects’ qualitative subjective opinions of presence. The results of the study appeared to indicate that the approach was successful. Significant changes in the subjects’ opinions of their sense of presence seemed to coincide with certain scenes in the movie which were expected to create a greater sense of presence. For example, the subjects indicated an increasing sense of presence during parts of the movie where the images were presented stereoscopically, and when the camera was panning in a way to imitate observer movement. It seems that this approach was valid, but no reliability testing has been carried out on this approach.

[21] gives a collection of presence experiments of which 53 of them used subjective measures, and 16 used objective measures. These include memory of events, perception of objects, effects of simulated motion, changes in heart rate, changes in respiration, eye movement, and performance efficiency. None of the measures appeared to have a definite advantage over the others. Even though there appears to be an overwhelming number of different presence measures, they often measure similar notions of presence such as realism, immersion, transportation, and social richness.

[21] states that the criteria for good measures of presence are reliability, validity, robustness, sensitivity, non-intrusiveness, and convenience. Reliability, validity, and robustness are necessary requirements for usefulness, relevancy, and repeatability of a

measure, respectively. Sensitivity allows a measure to achieve sufficient resolution between different degrees of presence. Non-intrusiveness is related to validity since it would be highly ineffective to have a measure that interferes with the presence experience or tasks being performed. Convenience refers to how easy it is to apply a measure. This criterion adds to a measure's usefulness if it requires minimal training, time, and monetary investments. Measures must be evaluated against all of these criteria in order to determine whether they are adequate to measure presence.

This section has presented the strengths and weaknesses of employing subjective or objective measures alone. It is suggested that rather than making a clear distinction between subjective and objective measures, it might be best to view them as a continuum [21]. As a result, the research method presented in Chapter 4 used a combination of subjective (questionnaires, observer notes) and objective (video analysis) measures. This approach took advantage of the strengths of both types of measures while attempting to compensate for some of the weaknesses outlined in this section. Physiological measures such as heart rate and respiration rate were not practical for this thesis because the presence of the measuring equipment would interfere with the natural behaviour of the subjects.

2.3 Videoconferencing Technologies

Videoconferencing technologies have arisen from combining the technologies of television, communication networks, and telephones with people's desire to communicate and interact with each other. One of the initial goals of videoconferencing was to emulate face-to-face conversations as closely as possible [1]. The concept was that the video component of videoconferencing provided visual information so that interlocutors had

access to the facial expressions, gestures, and eye contact of their communication partners. This information is normally “hidden” with audio-only conversations such as conversations by telephone or conference calls [68].

The underlying technology of videoconferencing consists of a live audio and video connection between two or more interlocutors over high-speed networks. The simplest videoconferencing system uses a microphone, a camera and a display screen managed by a computer at one location, a matching set of hardware at a second location, and a communication channel linking the two locations.

The first videophone, called PicturePhone, was publicly exhibited by Bell Laboratories at the World’s Fair in New York in 1964 [3]. The video was in black and white and the system had a frame rate of 30 frames per second (fps). Each frame had 250 lines and the screen measured 13.97 cm x 12.7 cm. It required a bandwidth of 1 MHz carried over 6 standard telephone wires: One pair for voice data, and two additional pairs for sending and receiving video data. Users had the option of enabling the video capabilities or disabling them for making ordinary voice calls [2].

In 1982 the first commercial systems appeared. The system offered by Compression Labs cost \$250,000, and the special telecommunication lines required for the system cost \$1,000/hr. In 1986, PictureTel released the first economical alternative to Compression Labs’ videoconferencing system. PictureTel’s system sold for \$80,000 and the telecommunication lines were available for \$100/hr. In 1991, PictureTel and IBM introduced the first PC based videophone called PicTel. The system sold for \$20,000 and the lines only cost \$30/hr. In 2000, Samsung released the first 3G cell phone with video streaming capability. In 2002, KT-ICOM and J-Phone demonstrated 3G video cell phone

roaming [69]. It is evident by tracing videoconferencing's history from the PicturePhone to the PC to the cellular phone, that its development is closely linked to the trends in telecommunication technology and infrastructure. These developments have also led to the possibility of videoconferencing being mobile instead of being used at a fixed location as required for the older systems.

Modern videoconferencing systems can use a variety of telecommunications technologies. For example, it is possible to conduct a videoconference using a regular PSTN (public switched telephone network) or over a wireless cell phone network or using special high speed digital telecommunication networks and the Internet.

The introduction of digital communication networks and efficient compression algorithms presented an opportunity to considerably enhance the performance of videoconferencing over the performance experienced over a PSTN running at 33.6 kbps (maximum bandwidth over a PSTN using 56 kbps modems) [70]. For example, switched-56 lines use the a PSTN but are actually capable of 56 kbps because the protocol employs digital communication techniques [71]. Integrated Services Digital Network (ISDN) lines also use existing phone lines similar to switched-56, but are capable of 64 kbps. This makes ISDN a better choice than switched-56 for videoconferencing applications which require more bandwidth. Typically, multiple ISDN lines are used so the speed can be doubled to 128 kbps using two lines, or raised to 384 kbps by using six lines.

ISDN requires the installation of dedicated networking equipment so that existing phone lines can be used. The network access fees are based on a monthly fee for the lines plus an hourly fee (with long distance charges) for line usage. This can result in a high

cost to use the lines for long distance calls which would occur frequently if people were primarily using the system for communicating across national borders.

Recently, Internet Protocol (IP) is becoming the preferred connection method for videoconferencing because it requires less equipment than ISDN, its costs are typically much lower, and its available bandwidth can be much higher [72]. IP is also fairly widespread in office and public networks contributing, in part, to the lower cost of using IP for videoconferencing.

The two most popular methods for IP connections for home users are Digital Subscriber Line (DSL), and cable. DSL is similar to ISDN in that it uses existing telephone wires, but it is capable of 1.5 Mbps, and requires a DSL modem and has monthly fees. The drawback of DSL is that it is not always available, especially in rural areas, and the speed decreases as the distance between the phone company's central office and the modem increases [73]. A second technology, digital cable, is capable of 30-40 Mbps, and also requires a cable modem and has monthly cable fees. Unfortunately, most users are incapable of achieving those optimal speeds because the bandwidth is shared among local subscribers (i.e. the more subscribers, the lower the bandwidth available to each subscriber) [74].

In order to communicate effectively through a telecommunications channel, videoconferencing systems require codecs to improve communication and signal reliability. Codecs are devices which can code and compress data to fit within a prescribed bandwidth, and later decompress and decode the signal to its original data or an approximation of the original data. The design of codecs is based on standards determined predominately by the International Telecommunication Union (ITU) [75].

These standards ensure that different videoconferencing systems made by different manufacturers are interoperable and compatible (able to communicate) with each other. In addition to ensuring compatibility within the same communication channel, there are ITU standards which govern data compression by codecs. Some of the more commonly used standards in videoconferencing are H.320 (ISDN), H.323 (IP), and H.324 (PSTN). These standards define audio, video, and data communication standards. Further details can be found through the ITU webpage [75].

One drawback of the existing standards is that do not allow for full compatibility across different networks. For example, the H.320 (ISDN) standard is not compatible with the H.323 (IP) standard. This incompatibility, however, can be mitigated with the use of a gateway. A gateway is a device which serves as a bridge between incompatible codecs by translated between the various network standards.

Not only does videoconferencing consists of a signal transmission system but also it requires appropriate I/O devices for capturing and displaying video, audio and data. PC-based videoconferencing stations consisted of a camera, microphone, monitor, and speakers attached to each computer participating in the videoconference (see Figure 3). A picture-in-picture approach is used to display the video captured by the remote camera and video captured by the local camera pointing at the user (if available). Typically, the remote video is displayed near or close to the center of the display and occupies most the display area. The local video occupies a smaller area and is usually located in a corner of the display.

While most modern-day systems still use those components, existing components have been modified, or additional components have been added to improve the sense of

presence. One of the added components developed to increase presence is the whiteboard. A whiteboard is an application that is used to make simple sketches draw and allows users share their sketches. Although it appears to be a simple space for sharing digital doodles, a whiteboard can also be used to share ideas through digital drawings and documents without relying on a video camera to capture images from paper versions of those documents (held up or presented in front of a camera). The whiteboard has the added benefit of allowing all participants in the videoconference to directly add modifications to any presented material [76]. Another tool is application sharing; the ability to show others your work that was entered into another application such as a spreadsheet and allow them to make modifications to it directly through that application even if they do not have that application on their local computer. Microsoft NetMeeting is one example of software that supports application sharing during videoconferencing.

Telephone conversations and videoconferencing have been used to project a user's presence to another location. This approach has been favoured for many business applications where face-to-face meetings are not possible due to overwhelming travel costs or time restrictions. Videoconferencing evolved from telephone conversations as a potentially more effective method for conveying messages and sharing work and ideas. As a result, videoconferencing has been used mainly by corporations and research organizations.

In education, videoconferencing has been relegated to a supplementary role. It is mainly used as a cross-cultural tool for linking two different schools [77], or for introducing special guests to the curriculum. An example of the latter is the NASA LIVE program which has staff members from NASA act as guest lecturers on a variety of

aerospace topics via videoconferencing [78]. There have been few instances where videoconferencing in schools was used to allow student in different schools to collaborate on projects [79, 80]. In these cases, elementary school students were working on TV production with high school students, and learning about simple machines from university students. It has been very useful in stimulating social interactions in the classroom which were beneficial to the learning process [81].

Other reported benefits and uses of telepresence education include the ability of a teacher to educate a remote student [82], and the opportunity for an experienced tradesperson to aid in the training and tasks of a less experienced colleague from a distance [42]. The uses can also extend beyond academic purposes to accomplish social tasks. This was demonstrated by [83], where performers were situated at separate physical locations, and a live violin duet was performed via videoconference. Powerful computers and a high speed communication channel were employed to ensure that time delays were minimized so the performers were closely synchronized. The performers experienced telepresence and remarked that it was almost as if the other person was in the same room with them.

The advantages of videoconferencing over simple telephone calls are numerous. Some of the common perceived benefits of using videoconferencing are that it leads to more natural conversations that are more interactive, increases the ability to listen selectively to particular speakers, allows a user to track the attention of others, and to generally keep track of the conversation [84]. It has also been reported that groups collaborating through videoconferencing technology tend to like each other more [68], and they are capable of establishing trusting relationships [85]. For example, [86]

reported that when a group was assigned a design task, the group that used videoconferencing technology with a shared workspace produced higher quality designs compared to those produced by groups communicating with audio only.

Given these benefits and the potential to significantly reduce travel costs, it would seem that videoconferencing would be a widely deployed and standard technology. However, that is not the case. A survey of corporate users revealed that 70% used telephone conferencing, but only 16% use videoconferencing and 20% use web conferencing [87]. [88] points out despite advances in technology, videoconferencing is inadequate for replacing face-to-face communication because there are still many obstacles such as limited field of view, lower sense of presence, not being physically co-located, technical complexity, interface designs that are difficult to use, and little or no mobility that must be addressed.

The most common complaints about videoconferencing concern signal latency and poor audio and video quality [89]. These issues arise from the technical limits of the I/O hardware, available bandwidth, codecs used, and processing speed. Latency and I/O devices will be examined here and in section 2.5.

Latency is a significant obstacle for videoconferencing to overcome. It is a result of audio and video arriving at a remote location delayed. This can result in unnatural breaks in conversations. For example, a user may ask a question and a second user will experience a delay in hearing it. The response to the question is also delayed, and during this delay, the first user may have asked another question to check if the second user heard the original question. These breaks in conversations can adversely affect sense of presence because it gives the impression that people are not being acknowledged when

they speak. A difference between audio and video delays can also cause a large decrease in the sense of presence as a result of lower realism. If the audio and video become unsynchronized where the audio does not properly match with the movement of a speaker's lips (i.e. the audio signal arrives after the person can be seen speaking) causes a mismatch between what the remote user sees and hears, and in turn causes confusion.

In a study on the effects of latency on collaborative problem solving, [90] found that performance was 36% and 40% poorer in situations with audio and video delayed by 500 ms, respectively. Situations with the 500 ms delay also resulted in higher rates of speaker interruptions. Audio and video delay caused 40% and 50% speaker interruption, respectively, compared to 15% for videoconferences with no delay. In comparison, there was only a 9% speaker interruption rate for face-to-face communication.

The ITU latency guideline for IP telephony is 150 ms [87]. Microsoft's Instant Messaging application has a LAN voice latency measured at less than 130 ms, and NetMeeting has a latency of 290 ms [87]. For Instant Messaging, the computer needs to encode the text data and transmit to the other end. The receiving computer needs to wait for the data to arrive before it can decode the text data. NetMeeting is more computationally intensive because (assuming the MPEG codec is used) video data needs to be buffered and encoded before it can be transmitted. The receiving computer needs to wait for a larger amount of data to arrive, buffer it, and decode it before it can be displayed.

Running these communication applications on shared networks may increase their reported latency because of the shared nature of network and Internet bandwidth. If there are no other users on a network, the entire bandwidth of the network can be used for a

videoconference, and latency is minimal. If there are other users on the network, the total available bandwidth of the network needs to be shared among all the users, resulting in decreasing bandwidth available for the videoconference and latency increasing.

The input hardware is limited by the quality of the camera and the sound recording equipment. The type of image sensor, colour depth, frame rate, and zoom capability are all factors that need to be considered for cameras [91]. A CMOS (Complementary Metal Oxide Semiconductor) image sensor cannot capture higher resolution than a CCD (Charged Coupled Device) image sensor can because the pixels of a CMOS image sensor have a smaller surface for capturing light than the pixels of a CCD image sensor. Colour depth affects the variety of colours that can be displayed. For example, 32-bit colour depth allows for over 4 billion different colours, whereas 8-bit colour depth is restricted to only 256 different colours. A high frame rate makes video appear more natural and fluid. Most cameras have a frame rate of 30 fps which is rated at broadcast quality, but inexpensive webcams usually have a lower frame rate. A lower frame rate results in unnatural, jerky motion.

Sound recording equipment consists of mainly microphone and mixer [92, 93]. The choice between a table-top microphone and a wireless lavalier microphone depends on the setting. A table-top microphone is more suitable for stationary participants whereas a wireless microphone would be better for mobile participants. A mixer is used to improve the sound quality by acting as a bandpass filter to reduce echoes and unwanted background noise.

Output hardware depends on the quality of the displays and the speakers. A large display can create a sense of realism since the person appears close to their actual size

[89]. However, the largest display size is dependent on the video resolution. Low resolution video on a large display is uncomfortable to look at because there is insufficient image information for all of the display's pixels. The same resolution on a small display appears smoother because there are fewer pixels, and enough image information for all the display's pixels.

There are two important features of speakers: Frequency response and Sensitivity [94]. Frequency response describes the range of frequencies that a speaker can output. A low frequency response results in hollow sound, similar to AM radio. Sensitivity describes how well the speaker can play loud volumes without distortions and without additional power. Typical computer speakers have a frequency response of 50 Hz to 20 kHz and a sensitivity of 85 dB.

Processing speed depends on the speed of the electronics that perform the signal processing tasks. For example, how quickly the camera converts the images it receives into digital information. A high resolution camera requires more time to convert images than a lower resolution camera because there are more pixels per image. For a PC videoconferencing scenario, processing speed depends on the speed of the DSP's (Digital Signal Processors) in the camera, mixer, video card, sound card, communication (codec) cards, modems (if applicable), and the CPU. Processing speed is critical in videoconferencing because it can account for 50% of the latency [95].

Bandwidth and codecs are related. Codecs are required because of bandwidth limitations, and place restrictions on video resolution. One the most common video codecs is MPEG. The codec saves bandwidth by examining the differences in a block of video frames and only transmitting a few compressed frames and a compressed

difference signal using the discrete cosine transform (DCT) [96]. This process is called interframe coding because it encodes the difference between successive frames. The codec saves bandwidth by transmitting only a few frames and the difference signal instead of the whole sequence. A drawback of the MPEG codec is that it creates visual artifacts when there is fast motion because the difference between frames is too large. Further information on some of the common video codecs used in videoconferencing can be found in the Appendix A.

An example to illustrate the limitations of technology can be found in the Coliseum videoconferencing system seen in Figure 6 [95, 97]. The researchers have devised a multiparty videoconferencing system that uses five CCD cameras arranged in a circular fashion, a 19" LCD monitor, an earbud, and a microphone (an unspecified type). The system also uses dual processor PC's with processor speeds ranging from 2.0-3.06 GHz and memory ranging from 1-4 GB, running modern Windows operating systems. The MPEG codec, and a LAN and Internet-2 connections are used. They found that the cameras, processing, network, and display contributed to 20%, 50%, 5%, and 25% of the delay or latency, respectively. Using dual-processor PC's, they found that the CPU usage jumped from 80% to 100% when the videoconference was increased beyond two users. Bandwidth consumption also nearly doubled from 600 kbps to 1100 kbps when there were more than two users. The frame rate for every user also decreased dramatically, dropping from 15 fps to 7 to 3 fps when expanding from two to four to ten users.

Figure 6: Coliseum Videoconferencing System [95]

The authors neglect to mention any results of usability testing and any negative effects caused by the low frame rate, but emphasize that the video remained at a high resolution [97]. However, sufficient frame rate is important because movement appears jerky otherwise. Even though the input and output hardware was high speed and fidelity, and the CPU was a fast processor, the CPU still could not process the video fast enough to allow for high enough frame rate.

Other more human-oriented limitations of videoconferencing create barriers to using it effectively. Most videoconferencing systems have only a single monitor, one camera, and a single set of speakers with fixed directions. This can result in a loss of valuable interaction indicators like sound and gaze direction [76, 98]. It is difficult to tell where a person's attention is focused when looking at their face on a two dimensional display. The person on the remote end appears to be just looking at their own display in a general fashion or worse looking down because the camera that is capturing their image is located above their head (often on a monitor or television screen). The loss of gaze direction becomes more apparent when a multi-party conference is being held or if there is more than one person at a location. Users also cannot always distinguish who the target

receiver is unless a specific person's name is used. If there is someone speaking to the remote user outside of the field of view of the camera, the user might be unable to tell who or where the person is because the single set of speakers makes it impossible to tell where the person is located even if they are standing beside the camera. These issues can cause a decrease in the sense of presence for all parties. The local user may not believe that she has been transported to the remote location because she is unable to interact with the remote location as she normally would (social richness, transportation, immersion). The remote user will also believe that the other user has not been transported to the same location because the technology limitations of the system become more apparent and the videoconferencing system appears more like a talking box rather than a representation of the other user (transportation, realism, medium as social actor).

One factor that seems has received little attention but has the potential to cause disruption in meetings and exclusion of the remote participant, thus decreasing her sense of presence, is the ability to gain the attention of the group. Meeting conventions dictate that in order to gain the attention of all others present or to request a turn, a participant would normally raise her hand [99]. Raising one's hand to request attention is a form of etiquette that is commonly taught and practiced in schools.

Using a single fixed camera results in a loss of peripheral vision, and without peripheral vision, hand-raising likely goes unnoticed. The remote participant in a video conference is restricted to raising her hand within the screen space of the videoconferencing system potentially obstructing her face or causing her to assume awkward and unconventional body positions. An alternative to raising a hand is to interrupt with an audio cue such as a cough or subtle vocalization.

Turn-taking is a critical component in synchronous communication, especially videoconferencing [68, 90, 100-102]. In face-to-face meetings, floor control can be passed around by verbal and visual cues such as ending with a question, explicitly passing her turn to a specific individual, hand raising, interrupting, and physically touching someone. In videoconferencing, turn-taking is accomplished through verbal and visual cues as well such as turning to face or turning away from someone [100], interrupting a speaker [90], hand raising [101], activating a light [11], and asking a question to a specific person [102]. Other methods include indicating that they wish to speak through a moderator, pointing at the current speaker, or making a disruptive noise (e.g. knocking, coughing, clearing their throat). The latter method is usually only used when all else fails because it causes a disruption in the normal flow of a conversation which typically leads to disruptions in collaborative processes and can result in decreased productivity.

In videoconferencing situations, using these cues can be problematic. Touching the current speaker is physically impossible, purposely disrupting a conversation is often frowned upon in many settings, and visual and verbal cues are often unnoticed because of limitations in the quality of the audio and video technology [101, 103]. This leads to a decreased sense of presence because the user thinks that they have very little influence on the interactions.

2.4 Videoconferencing Applications

This section briefly covers some examples of videoconferencing technologies that have been developed or are currently under development. Through these examples, I will

show how various features of videoconferencing could be used in my particular application.

The Ontario Telepresence Project [104] was a three-year collaborative research project between academics and industry scientists that began in 1992. The main purpose of the project was to study sociological and technological issues surrounding computer supported collaborative work systems. A second aim of the Ontario Telepresence Project was to develop technologies to support computer-mediated collaboration over great distances.

The Hydra system was one of the resulting products of the project (see Figure 7). Hydra was a desktop videoconferencing system that attempted to recreate the natural feeling of a round-table meeting [100]. The Hydra system introduced a sense of spatial awareness by arranging individual stations in specific positions as though the individuals themselves were sitting in the respective positions. This arrangement allowed a local user to “face” a unit that corresponded to a specific person when they wanted to address that person, and he/she could clearly see when the person was addressing them specifically. The main benefit of Hydra was that it used relatively inexpensive hardware to accommodate multiple users while supporting spatial and gaze awareness. The footprint of the Hydra unit was small which made it easy to place next to a computer monitor. These features and the unobtrusiveness of the Hydra system were designed to enhance the feeling of presence for all of the participants. The users responded that the act of facing a specific unit to address a person resulted in a greater sense of presence for all parties. However, the display screens were very small which made it difficult to see smaller objects, and decreased the sense of having the other participants present.

Figure 7: Hydra Videoconferencing System [105]

The Portholes system (see Figure 8), developed by Xerox in 1992, was designed to connect multiple users through a single application on their computer screen [106]. All of the connected users were able to see each other (unless they desired privacy) and they were able to communicate with each other through recorded audio clips and e-mail. Although this was not a true videoconferencing system, it was able to create an atmosphere of a community similar to videoconferencing. A sense of community was reported as developing among participants because people could see what other users were doing outside of the context of a formal meeting, and they were able to tell when somebody was in their office instead of phoning or visiting an empty office. In addition, the users were able to see and informally meet with colleagues they may not have met in face-to-face situations before. The drawbacks to this system were that it used a frame grabber (once/minute) resulting in captured frames with low resolution [107], the system required a network of servers to link multiple locations, and the video quality depended on the quality of the image-processing facilities locally available to each server [106].

Figure 8: Portholes System

The LiveWire system [100] used voice-activated switching instead of the traditional picture-in-picture approach for multiparty videoconferences (see Figure 9). Voice-activated switching caused the remote view to be switched to whoever was speaking. The idea was that by switching to the view of the speaker, the natural behaviour of turning to face the person who was speaking was replicated. Unfortunately, the system was too sensitive and would switch to people who were making sounds unrelated to the ongoing discussion (i.e. coughing). Also, the users believed they had very little presence since they could only see the speaker and no other participants, and there was no feedback from the system to indicate whether or not each participant could be seen by the others. The lack of sense of community was related to a lower sense of presence as transportation since they did not have the impression they were together.

Figure 9: LiveWire's Voice-Activated Switching [100]

PEBBLES (Providing Education By Bringing Learning Environments to Students) is a videoconferencing system designed to link children in the hospital with their regular classroom [34]. PEBBLES was developed to meet the social and academic needs of children in elementary school. The design of PEBBLES attempts to overcome some of the limitations of other videoconferencing systems by using robotic elements to add motion and controllability, and by incorporating a simplified user interface. For example, the system uses motors to allow the remote user to rotate the monitor, speakers, and camera assembly. This simulates head turning which can then show the local audience where the remote student is looking or attempting to look. Since the system is meant for use in a classroom environment, it attempts to preserve the normal rules for turn-taking by featuring a waving hand for gaining attention during class. PEBBLES seems to address some of the specific issues related to children and the school environment because it uses a simple interface in the form of a gamepad, and most of the technology is hidden from view to make it appear less imposing.

The researchers reported that the hospitalized student became more comfortable with using the system, exhibiting more confidence in answering questions as time progressed. The classroom students formed a good impression of the hospitalized

student's well-being, and the hospitalized student's parents believed her academic progress was good. However, her classroom teacher reported having a greater workload as a result of having PEBBLES in the class, and all the participants expressed concern with technical difficulties, especially audio quality. A full description of the system can be found in section 2.5.

After examining these various examples of videoconferencing systems in this section, and reviewing the technology in section 2.3, it is not difficult to see how videoconferencing can be considered to be an enriching yet delicate resource. Videoconferencing has definite benefits over text chatting or audio only conferencing, but user acceptance remains its largest challenge.

2.4.1 Videoconferencing System Design Considerations

The design of videoconferencing systems has a great impact on its success because it influences users' impressions. The limitations of the hardware have already been discussed (see section 2.3) as well as some of the issues with existing systems. An effective videoconferencing system should account for these hardware limitations, but still allow its users to communicate and work as naturally as possible.

The PicturePhone was branded as a failure when the public did not embrace the technology as warmly as expected by the AT&T executives [3, 87, 108]. Users who were surveyed at the World's Fair were unhappy with the size of the system, the size of the video image, and the awkward controls [108]. Later, consumers were unhappy with the cost, the size and shape, and the appearance of people they were talking to [3, 108]. It seems in their rush to announce and profit from their new invention, AT&T neglected to consider that being able to see the other party did not necessarily qualify it as a

replacement for traditional communication media like mail, telephone, and face-to-face meetings [1, 3].

There is an increasing shift in design focus to user-centered products and services [47]. There is also a growing tendency to design products with interfaces that can accommodate different users as opposed to forcing users to conform to the product's interface. Many researchers have provided guidelines for creating user interfaces [87, 109, 110]. [109] provides a list of general criteria that was developed 20 years ago and seems to still apply:

1. *Speed* – It must not take the user longer to do the job with the help of the system than without.
2. *Accuracy* – Information to which the user has access must not be less accurate when using the system than without it.
3. *Completeness* – The user must have access to as much information when using the system without it.
4. *Objectiveness* – The system must meet its objectives.
5. *Pleasure* – The program must not “take over” the parts of the work the users enjoy doing, and leave them with parts they find boring.
6. *Flexibility* – The system must accommodate different user needs (e.g. ability to create custom macros).

More current, [110] presents ten principles for user interface design:

1. *Visibility of system status* – The system should always keep users informed about what is going on, through appropriate feedback within reasonable time
2. *Match between system and the real world* – The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.
3. *User control and freedom* - Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.
4. *Consistency and standards* – Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.
5. *Error prevention* – Even better than good error messages is a careful design which prevents a problem from occurring in the first place.

Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

6. *Recognition rather than recall* – Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.
7. *Flexibility and efficiency of use* – Accelerators (unseen by the novice user) may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.
8. *Aesthetic and minimalist design* – Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.
9. *Help users recognize, diagnose, and recover from errors* – Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.
10. *Help and documentation* – Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

[87] proposes four requirements for videoconferencing to be successful:

1. Voice quality must be at least competitive with telephony
2. Video technology should increase, not decrease “presence”
3. Setting up a videoconference has to be as easy as making a POTS (Plan Old Telephone System) telephone call
4. Videoconferencing must be as ubiquitous as telephones

Comparing these lists, a number of parallels arise. The voice quality and presence requirements fall into the categories of accuracy, completeness, speed, and pleasure from the list by [109], and item 5 from the list by [110]. Videoconferencing becomes a viable alternative to audio-only conferencing when the data transmitted between the two participants is reliable, otherwise the participants will choose to use the telephone and e-mail. Pleasure can be equated with satisfaction if the videoconference is conducted with few or no connection or transmission errors.

The ease in setting up a videoconference falls into the categories of speed and pleasure from the list by [109], and items 2, 3, 6, 7, 9 and 10 from the list by [110]. If users become frustrated with the setup process for the system, they will likely choose an easier alternative again. Ideally, videoconferencing systems should require very little user input to setup, and assistance should be readily available if any problems occur.

The ubiquity of videoconferencing falls into the category of flexibility from the list by [109] and items 3, 7, 8, 9, and 10 from the list by [110]. In order for videoconferencing to be universally accepted in the same manner that telephones are, the systems must be able to adapt to the needs of its users. For example, videoconferencing systems that have additional features for sharing applications or other common workspaces would be ideal for groups desiring to use videoconferencing for the purpose of brainstorming. However, the process of sharing should follow a process similar to how users normally share documents or ideas. Users should be able to make their work visible to everyone else and they should all be able to make (or suggest) changes simultaneously. Another example would be that the videoconferencing system would be capable of movement to focus on various points of interest, or to allow users to direct attention to different objects in a room. This is similar to NASA's Mars rovers except a mobile videoconferencing system should have a humanoid appearance to achieve a natural look.

Several factors need to be considered when designing the interface for an effective videoconferencing system. The display and audio fidelity, and placement of the interface devices all have an impact on the system performance and the users [19], but the purpose of the system is also a factor [110]. [3] suggests that videoconferencing should be used to supplement face-to-face meetings rather than replace them completely. [48]

also suggests that each medium has strengths and weaknesses, and that the goal of videoconferencing system design is to maximize the advantages rather than try to replicate face-to-face communication.

Videoconferencing could be used as a tool for conducting quick, informal meetings instead of organizing a large formal meeting which might not be appropriate. Videoconferencing could be used to give and receive quick updates on work progress, and to conduct meetings between individuals who are separated by a large distance. The technology should allow people to talk to each other with the same convenience that they pick up a phone to talk. There is the added benefit of visual information that can be used to supplement what would normally be an audio-only conversation.

[68] suggests that the benefits of including video depend on the particular task. For example, a low-cost videoconferencing system that uses low-resolution video, low frame rate, and low sound quality may be appropriate for an inexpensive video phone application such as two long time friends in separate countries conversing, but the same system would be unacceptable for an important business meeting where being unable to notice fine details could be costly.

Even if the videoconferencing system has been designed to take advantages of the strengths of the medium, there are other technical factors which may have a significant impact on the perception of telepresence. These include display size, video resolution, frame rate, audio quality, bandwidth, placement of hardware, and additional functionality beyond basic videoconferencing.

Display size has been shown to be important but not that crucial. A life-size display increases the degree of presence because it enhances the illusion that the person is

physically present [10, 111]. Although large and persistent displays are more lifelike and memorable [89, 112], there is some research that shows that realism and presence might not be directly related [19]. As demonstrated by the Hydra system, small display sizes in the interest of saving space do not necessarily render the system ineffective. For a lecture hall, a larger-than-life display might be ideal since the necessary infrastructure to support the display would be economically feasible. For simple desktop videoconferencing, the smaller display would be a more economical choice. Video resolution is closely linked with display size. A smaller display is more suited for lower resolution video than a large display to avoid “blocky”, pixilated video.

Video resolution also has been reported to have some influence on display size. High resolution video can reveal intricate details, but it requires a greater resolution and requires greater bandwidth to transmit a greater number of pixel data. Low resolution video that consumes less bandwidth is best displayed on smaller displays to achieve better image quality. The ITU standards for resolution are Common Intermediate Format (CIF), Quarter CIF (QCIF), and Sub-QCIF which have respective resolutions of 352 x 288, 176 x 144, and 128 x 96 [75]. These resolutions are very small in comparison to more common formats (e.g. SVGA has a resolution of 800 x 600 and NTSC has a resolution of 480 x 440 [111]). In effect, it is difficult to achieve high quality resolution when following the ITU standards. This has led at least one researcher [89] to use high bandwidth DV instead to achieve very high resolution. The tradeoff is the requirement for higher bandwidth networks to preserve the frame rate.

Frame rate also has also been shown to have an effect on user perceptions. The frame rate for motion pictures is 48 fps [111]. For television, the frame rates are 25 fps

for PAL and 30 fps for NTSC [113]. These frame rates are high enough to fool the human eye into seeing smooth motion because they are at least 15 fps [114]. The experimental model for PicturePhone was initially only able to transmit 1 frame every 2 seconds [108] whereas the version exhibited at the World's Fair had a frame rate of 15 fps [2]. Today, most webcams are capable of transmitting up to 30 fps. There has been a trend towards increasing frame rates up to 30 fps because the human eye captures images at a rate of 25 fps [114]. This makes the video appear natural without the jerky motion that is typical of early silent movies and webcams. The significance of frame rate as it relates to presence can be seen in an experiment that tested presence with different frame rates. [66] used frame rates of 10, 15, 20, and 30 fps in a virtual reality environment. They found that the sense of presence increased monotonically with the frame rate from 15 to 30 fps.

Cellular phones have become a new medium for supporting videoconferencing sessions. The Kyocera Visual Phone VP-210 was one of the first videoconferencing cellular phones, but it could transmit at only 2 fps [115]. The low frame rate combined with its high price and weight, made it as commercially unsuccessful as the PicturePhone. In fact, many cell phones which claim to have a videoconferencing feature, only use static images of the speakers. The telepresence afforded by this type of videoconferencing is low since it is hardly different from using a regular cellular phone and looking at somebody's photograph. This is a disappointing trend since cellular phones are becoming much more common. Having videoconferencing capabilities in these devices may actually allow it to become a successful communication application for business and for general use.

Audio quality is a vital factor in successful videoconferencing. Research has shown that users are unwilling to sacrifice audio quality for higher video quality [111]. The benchmark for audio quality has long been the telephone which passes frequencies from 200 to 3000 Hz, inadequate for music, but sufficient for voice conversations. Long-distance telephone audio is sampled at 8 kHz with 8-bit resolution for a data rate of 64 kbps, and AT&T's Videophone 2500 is capable of compressing the sound further to 6.8 kbps [111]. For comparison, the bandwidth required to encode CD-quality audio (sampled at 44.1 kHz with 16-bit resolution) is 705.6 kbps.

Audio requires significantly less bandwidth than video. For example, using Sub-QCIF resolution and 8-bit colour, one video frame would require 98304 bits. Using a frame rate of 15 fps would then require a data rate of 1.5 Mbps. This is over 2000 times more bandwidth than required for CD-quality audio. In order to manage this level of throughput given the limitations of network bandwidth, high compression algorithms and priority assignments are required for video. Based on this example, one can easily see how codecs become vital for reducing the necessary bandwidth for videoconferencing.

The placement of the hardware components can still compromise the telepresence effect and hamper the effectiveness of the videoconference regardless of the audio and video fidelity. Ideally, the camera and display should be placed to allow a user to behave naturally when using the videoconferencing system. [116] found that vertically aligning the centres of the camera and the display resulted in the best arrangement that enabled both users to determine when the other person was looking at them thereby reducing disruptions.

An experiment conducted by [117] manipulated the tilt and vertical positions of cameras and displays for videoconferencing. They found that, similar to face-to-face situations, users who appeared to be in a taller, more dominant position than others had a greater influence on decisions compared to users who appeared to be in a shorter, more submissive position. If one participant should have more clout in the group, it might be preferable to manipulate the camera and display to make the person appear more dominant. Manipulating the camera and display positions and angles to make all participants appear to be equal height might be helpful in stimulating discussions among peers.

Some examples of systems that have specifically developed to allow for seamless and integrated interaction are the ClearBoard, TeamWorkStation, and Shared ARK systems [10, 118]. These systems attempt to match the technology with the task requirements and system design so that the user is not required to put much effort into learning new methods of using them. The ClearBoard system takes the form of a regular-looking desk. The users can write and draw on the desktop, and they can also see the video of the other person being projected onto the writing surface. In effect, the users are able to share ideas and see the other user and the other user's ideas by shifting their gaze a small amount. The TeamWorkStation and Shared ARK systems employ two adjacent displays with one display dedicated to videoconferencing and the other display meant for running computer applications. Placement which promotes seamless interaction is beneficial because it allows users to interact and work in a similar fashion as writing notes at face-to-face meetings.

Separation of the work area from the communication area can lead to improved performance because it can support a more natural communication situation for the remote participants [10]. For example, a user does not write notes on a large piece of paper next to the face of somebody they are having a face-to-face conversation with. [23] uses the metaphor of a keyhole to explain the differences between using a single or multiple displays. The single display saves physical space, but the amount of information that can be displayed is limited (similar to what could be seen of a room when looking through a keyhole) and there is a potential for losing information. For example, the AR system designed by [119] has only a single display and sacrifices a view of the AR user's face in order to fit the whiteboard, local feedback, and the AR user's view on a single screen. The TeamWorkStation and Shared ARK systems have multiple displays to allow for a greater amount of space for the information to be displayed. However, they also have larger physical space requirements for the equipment in order to implement two displays, and the user must constantly shift their eye gaze and focus between screens. Designers should be aware of the physical space limitations before they choose to design systems with multiple displays.

Having multiple displays presents an opportunity to share applications in a dedicated space. Applications can appear clearly in a dedicated display to avoid crowding a single display. One of the advantages of videoconferencing is the ability to facilitate electronic document and application sharing between interlocutors. For example, a whiteboard allows users to simultaneously share their ideas in a common workspace using drawing, sketching and text. Whiteboards are traditionally used in classroom or meeting rooms to encourage ideas to be shared freely through drawing, sketching or

documenting them on the whiteboard. [104, 119, 120] suggest that the value of a whiteboard, for videoconferencing, is to act as a conduit for quick and informal sharing of ideas between remote and local participants. Whiteboarding tasks require different physical and cognitive skills compared with communication tasks. A user drawing on a whiteboard has the benefit of being able to focus an observer's attention on specific parts of a drawing. However, they must be able to effectively represent their thoughts and ideas in a graphical form that can either be easily understood or explained.

Often, communication tasks must occur simultaneously with whiteboard tasks. People may want to discuss their whiteboard activities while carrying out those activities (e.g. a person will draw on the whiteboard while explaining what is being drawn). Application sharing expands on sharing a whiteboard in a more formal manner by allowing users to sharing applications with other users that may or may not exist on their computers. For example, one user could share her spreadsheet application while the other user shares his word processor document. The first user would be able to make changes to the other user's document despite the data not residing on her computer, and vice versa.

Latency is a significant obstacle for videoconferencing to overcome. It is a result of audio and video arriving at a remote location delayed. This results in breaks in conversations because short delays can add up to longer delays. An example is when a user asks a question, and the second user hears the question delayed. The response to the question is also delayed, and during this delay, the first user may have asked another question to check if the second user heard the question. These breaks in conversations can adversely affect sense of presence because it gives the impression that people are not

being acknowledged when they speak. A difference between audio and video delays can also decrease sense of presence as a result of lower realism. When this occurs, the audio and video can become unsynchronized, and when a person is speaking, the audio does not properly match with the movement of her lips.

A study on the effects of latency on collaborative problem solving [90] found that performance was 36% and 40% poorer in situations with audio and video delayed by 500 ms, respectively. Situations with the 500 ms delay also resulted in higher rates of speaker interruptions. Audio and video delay caused 40% and 50% speaker interruption, respectively, compared to 15% for videoconferences with no delay. In comparison, there was only a 9% speaker interruption rate for face-to-face communication.

The ITU latency guideline for IP telephony is 150 ms [87]. Microsoft's Instant Messaging application has a LAN voice latency measured at less than 130 ms, and NetMeeting has a latency of 290 ms [87]. This illustrates the effect of software and codecs on latency. For Instant Messaging, the computer needs to encode the text data and transmit to the other end. The receiving computer needs to wait for the data to arrive before it can decode the text data. NetMeeting is more computationally intensive because (assuming the MPEG codec is used) video data needs to be buffered and encoded before it can be transmitted. The receiving computer needs to wait for a larger amount of data to arrive, buffer it, and decode it before it can be displayed. The ITU guideline cannot be guaranteed every time because of the shared nature of network and Internet bandwidth which contributes to latency. If there are no other users on a network, the entire bandwidth of the network can be used for a videoconference, and latency is minimal. If there are other users on the network, the total available bandwidth of the network needs

to be shared among all the users, resulting in decreasing bandwidth available for the videoconference and latency become more noticeable.

Interface design also contributes to the success of videoconferencing applications and presence. In a videoconferencing application not only does interface design include the application elements such as menus, buttons and error messages with which people must interact but it also includes factors such as presence that influence people's communication strategies.

Videoconferencing is not identical to face-to-face communication. A study by [49] highlights the asymmetry that exists in videoconferencing compared to face-to-face communication. A videoconferencing system called Telewindow was set up at several senior centers and in the homes of homebound seniors to give them the opportunity to see and talk with their friends at the center. Telewindow used a POTS-based system called ViaTV that used a speakerphone for audio and a TV for video. The most noticeable differences between meeting face-to-face and meeting through the Telewindow system were video and audio quality, mobility, and control. The Telewindow system had poor video and the audio was acceptable because of the hardware limitations. In a face-to-face setting, video and audio are only limited by eyesight and hearing conditions. The Telewindow system did not allow the homebound user to venture around the senior center and was restricted to a fixed point of view. In a face-to-face setting, people are free to walk around and look about at different parts of a room. The Telewindow system did not have functionality for the homebound users to manipulate objects at the senior center. They would have to ask somebody there to do it for them. In a face-to-face setting, people are able to pick up and move objects freely around a room.

Since technical limitations prevent videoconferencing from being identical to meeting face-to-face, designers should develop systems in a way that masks the technology or mitigates the negative effects of the limitations. By accomplishing this, videoconferences will become more natural and emulate face-to-face meetings more closely.

2.5 PEBBLES

PEBBLES is an innovative system that combines videoconferencing technologies with simple robotics technology to allow a student confined in the hospital to attend his/her regular school. This is made possible by placing one unit of PEBBLES inside the classroom, and its counterpart in the hospital which enables the student to control the classroom unit.

PEBBLES allows a student to maintain a connection and presence in his/her regular school environment from an isolated and non-normal setting. Having this connection may create a healthier and less stressful situation for a hospitalized child/youth that may in turn reduce trauma levels and health care costs. It may also ease that student's re-integration back into the classroom [121].

PEBBLES has undergone several revisions throughout its existence [122]. The first incarnation of PEBBLES (PEBBLES I) consisted of a PictureTel PCS100 desktop videoconferencing system for the hospital end and a Mitsubishi Diamond Series 9000 for the school end. The school system was placed on a wagon with a rotatable pedestal. The resulting system can be seen in Figures 11 and 12. A signaling device in the form of a red light was positioned on top of the classroom display, and all motor controls were transmitted through audio tones. The remote student was able to control all motor and

camera functions with a Nintendo gamepad. Using the familiar interface of a gamepad reduces the complexity of the user interface, making the driving technology of the videoconferencing system invisible to the students and reinforcing their sense of presence.

Figure 10: PEBBLES I (hospital unit)

Figure 11: PEBBLES I (classroom unit)

The next revision of PEBBLES (PEBBLES II) featured an improved industrial design and a waving hand to replace the red light as a signaling device. The waving hand

was determined to be more effective as a signaling device [123]. The revised PEBBLES II can be seen in Figures 13 and 14. In addition, the motor controls and audio were transmitted on separate channels. The gamepad controls remained unchanged, though onscreen feedback was provided to indicate which button was being pressed.

Figure 12: PEBBLES II (hospital unit)

Figure 13: PEBBLES II (classroom unit)

A modification of PEBBLES II (PEBBLES II.5) resulted in the addition of a feedback monitor and a secondary, wide-area camera. A scanner/printer was added as well to facilitate paper transfer between the classroom and the remote site. A gamepad

remained as the primary input device. Additional functions were added for switching the view between the primary camera and the secondary camera, and to start, stop, or pause the videoconference. The signaling hand was shortened and repositioned in the interest of safety. The revised PEBBLES II.5 units can be seen in Figures 15 and 16.

Figure 14: PEBBLES II.5 (hospital unit)

Figure 15: PEBBLES II.5 (classroom unit)

The elementary school version of PEBBLES has had tremendous success in Canada and the USA, and has been commercialized (see Figure 17). However, there is no

high school version of PEBBLES. It has been proposed that this new version should build upon the strengths of the elementary school version to accommodate the unique needs of a secondary school student [124].

Figure 16: Commercial Version of PEBBLES

The technology has been designed to support the communication and participation tasks of children by creating an interface that allows the child to interact naturally with her teacher and fellow classmates. She is able to see and hear almost everything in the classroom and can communicate with people nearby. Just as natural human gaze can change its focus, a user can manipulate the videoconferencing camera to focus on whatever interests them. The students can also share any drawings or written work by displaying it to the camera as if they were presenting it to an actual person. It has been shown that PEBBLES enables the remote child to maintain an effective presence in the classroom, improves the remote child's sense of belonging, and reduces the amount of time required for catching up on missed assignments during their absence [121].

While PEBBLES seems to be successful in supporting elementary age students, there are key differences between the types of tasks high school students carry out and

those accomplished by elementary age students. An earlier study found the most common tasks for high school students were participating in class discussions, working in groups, taking notes, performing presentations, and completing exams/tests [124]. Three to four group projects were assigned in each class and about one to two group projects per week. 75% of the students communicate by email/chat when doing their group work. They also identified that communication with peers, friends and teachers is an important aspect of their school activities.

Preliminary and informal evaluation with the elementary version of PEBBLES and high school students showed that while the students were able to perform some communication tasks with the system, several hindrances were identified which made them hesitant to use PEBBLES in their school. Some of the concerns were with regards to the appearance of the system, audio problems, and problems with sharing work [15, 16]. The HSPP seeks to address these limitations of the elementary version of PEBBLES.

CHAPTER 3: HSPP DESCRIPTION

3.1 HSPP Design Process

Previous research investigating the needs and common school activities of high school students [124] provided the foundation for developing the HSPP. In the research, a mockup of the HSPP was built to explore the impact of a collaborative videoconferencing system on high school students. The mockup consisted of a videoconferencing system that mimicked the robotic capabilities of PEBBLES, but used off-the-shelf webcams and headset microphones. The most important features of the study were using three screens instead of a picture-in-picture approach, and adding collaborative capability in the form of application sharing.

Using three screens allowed the users to maintain a constant presence regardless of the tasks being performed. There was a workspace screen, a communication screen, and a local feedback screen. Users were able to work on documents and do research on the Internet using the workspace screen without obscuring the video image of the other person appearing in the communication screen. The local feedback screen allowed the users to check what the other person was seeing from their webcam. Application sharing was accomplished using the Remote Desktop feature of Windows XP.

The design of the HSPP for this thesis was informed by the earlier “Wizard of Oz” study [124], other videoconferencing systems described in the literature and reviewed in this thesis, and the limitations of the elementary version of PEBBLES such as the lack of support for group work, the aesthetics, the size and weight being too large and heavy, and the lack of portability. The social and academic needs of high school students (e.g. communication, note-taking, and group projects) identified in the earlier

study [124] were also considered in the design of the HSPP. The design process of the HSPP can be seen in Figure 17.

Figure 17: System Design Process

The desired features of the HSPP were thus portability for transporting between classrooms, support for social communication, and group and individual work, and minimize disruptions of normal classroom activities. Of the videoconferencing systems presented in Chapter 2, the Hydra, PEBBLES, TeamWorkStation, and ClearBoard systems were considered to have some of those features implemented in some form, and could be useful with the HSPP.

The strengths of the Hydra system are the compact integrated design, and the ability to support social communication through simulated gaze direction. The strengths of the PEBBLES system are the ability to support social communication through actual gaze direction, and support for the traditional turn-taking method of hand-raising.

The TeamWorkStation and ClearBoard systems have support for conducting group and individual work by integrating the work and communication interfaces into a single system. The integrated interfaces allow for seamless transitions between the work and communication displays. The seamless transition is an important feature since it simulates the students' natural shift of focus from their conversation partner to their work and vice versa. Without the seamless quality, users would be required to manage two different interfaces potentially causing difficulty using the system. For example, a student might struggle with trying to write notes on one screen while trying to listen to and view the teacher on another, having to constantly pay attention to two physically separated screens. Ideally, the seamless transition enables students to work on electronic documents and conduct the videoconference as efficiently and as naturally as if they were sitting in the classroom and shifting focus from their notes to whomever they might be speaking.

The portability of the HSPP was implemented by using smaller displays and a design which allowed the classroom end to be manipulated into a compact form and carried. This required the use of a smaller computer with only essential components as opposed to the full sized desktop computer used in the elementary version of PEBBLES. The mechanical design employed an LCD monitor arm that could be folded up in such a way that allowed all of the system components to fit inside a single housing.

The social communication aspect of the HSPP was implemented by preserving the existing videoconferencing and robotic features of the elementary version of PEBBLES, specifically dedicating an entire display to the videoconferencing feature so that the face of the remote student would occupy the entire screen, and enabling users to

“look” around a room and zoom in on objects of interest (see section 3.2 for a full description of the mechanical system).

The support for group and individual work was implemented by adding a workspace display dedicated to running computer applications, and adding an application sharing feature so students could share electronic documents as easily as sharing paper documents. This enhances the concept of separating the work and communication space used in the TeamWorkStation and ClearBoard systems as the work space is located on a flat horizontal surface adjacent to communication screen, emulating where people would normally write while facing a communication partner.

Minimizing disruption of classroom activities was implemented by having the work and communication screens separated and in more natural-like locations, as well as implementing more human-like characteristics such as a hand that could be raised and gaze that could be physically moved. These features were designed to make the technology more transparent. In addition, the physical gamepad was replaced with an onscreen gamepad to reduce the number of physical input devices to only a keyboard and mouse.

3.2 Classroom End

The HSPP was developed from the results of the research using the mockup, and the classroom end can be seen in Figure 18. There are three screens for the HSPP: A communication screen, a workspace screen and a local feedback screen. In comparison, the elementary version of PEBBLES has only two screens (missing a workspace screen).

Figure 18: HSPP (classroom end, missing local feedback screen)

The communication screen is a 10.4" LCD monitor and is primarily used for the videoconferencing aspect of the HSPP. The video captured by the remote camera is displayed in the communication screen. The hospitalized student is able to see the classroom, and the people at the classroom end are able to see the head and shoulders of the hospitalized student. The videoconferencing camera can be adjusted to allow the people in the classroom to see the remote student's face and hand gestures as well.

The workspace screen is a 15" LCD monitor. The workspace screen can be used separately from the HSPP and can be used as a touch tablet with an optional USB attachment. The touch tablet was added in the event that there was insufficient space to operate a mouse efficiently since the classroom end was designed to be placed on a student's desk in a classroom and typically, students' desks are not very large. If desired, the workspace screen can be placed on a flat surface and operated as a tablet, or a monitor

stand can be used to position the screen like a regular LCD monitor. The workspace screen functions in the same manner as a monitor for a PC. All applications appear in this screen with the exception of the videoconferencing application.

The local feedback screen is a 2.5” LCD screen. Its purpose is to provide each end with a view of what is being captured by the local videoconferencing camera. This allows users at both ends to be aware of what the other end is seeing. The local feedback screen also aids in adjusting the videoconferencing camera to fit the remote student’s head and shoulders in the communication display at the other end.

Using two display monitors physically separates the student’s communication space from his/her personal workspace. A student can work on collaborative or individual projects, or use computing resources such as the Internet while maintaining full and separate access to the communication functions. This design is similar to the TeamWorkStation and the Shared ARK systems mentioned in Chapter 2.4.1 [10, 118]. The dedicated communication space also allows the video to be displayed at larger, more life-like size. This allows students to maintain a mutual sense of presence that is reported to increase the success of communication with videoconferencing [102] while have simultaneous access to working files and documents. The video image appears at a resolution of 640 x 480 on a monitor set at a resolution of 800 x 600, but is received at the ITU standard Sub-QCIF resolution of 128 x 96. The video image appears pixilated, but as the results in Chapter 5 show, this did not have a negative impact on the users’ impressions.

The communication screen, feedback screen, and videoconferencing camera are mounted on an 18” LCD monitor arm. The feedback screen is located adjacent to the

camera, and below the communication screen. This configuration creates a load of approximately 3.6 kg (35.3 N) at the end of the monitor arm and generates a moment of approximately 12.3 Nm about the base of the monitor arm.

The videoconferencing camera is a Sony EVI-D30 PTZ camera. The camera has a tilting range of 50° and is capable of 12x optical zoom. The LCD monitor arm has a lateral rotation arc of approximately 70°. The LCD monitor arm can be folded in such a way that the camera and both screens can fit inside the classroom end, and the lid can be folded up to create a more compact form for transporting.

The LCD monitor arm is secured to the base of the HSPP using a metal assembly designed to reduce the vibrations and counteract the gravitational forces experienced at the end of the monitor arm while in motion. The assembly can be seen in Figure 19. The monitor arm (on the left) rotates laterally, driven by a DC gear motor (on the right) and a drive belt. The DC gear motor is a Buehler 61.46.037 DC gearhead motor rated for 0.137 Nm and 13.5 rpm at 23.5 V.

Figure 19: Assembly Securing Monitor Arm to Base

The classroom is surrounded by a wooden frame with a metal carrying handle at the top and swiveling hinges in front to secure the lid. The lid is transparent to allow the internal contents to be inspected easily. The hand is made from a cardboard cutout attached to a wooden shaft which is rotated by a rotary solenoid. A spring is attached to the shaft to ensure the hand returns to its resting position inside the frame.

The hand/attention-getting device is a distinctive feature of elementary school PEBBLES that has been transferred to the HSPP. The hand used in the HSPP differs from the elementary PEBBLES version in that it is lighter, smaller, and relies on the sound of the solenoid energizing/de-energizing rather than a rattling noise.

An external sound mixer is used to ensure audio quality. An ALESIS MultiMix 6FX mixer is used to control a Crown PCC-160 tabletop microphone and an audio-

technica AT829cW wireless lapel microphone with the ATW-1451P UHF wireless microphone kit operating at 742.70 MHz.

The classroom and hospital ends are each tethered to a Soltek EQ3401 Mini Qbic PC. These computers are equipped with a Celeron 2.4 GHz processor with 1 GB of RAM running Windows XP. In addition, the computers have an integrated AC97 sound card, an ATI Radeon 9600 XT video card for dual monitor support, and a Zydacron Z353 codec board for IP videoconferencing.

One of the main goals in the physical design of the HSPP is to allow it to be easily transported as high school students tend to have rotary classroom systems. In order to be easily transportable, the system must be as light weight as possible, and be compact while still protecting the sensitive audio and video equipment contained within the housing. The classroom end (folded open) has dimensions 80 cm (L) x 41 cm (W) x 48 cm (H) and weighs approximately 20 kg. The Soltek EQ-3401 Mini Qbic PC has dimensions 33 cm (L) x 21.5 cm (W) x 20 cm (H) and weighs approximately 5 kg. In comparison, the commercial version of PEBBLES (folded open) measures 80 cm (L) x 60 cm (W) x 120 cm (H) and weighs approximately 60 kg; 35 kg lighter in weight and 70% smaller in size.

3.3 Hospital End

The hospital end currently uses a less elegant design compared with the classroom end as seen in Figure 20. Similar to the classroom end, the hospital end uses three screens and a Soltek PC, but uses a Shure M267 mixer to control a Crown PZM-185 tabletop microphone. The PC is identical to the one at classroom end, and the three screens also serve as the communication, workspace, and local feedback screens. The local feedback screen is still a 2.5” LCD screen, but the communication and workspace screens are 17”

CRT monitors which occupy a large amount of space on a desktop. The videoconferencing camera is also different. The camera is a Sony EVI-G20 PTZ camera. The camera has a tilting range of 30°, a panning range of 60°, and is capable of 3x optical zoom.

Figure 20: HSPP (hospital end)

The student operates the hospital end using a mouse and keyboard in order to use the onscreen gamepad and to launch and share applications. The onscreen gamepad for controlling the classroom end and the application manager for sharing applications appear in the workspace screen. A description of the software used by the HSPP is provided in the next section. Planned developments for the hospital end are discussed in Chapter 7.

3.4 Software

The software for the HSPP was developed by another member of the PEBBLES research team using Microsoft Visual C++, the Zydacron software development kit (SDK), and the Microsoft NetMeeting SDK. Application sharing was developed with the Microsoft NetMeeting SDK instead of using the Remote Desktop feature of Windows XP. This gave users the ability to select specific programs they wanted to share instead of forcing them to share all their programs.

The onscreen gamepad (see Figure 21) replaced the traditional gamepad used for the elementary version of PEBBLES. The purpose was to reduce the number of physical input devices for the student to manage and transport. The onscreen gamepad retains all of the original control functionality of the gamepad for the elementary version. These include buttons for the directional controls, buttons for managing the zoom function, buttons for managing the videoconferencing session, and a button for activating the hand/attention-getting device.

Figure 21: Onscreen Gamepad for HSPP

The startup windows for the HSPP can be seen in Figures 22 and 23. Figure 22 shows the startup windows (main application window and onscreen gamepad) in the workspace screen for the hospital end.

The software interface for the classroom end is similar to the interface for the hospital end except there is no gamepad as there are no motor control requirements for

the hospital end (i.e. classroom students have no control functionality for the hospital system). The remote student uses the main application window to launch the PEBBLES videoconferencing application by clicking on the button labeled 'PEBBLES'. Figure 23 shows the HSPP startup window in the communication screen. The 'Setup' button is used on the hospital end to enter the IP address of the classroom end. The classroom end does not need to enter the IP address of the hospital end since it is not capable of initiating the videoconference. The onscreen gamepad then appears in the workspace screen, and the student clicks on the 'GO' button to begin the videoconference. When the student is finished, she can click on the 'STOP' button to end the videoconference.

The student at the hospital end can also control the applications being shared by clicking on the button labeled 'Sharing'. Clicking on the button labeled 'Connect' alerts users at the classroom end that the remote student wishes to share applications. Only the hospital end has the ability to initiate application sharing with the 'Connect' button. Clicking on button labeled 'Update' presents a list of all the programs currently available to be shared. Users at both ends can check off which programs they want to share under the 'Show My Work' column. Clicking on 'Work Together' then gives users at the opportunity to take control of the applications at the other end. All applications are launched in the workspace screen except for the HSPP videoconferencing application which is the only application that appears in the communication screen.

Figure 22: Startup Windows in Workspace for HSPP (hospital end)

Figure 23: Videoconferencing Window for HSPP

An additional collaborative tool developed for the HSPP was a whiteboard application. The whiteboard application is launched from the main application window by clicking on 'Whiteboard'. The simple interface is similar to Microsoft Paint and includes tools such as line drawing and colour for drawing simple shapes and figures that are common to paint programs and shared whiteboard applications used in standard videoconferencing applications. However, this tool has been simplified from the more standard whiteboard functions in order to support those identified by high school students to support their collaboration tasks. The corresponding interface has also been simplified to support sketching, annotating and capturing ideas rather than "painting" or "formal drawing" activities because students are expected to use more sophisticated computer applications for those purposes.

3.5 Electronics

The control system for the HSPP consists of an electro-mechanical system that allows remote control of motor and camera functionality of the classroom end. The tilt and zoom functions of the videoconferencing camera are controlled separately from the rotation and attention-getting functions of the classroom end. The camera functions are relayed to the camera through the computer's serial port using the VISCA RS-232C control protocol. The rotation and attention-getting functions are relayed to a microcontroller through a separate serial port using a basic RS-232 protocol.

The circuit for the rotation and attention-getting functions required a microcontroller to interpret control signals, an RS-232 transceiver to manage communication between the microcontroller and the computer, a motor driver that could

handle the required power for driving the gear motor and the rotary solenoid. The circuit schematic for the classroom end can be seen in Figure 24.

The circuit board is powered by two separate power supplies. One supply (6 VDC, 500 mA) is regulated at 5 VDC, 100 mA using a LM78L05 voltage regulator to power the various ICs in the circuit. The other power supply (18 VDC, 1 A), is regulated at 15 VDC, 100 mA using a LM78L15 voltage regulator to drive the rotary solenoid and the DC gear motor. Separate power supplies were used to ensure that the power drain caused by activating the gear motor or rotary solenoid would not have an effect on the communication signals.

A Microchip PIC16F818 EEPROM is programmed to interface with the PC's RS-232 port via a MAX232 RS-232 transceiver. A structured, linear, low-level assembly code approach is used since the operations are not very complex, and future researchers can easily understand and interpret it. The PIC processor is instructed to loop continuously, checking for a flag from a serial RS-232 interrupt. Once the interrupt service routine (ISR) verifies the data as legitimate RS-232 data, the ISR branches to a sub-routine that buffers the bits in order to form an 8-bit ASCII code. The ASCII code is compared to a set of legitimate commands (shown in Table 2) using bit-test operations. If the received code is a legitimate command, the PIC output pins are configured accordingly. Additional information on the ASCII codes and the RS-232 protocol used are presented in section 3.6. The assembly code is in Appendix B.

A Raltron CO6100 4 MHz oscillator generates the clock signal for the PIC. The output pins of the PIC are connected to a L293D Quad Half-H Driver which controls the direction and activation of the DC gear motor. The solenoid is controlled via an IRF510

In addition to the RS-232 inputs, the PIC can also receive input from two limit switches. The normally-open switches close when the DC gear motor has rotated the LCD monitor arm to a set limit. The switches signal the PIC to prevent the LCD monitor arm from physically damaging the classroom end's housing. Also, when the switches are closed, the PIC transmits a signal back to the PC and the software notifies the user that the physical limit has been reached.

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3.6 Communication

The camera functions are relayed through the computer's serial port using the VISCA RS-232C control protocol at 9600 bps, 8 data bits, no parity, 1 stop bit, and 1 start bit.

The PIC microcontroller and the computer communicate serially using the basic RS-232 protocol at 9600 bps, 8 data bits, no parity, and 1 stop bit. Simple ASCII characters were used as control commands. For example, 'A' would be transmitted to the PIC to activate the hand, and 'S' would be transmitted to stop driving the motor or solenoid. A list of the ASCII codes can be found in Table 2 below.

Table 2: ASCII Codes for PIC Microcontroller

ASCII Character Received	Action	ASCII Character Sent	Condition
L	Turn left	D	Right limit
R	Turn right	G	Left limit
A	Activate hand		
S	Stop all motors		

For example, the user at the hospital end presses the left arrow button on the onscreen gamepad. The HSPP software captures the button event and sends a three digit code across the network connection to the classroom end. At the classroom end, the HSPP software interprets the three digit code and translates it into the single ASCII character 'L' which would be sent through the serial port of the computer and received by the PIC. The PIC would then translate the letter 'L' into the proper output pin configuration for activating the DC gear motor in the appropriate direction. When the user at the hospital end releases the left arrow button, the letter 'S' is sent to the PIC to stop turning the motor.

Although the elementary version of PEBBLES is capable of using ISDN or IP networks for communication, the HSPP is only capable of using IP networks. This simplifies the design process since ISDN is less capable of satisfying the bandwidth needs of the HSPP, which hovers around 1.5 Mbps for just the videoconferencing application, and peaks to about 5 Mbps while viewing streaming video over the Internet. ISDN is only capable of 512 kbps before the installation costs become impractical compared to using IP networks which can handle much more [71]. Most high schools already have IP networks in place so installation and setup is simplified. IP networks are also more available and less costly than ISDN [72], again simplifying and expediting the implementation and setup process.

CHAPTER 4: METHOD

4.1 Research Questions

The primary objective of this thesis is to examine how presence factors implemented through the HSPP affect the ability of high school students to experience telepresence, and to accomplish typical tasks required of those students. In addition, these results can be used to improve future versions of the HSPP. Important considerations, including the appearance of the system, and the need to share work, identified in previous studies (see section 2.5) [15, 16] have an impact on telepresence and task success, and are also factors in this thesis.

By observing the behaviour of high school students in a collaborative environment with the HSPP, I will explore how telepresence factors are mediated by the design. The research questions to be addressed in this thesis are thus:

- 1) Is the HSPP easy to use?
- 2) Can the HSPP support students in accomplishing assigned academic tasks?
- 3) What aspects of telepresence are supported by and can be applied to the HSPP for the hospitalized student and his/her classmates? Telepresence for the purposes of this thesis is defined by using the notions of presence as social richness, and as transportation [20].

For item 3, telepresence is defined by using the concepts of presence as social richness, and as transportation [20] because they are the most applicable. The HSPP is designed to support social interactions, and the ability to accomplish remote tasks gives the classroom students and instructor the impression that the HSPP user has been transported to the classroom to work.

Laboratory-based case studies with the HSPP that simulated a hospital/school situation were carried out in order to explore the above questions. Participants were organized into four groups of two or more students for the study.

All participants were videotaped and the videos were analysed to gain greater insight into the real-time behaviour of high school students when collaborating with the HSPP. Pre- and post-study questionnaires were used to gather attitudinal data on the participants and to collect their opinions on their experience with the HSPP. These data were then used to investigate the impact on presence that the HSPP enables for simulated hospitalized students.

Through an information and consent form (available in Appendix C) approved by the Ryerson Research Ethics Board, all participants were informed of our intent to collect verbal and non-verbal information through note-taking and videotaping, and that the data would be analyzed and presented in summary form.

4.2 Study Procedure

4.2.1 Pre-Study Questionnaire

Each participant was asked to complete a pre-study questionnaire prior to beginning the study. This questionnaire consisted of 12 questions that were used to collect demographic information (e.g. gender, grade), determine the participant's familiarity with computers and learning new computer applications, and collect their self-reported social communication habits (e.g. how comfortable they are around strangers). Ten questions were forced-choice questions with four of the 10 using a five-point Likert scale. Two of the 10 forced-choice questions were optional depending on the student's hospitalization history. The questionnaire was also used to select the hospital student based on his/her hospitalization history and his/her social communication tendencies. The pre-study questionnaire is available in Appendix D.

4.2.2 Training

Following the completion of the pre-study questionnaire, participants spent 10-15 minutes learning how to use the HSPP, and practicing using the camera, the hand, and the application sharing feature. The groups with more available time for the study (i.e. Group 1 and Group 2) were able to have more time allotted to them for training. Due to scheduling difficulties, some groups (i.e. Group 3 and Group 4) had limited time to complete the study. The training process was similar to that used with the elementary version of PEBBLES when a hospitalized student was introduced to the system for the first time.

4.2.3 Collaboration Session

Once participants completed their pre-study questionnaires and training, the study began. The students were divided into remote (hospital) and local (classroom) participants. One participant was assigned to simulate the hospital student and the others were assigned as classroom students. The hospital student was chosen based on gender, hospitalization history and social communication habits to obtain a more varied distribution of hospital students.

The hospital student for each group was located in a room that was physically separate from the rest of the group and this person could only communicate with her group using the HSPP in order to simulate an isolated, hospital room setting. One researcher remained with the hospital student to provide technical support and guidance if needed. The hospital student was not completely isolated for safety reasons, and to better simulate a hospital situation where a student would likely have a legal guardian, a volunteer or a child life specialist present to assist them with their academic activities.

The classroom students worked in a room around a meeting table to simulate a collaborative brainstorming session in a classroom. A second researcher remained with them acting as an instructor, and providing technical support.

The collaboration session was designed to promote group discussion and the need to work together to complete simple tasks using the features of the HSPP. It consisted of a brief five-minute lecture given by the instructor on the process of storyboarding followed by a three-minute tutorial where the students could ask and answer questions on storyboarding. The remainder of the session was dedicated to giving the students an opportunity to complete an assigned task of storyboarding a short music video clip for a song of their choosing based on the material presented by the instructor.

Each segment of the collaborative session was designed to simulate some of the different teaching and learning approaches used in high school environments. The lecture required students to focus on the presented material and listen to an instructor. The tutorial gave students an opportunity to interact with the instructor. Finally, the storyboarding task required the students to apply what they had just learned, and work together to finish the task on time. The storyboarding task was selected because it allowed group members to discuss what they would like to see in the music video through gestures, pictures, and words. This combination also gave the participants an opportunity to take advantage of the collaborative features of the HSPP (i.e. document sharing, whiteboard).

The collaborative sessions were videotaped and both researchers took notes on the behaviour and interactions between the hospital subject and the local group. After the time limit had expired, the participants were asked to complete a post-study

questionnaire. All sessions were conducted at the Centre for Learning Technologies at Ryerson University using the university's Internet connection.

4.2.4 Post-Study Questionnaire

A post-study questionnaire was used to gather opinions of the participant's experience with using the HSPP, to analyse the presence factors and usability of the design, and to determine avenues for improvement. There were 12 forced-choice questions with 10 using a five-point Likert scale, and there were three open-ended questions (likes, dislikes, other comments). The post-study questionnaire is available in Appendix E.

The questionnaire asked the participants to evaluate the physical appearance of the HSPP, and the audio and video quality. They were also asked to give their impressions on the collaboration session and to state what they liked and disliked about the HSPP. Participants were also given the opportunity to provide additional feedback that did not fit in any specific category.

The hospital students completed a similar questionnaire but with eight additional forced-choice questions using a five-point Likert scale. The additional questions were used to evaluate the controls and the effect of the HSPP on the hospital students' emotional state.

4.3 Subjects

Twelve students between the ages of 13 and 18 and all attending high school were selected to participate in the study. The participants worked in four groups of between two and four members, and they were familiar with their group members. The subjects were required to have experience using basic computer applications for academic and

entertainment purposes. The subjects were recruited from the Discover Engineering Program at Ryerson University, and from family members of lab employees not directly involved in the study.

Six of 12 (50%) indicated that they used computers on a daily basis, four (33%) indicated they used them four to six times each week, and two (17%) indicated that they used them one to three times each week. All students stated that they had been using computers for at least three years.

Most of the students in this study cohort seemed very comfortable learning new software. Nine of 12 (75%) indicated that they needed between 15 minutes to one hour to learn a new program, only two (17%) indicated they needed more than one hour, and only one (8%) indicated that he needed less than 15 minutes.

As seen in Figure 25, most of the students had flexible social communication tendencies. They appeared to be confident in their ability to speak among friends and strangers alike, but usually choose to assume the role of listener rather than speaker. Most of the students (11 of 12 or 92%) reported being comfortable in large groups. Four of 12 (33%) agreed or strongly agreed that they were good listeners while six (50%) were neutral, and two (17%) disagreed. Six of 12 (50%) agreed that they had no problems talking with strangers in safe situations such as at school, and three (25%) disagreed, the majority of students, eight (67%), thought that it was not difficult for them to speak loudly.

Figure 25: Social Communication Tendencies

The following sub-sections describe the groups that were formed. Efforts were made to select hospital students with different hospital experiences and different social communication tendencies to avoid biases towards any one specific type of high school student.

4.3.1 Group 1

Group 1 consisted of two female classmates in grade 12. They had previous experience with videoconferencing and the process of storyboarding. Group 1 was given 32 minutes to complete their task and they chose to storyboard part of the chorus of “Colors of the Wind”. One of the students was selected as the hospital student because she made regular visits to the hospital for treatment.

4.3.2 Group 2

The second group consisted of four students. Three of the four were in grade 11 and the other was in grade 9. Three participants were male and one of the grade 11 students was female. Group 2 was given 67 minutes to complete their task and chose to storyboard part of the chorus of “I Believe I Can Fly”. The female student was chosen to be the hospital student since she had hospital experience.

4.3.3 Group 3

The third group consisted of three students. None of the participants had been hospitalized in the past. They were all female classmates in grade 11. They were given 22 minutes to complete their task and they chose to storyboard part of the chorus of “Colors of the Wind”. One of the female students was chosen as the hospital student on the basis that she indicated in her responses to the pre-study questionnaire that she was not shy.

4.3.4 Group 4

The fourth group consisted of three students. Two of the three were in grade 11 and the other was in grade 9. One of the grade 11 students was male and the other students were female. Group 4 was given 33 minutes to complete their task and chose to storyboard part of the chorus of “I Believe I Can Fly”. Although both female students were receiving regular hospital treatment, the male student was selected to be the hospital student because he had never been hospitalized, and because all the previous groups had female hospital students.

The exercise timing was calculated to allow for 15 minutes per group member (i.e. for three group members, the time would be 45 minutes). This time was chosen to prevent the groups from becoming bored with performing their tasks, and 15 minutes per

group member seemed reasonable. As mentioned previously, Group 3 and Group 4 had limited time to complete the study due to scheduling difficulties. However, all teams had sufficient time to complete the assigned tasks to their satisfaction.

4.4 Data Collection and Analysis

Data were collected through the questionnaires, videotaping the sessions, and the observational notes taken by the researchers.

The HSPP was tested using a small-N design with only 12 participants for several reasons: (1) Usability had to be validated before proceeding with larger studies involving more participants, (2) there was difficulty in recruiting high school students, and (3) a case study approach was more effective for closely studying their behaviour and discovering significant effects [125].

4.4.1 Pre-Study Questionnaire

In addition to selecting a hospital student from each group, the data were used to determine if previously reported hospitalization history and social communication traits had a relationship to the participant's performance during the study and their responses to the post study questionnaire. SPSS v12 was used to perform Chi-square (χ^2) analyses and cross-tabs analyses to detect significant differences in the responses and to examine any possible significant effects between questions, respectively.

4.4.2 Video Analysis

The videotapes were analysed using thematic categorization [126] with three qualitative themes and two quantitative categories (as seen in Table 3) similar to those used in earlier PEBBLES studies [15, 34, 127-129]. The categories were determined a

priori according to the categories used in those earlier PEBBLES studies, and the conceptualizations of presence as social richness and transportation [20].

Table 3: Quantitative and Qualitative Categories for Video Analysis

Category		Definition
Qualitative	Activity Type (Sub-categories: Group, One-to-one, and Individual)	<ul style="list-style-type: none"> Group activities are any verbal and non-verbal interactions between hospital student and two or more other people in the classroom. One-to-one activities are any verbal and non-verbal interactions between hospital student and one other person in the classroom. Individual activities are any verbal or non-verbal actions involving only the hospital student.
	HSPP Actions/ Issues (Sub-categories: Zooming, Reading, Getting attention, and Technical issues)	<ul style="list-style-type: none"> Zooming actions were those occurring whenever the hospital student used the HSPP gamepad to cause the videoconferencing camera to either zoom in or out. Reading actions were those occurring whenever the hospital student was either reading or working (typing, drawing) on a document in the workspace screen, or reading a document or reading from the blackboard in the communication screen. Getting attention actions were any attempts by the hospital student to gain the attention of somebody who was not listening before, or attempts to make the group listen to her in a discussion. The exception was when the hospital student was talking to herself without the intent of drawing attention (i.e. thinking aloud). Getting attention actions did not necessarily need to be successful in gaining attention. Technical issues were any reported problems with sound, video, software. To qualify as a technical issue, the student had to report it or comment on it to other students or the instructor.
	Gamepad Errors	<ul style="list-style-type: none"> Overshoot errors occurred if the hospital student rotated the videoconferencing camera past the intended target. Undershoot errors occurred if the hospital student did not rotate the camera enough and had to continue to rotate. Zooming errors occurred if the hospital student zoomed in on the wrong object. Button errors occurred if the hospital student pressed an unintended button on the gamepad. Limit errors occurred if the hospital student attempted to rotate the HSPP beyond its physical left/right limits.

Quantitative	Task Success	<ul style="list-style-type: none"> • Successful completion of a task required initiation, maintenance, and closure of the task. • A task was partially successful if it was missing any of the three components, typically maintenance (i.e. the student delegated the task to somebody else). • A task was unsuccessful if the hospital student was unable to perform it (i.e. the student refused to do it)
	Presence Measures (Sub-categories: Positive and Negative)	<ul style="list-style-type: none"> • Communication Interaction judges the ability of the student to carry out appropriate verbal (spoken or written) communication with the group or instructor. Positive occurrences were those between the hospital students, their classmates or instructor that appeared to be natural, positive, or appropriate. Negative occurrences were disruptive or minimal (i.e. no interaction when it would have been appropriate to have one). • Concentration is concerned with how focused the hospital students were despite being physically removed from their instructor and classmates. Positive occurrences were those in which the hospital student was able to pay attention to, or focus on, the task-at-hand for more than brief periods of time. Negative occurrences were those that appeared to be unfocused or fidgety. • Initiative was used to identify the ability of the hospital student to begin a communication or activity. Positive occurrences were those when the hospital student took the first step in any activity (i.e. answered question without being asked directly, asked students to share program first, took anticipatory action). Negative occurrences occurred when the hospital student appeared disinterested and inattentive (i.e. had to be pressured to carry out a task).

Each videotape was divided into one minute time divisions and then analysed using quantitative and qualitative categories. One minute time divisions were used to normalize the data to account for the different lengths of time used by the different groups.

To ensure that the thematic categories and their definitions could be reliably coded, two independent raters coded one 20-minute sample of videotape to ensure that the categorical assignment was reliable. SPSS v12 was used to calculate a two-way

mixed, single measures model for the intraclass correlation coefficient (ICC) [130], comparing the coding by the two raters for each category.

The inter-rater reliability was good overall ranging from 0.620 to 1.000. The ICC's and significance (p) for the quantitative and qualitative categories are reported in Table 4. Only one rater was retained to perform the remaining video analysis.

Table 4: ICC and Significance for Video Analysis Categories

Quantitative Category	ICC, p	Qualitative Category	ICC, p
Activity Type	0.933, $p < 0.05$	Task Success	0.658, $p < 0.05$
Zooming Camera	1.000, $p < 0.05$	Comm. Interaction	0.777, $p < 0.05$
Reading	0.969, $p < 0.05$	Concentration	0.662, $p < 0.05$
Getting Attention	0.620, $p < 0.05$	Initiative	0.767, $p < 0.05$
Technical Issues	0.807, $p < 0.05$		
Gamepad Errors	1.000, $p < 0.05$		

The video data were examined to identify trends over time. The cumulative occurrences of each category for all groups were counted over a 20-minute time period (common to all groups) that began in the first minute of the recording period. The purpose was to examine trends across time for the groups. Observer notes were used to provide explanations for trends occurring in the video data.

4.4.2.1 Activity Type

The type of activities the hospital student was engaged in was important to document because it characterized the verbal and nonverbal interactions (e.g. talking, drawing) between the hospital student and his/her group as well as individual activities carried out independent of the group.

The activities in which the hospital student was engaged were classified as group, one-to-one, or individual. An activity was considered to be a group activity if the hospital student and two or more people in the classroom were involved. For example, taking part

in a group discussion or a brainstorming session was considered a group activity. A one-to-one activity occurred when the hospital student and one other person in the classroom were involved. The other person could be a student or the instructor. Examples of one-to-one activities were speaking with a specific student, and listening to the instructor. An activity was classified as an individual activity if only the hospital student was involved. This included any tasks they were performing independently such as quietly working on an assignment or talking to themselves.

The hospital students were expected to participate in group and one-to-one activities as a result of the types of tasks required to complete the study exercise. A large number of group or one-to-one activities suggested that the remote student was experiencing enough social presence to be comfortable with those types of interactions. A large number of individual activities does not necessarily indicate a lower degree of presence since the student may be concentrating on completing an assigned task independently.

A small number of group or one-to-one activities might be an indication that the student was uncomfortable with the using the HSPP, there may have been technical difficulties, or that the student was not motivated enough to participate in those activities.

The interaction types were not necessarily exclusive from each other (e.g., a person could be working on an individual task and still acknowledge another group member entering the room). Whether or not the activity occurred in the time slot was categorized.

4.4.2.2 HSPP Actions/Issues

Various actions could be performed with the HSPP. These included using the zoom functionality on the gamepad, reading from the workspace screen, getting attention and errors. Turning left and right and looking up and down were not included as actions because they were not of interest. The errors were accounted for instead in the Gamepad Errors category as overshoot, undershoot, button, and limit errors.

Using the zoom functionality was defined as any instance where the hospital student pressed the zoom in or zoom out buttons on the onscreen gamepad. Students were expected to use the camera zoom to look around the classroom. Typical activities for using the zoom out function were room orientation and to look at groups of people. The hospital student was expected to zoom in on specific people or objects of interest, and zoom out to become physically oriented in the classroom relative to the surroundings.

Working from the workspace screen was defined as the hospital student reading from or interacting with an electronic document (e.g. typing, drawing) in their workspace screen instead of using the communication screen to communicate or read. When a hospital student was “reading” from the communication screen, it meant that they were likely reading from the blackboard or from a paper document being presented to them via the videoconferencing camera.

Noting when the hospital students switched between “interacting with” their workspace and communication screens also suggested the student’s ability to manage two screens. Their ability to manage the two screens was based on whether or not the student was using the screens appropriately (e.g. talking while mostly facing the workspace

screen when it was more appropriate to face the communication screen), and whether any concerns were expressed to researchers.

The time spent reading from each screen was not measured since it was considered useful. The hospital students were expected to switch between the screens numerous times, similar to looking up and down from a printed handout. It was impractical to record such short durations since it would have been difficult to record the quick transitions between screens, and the short time durations.

The hospital student was performing a getting attention action whenever she attempted to ask a question of the instructor, to take a turn speaking in a discussion, to gain the attention of somebody in the classroom who was not listening to, or to make the group aware of her. All attempts to gain attention (with the HSPP hand, using gestures or other methods of gaining attention) and the time they occurred were rated regardless of success. Thinking aloud while working on a task was not considered attention getting behaviour.

Problems with audio, video, or computer hardware or software were categorized as technical issues. In order for these issues to qualify as technical issues, the hospital student had to make a comment about the problem aloud. The comment served as evidence that there was a technical issue the student deemed unacceptable instead of relying on the judgment of the researcher. Tracking technical issues was important because they can be the cause communication or interaction difficulties. Every occurrence was recorded, and it was possible to have no occurrences during a time division.

The purpose of tracking the number of occurrences of particular actions was to examine the frequency of use for the various features of the HSPP. By comparing these actions with the activities and interactions occurring during these actions, we can understand how different features are being used for different purposes. This data can also inform future versions of the HSPP. Every occurrence of an action was recorded, and it was also possible to have no occurrences of an action in a time division.

4.4.2.3 Gamepad Errors

Gamepad errors occurred when the hospital student made an unintended control action or selected the incorrect control for the intended function. The different types of errors were overshoot and undershoot errors. Overshoot errors occurred if the hospital student rotated the videoconferencing camera past their intended target. Undershoot errors occurred if the hospital student did not rotate the camera sufficiently and had to continue in a single direction. For example, an undershoot error would be coded for the situation where the student pressed the “left” button, realized that he had not reached his intended target, and pressed the “left” button again. Undershoot errors were not counted if the student alternated between horizontal and vertical movement for centering purposes.

A zoom error occurred if the remote student zoomed in on the wrong object. A wrong object was one that was different from the one specified through student’s verbalizations or identified by the local participants (e.g. “look at the blackboard”). Button pressing errors occurred when the hospital student caused the classroom end of the HSPP to move in a way that they did not intend. For example, moving left when they intended to move right to look at something. A limit error occurred whenever the hospital

student had moved the videoconferencing camera to the extreme left or right and then attempted to continue moving past its physical limits. All error occurrences were recorded, and it was possible to have no errors in a time division.

4.4.2.4 Task Success

Success level was tracked as an indicator of how well the hospital students could perform tasks using the HSPP. A task was considered to be assigned to the hospital student whenever she received a request to do something (i.e. make a decision, look in a certain direction, write/draw something). Successful completion of a task required initiation, maintenance, and successful closure of the task [15]. Partial success was achieved if the student was missing either the maintenance or closure phases. For example, a student achieved partial success if he attempted to complete a task, but either delegated the task to another person or gave up. A task was deemed unsuccessful if the student missed either the initiation or closure phase. For example, if the student made no attempt to begin or complete the task. The success level and related task were coded only when the outcome of the task assignment had occurred (i.e. the student completed it, he passed it to somebody else, or he discontinued any attempts).

4.4.2.5 Presence Measures

Communication Interaction, Concentration, and Initiative were categories used in previous studies with the elementary version of PEBBLES [127]. Positive and negative occurrences were recorded to determine the extent of telepresence that the hospital student achieved. These categories were related to the notions of presence as social richness and presence as transportation [20].

Social richness arises from verbal and non-verbal interactions between people, and transportation occurs when people are under the impression that they have been transported elsewhere or somebody has been transported to them. Communication Interaction and Initiative are related to the notion of presence as social richness and transportation since they are concerned with verbal and non-verbal interactions which can be expected to occur when two friends are meeting together. Concentration is also related to both notions of presence since a person's ability to focus and concentrate can be affected by their physical surroundings and their mental state. Physical surroundings can include people and a person's mental state can be affected by their verbal and non-verbal interactions, or lack thereof.

Communication Interaction was used to judge the ability of the hospital student to carry out appropriate verbal communication with the group or the instructor. Positive occurrences were those between the hospital students, their classmates or the instructor that appeared to be natural, positive, appropriate, or efficient. Negative occurrences were disruptive or minimal (i.e. no interaction when it would have been appropriate to have one). Communication Interaction is related to the Activity Type category, but is more specific since it only involves verbal communication between the hospital student and another person or group.

The Concentration category was used to observe how focused the hospital students were despite being physically removed from their instructor and classmates. Positive occurrences were those in which the hospital student was able to pay attention to, or focus on, the task-at-hand for more than brief periods of time. Negative occurrences were those that appeared to be unfocused or fidgety.

The Initiative category was used to identify the ability of the hospital student to begin a communication or activity. A comparison with the hospital student's responses in the pre-study questionnaire regarding their self-reported social communication tendencies was also carried out to examine whether using the HSPP caused any negative effects (i.e. the hospital students became less responsive when they had previously indicated they were outgoing). Positive occurrences were when the hospital student took the first step in any activity (i.e. answered question without being asked directly, asked students to share program first, took anticipatory action). Negative occurrences occurred when the hospital student appeared disinterested and non attentive (i.e. had to be pressured to carry out a task). Initiative is related to Communication Interaction since frequent occurrences of negative Initiative can result in frequent occurrences of negative Communication Interaction (i.e. the student is expected to take the first action in an activity by stating something, but does not).

Positive occurrences are expected to outnumber negative occurrences in each category if the hospital student is experiencing presence. Positive occurrences indicate that the hospital student is more socially engaged with the instructor, his peers, and engrossed with the material being presented in the classroom. As a result, the technology of the HSPP should become transparent and the hospital student should believe he has been transported out of the hospital environment and into the classroom. For example, if the student is focused on the material presented by the instructor, it indicates positive Concentration. If the student then asks and answers questions related to the material, it indicates positive Communication Interaction and positive Initiative (i.e. appropriate communication, and asking questions to promote discussion).

Negative occurrences may result from the student becoming socially disengaged from the classroom. The hospital student may become detached from the people and events and as a result, experience very little or no presence in the classroom. For example, if the student loses focus as a result of technical problems or boredom, it indicates negative Concentration. If the student makes inappropriate comments or must be persistently motivated by the instructor, it indicates negative Communication Interaction and negative Initiative.

4.4.3 Post-Study Questionnaire

SPSS 12 was used to perform χ^2 and cross-tabs analyses on the responses in the post-study questionnaires to determine if there were significant differences in the responses and significant effects between the responses. Finding significant differences in responses may affect the course of developments for the HSPP. For example, if a significant number of students responded negatively regarding the onscreen gamepad, then improving the user interface becomes a priority. Finding significant effects between responses may also affect future developments for the HSPP. For example, if opinions on video and sense of self-presence are positively correlated, then future improvements to the video quality should have a positive effect on sense of presence.

Descriptive analyses of the qualitative data contained in the open-ended questions were carried out because of the small number of subjects/groups. These analyses were used to determine which aspects of the HSPP could be considered successful, which aspects needed to be addressed, and gauge the students' level of satisfaction with the HSPP. The students were not expected to comment about every category. The responses

to the open-ended questions were intended to identify which aspects of the HSPP the students believed were important.

Two independent raters coded Group 2's responses to the open-ended questions. SPSS v12 was used to calculate the two-way mixed single measures model for the ICC, comparing the coding by the raters. The inter-rater reliability was good overall ranging from 0.622 to 0.867(see Table 5 for detailed ICC values). As a result only one rater was retained to complete the coding for the other groups.

Table 5: ICC and Significance for Descriptive Analysis Categories

Category	ICC, p	Category	ICC, p
Video	0.867, $p < 0.05$	Application Sharing	0.822, $p < 0.05$
Audio	0.845, $p < 0.05$	Presence	0.842, $p < 0.05$
Easy to Use	0.622, $p < 0.05$	Collaborating	0.632, $p < 0.05$
User Interface	0.634, $p < 0.05$	Communicating	0.766, $p < 0.05$

The open-ended questions provided reinforcement for the students' forced-choice opinions of the HSPP's strengths and weaknesses. The categories and positive and negative sub-categories used for the descriptive analysis were not exclusive (there was some overlap) and are summarized in Table 6.

Table 6: Categories for Descriptive Analysis

Category	Definition
Video	Positive comments expressed satisfaction regarding the video quality (e.g. could see people and objects clearly). Negative comments expressed dissatisfaction (e.g. video was pixilated).
Audio	Positive comments expressed satisfaction regarding the audio quality (e.g. could hear people clearly). Negative comments expressed dissatisfaction (e.g. it sounded noisy)
Easy to Use	Positive comments expressed satisfaction regarding procedures/methods for accessing features (e.g. it was easy to [do something]). Negative comments expressed dissatisfaction or confusion (e.g. couldn't figure out how to [do something]).
User Interface	Positive comments expressed satisfaction regarding controls, components and their placement (e.g. liked the hand). Negative comments expressed dissatisfaction (e.g. windows were too small).

Application Sharing	Positive comments expressed satisfaction regarding the application sharing feature specifically (e.g. liked being able to see other's work). Negative comments expressed dissatisfaction (e.g. couldn't get it to work)
Presence	Positive comments were related to a heightened sense of presence for either the hospital students or classroom students (e.g. seemed like person was there). Negative were related to a lower sense of presence for either side (e.g. they were ignoring me).
Collaborating	Positive comments expressed satisfaction regarding the collaborative processes (e.g. liked being able to work together). Negative comments expressed dissatisfaction (e.g. wish I could have made changes to their work instantly)
Communicating	Positive comments expressed satisfaction regarding verbal/nonverbal communication processes and turn-taking (e.g. could see their facial expressions clearly). Negative comments expressed dissatisfaction (e.g. wanted to speak, but nobody listened)

The Video and Audio categories were used to evaluate the video and audio quality of the HSPP. If a comment praised either the video or audio quality, then it was considered to be positive in the respective category (e.g. "I could see the other person clearly"). Any concerns with either the video or audio quality were considered to be negative comments for the respective category (e.g. "It was hard to hear the other person).

The Easy to Use category was used to inform the usability of the HSPP. A positive comment was when a student commented that the HSPP was easy to use or learn how to use (e.g. "It wasn't difficult to learn how to use"). A negative comment occurred if a student had said she experienced difficulty operating any feature of the HSPP (e.g. "I was confused with...").

The User Interface category represented when a student made a comment regarding the software for the user interface, but not related to the application sharing feature. Examples of negative comments were "The windows were too small" and "The font colour was hard to read". Examples of positive comments were "The gamepad made

it easy to figure out how to control the system”. The User Interface category had some overlap with the Easy to Use category (i.e. the latter example also counted as a positive comment in the Easy to Use category).

Comments regarding any aspect of the application sharing feature were rated in the Application Sharing category. An example of a positive comment was “I liked being able to share my programs.” An example of a negative comment was “It was hard to figure out how to share programs.” The Application Sharing category had some overlap with the Easy to Use and User Interface categories (i.e. the negative comment example also counted as a negative comment in the Easy to Use category). Despite the overlap, the application sharing feature of the HSPP was an important aspect and merited extra attention.

Positive occurrences in the Presence category were when the students made a comment related to the notion of presence as transportation (i.e. they believed that somebody was there with them, they were with somebody, or they were together) [20]. Negative comments were any comments where participants reported that anybody’s sense of presence was diminished (i.e. they did not believe that they were a part of the group’s activities).

The Collaborating category was used for when students gave their opinions on the process of working together. An example of a positive comment was “I liked being able to work together.” An example of a negative comment is “I didn’t like not being able to see their work.” There was the possibility of some overlap with the Application Sharing and Presence categories if the student described sharing documents as being similar to working in the same room.

The Communicating category was used for comments related to any aspect of communication between the students. Comments were considered positive when they expressed satisfaction (e.g. “I liked being able to talk with the other person”). Comments were considered negative when they expressed dissatisfaction (e.g. “I couldn’t get the other people to listen to my suggestions”). There was some overlap with the Video, Audio, Presence, and Collaborating categories. The Video and Audio overlap occurred if student stated that the video or audio quality affected their communication. The Presence overlap occurred if the student stated that their ability to communicate affected their sense of presence. The Collaborating overlap occurred if the student stated that their ability to communicate affected their ability to work with others.

CHAPTER 5: RESULTS

This chapter presents the results from the video analysis and the post-questionnaire. The results of the video analysis are presented using a time span of 20 minutes because it was common to all four groups. Typical high school classes last for approximately one hour, but by focusing on the 20 minute time span, this thesis is able to focus on the collaboration and communication processes that are expected to occur when group work is assigned.

The results of the post-study questionnaire are presented with any significant effects that were discovered using χ^2 and cross-tabs analyses. The responses to the open-ended questions are also presented in graphical form.

5.1 Video Analysis

Statistical comparisons between groups are not valid or useful for this thesis because there were no manipulated differences between the groups other than allotted time (which was unintentional). Also, I was more interested in behavioural trends, and was working with a small data set. The reporting of any group differences is only to examine differences in behaviour and approaches to tasks.

5.1.1 Activity Type

Figure 26 shows the percentage of time divisions (one-minute duration) spent by the students at the hospital end on each type of activity (group, individual, one-to-one). Group 1 spent no time doing group activities because there were only two of them. Instead, they spent almost all their time engaged in one-to-one activities (97%) with very few occurrences of individual activities (9%).

Figure 26: Percentage of Time Divisions Spent for Each Activity Type

The hospital student in Group 2 had the most group activities (85%) because there were audio issues with the instructor's microphone. Consequently, she spent a larger portion of time asking her peers in the classroom to clarify what the instructor said. Also, the hospital student in Group 2 was engaged in one-to-one activities less often than other groups since she tended to address all the group members rather than a specific person.

The hospital student in Group 3 was very frequently engaged in one-to-one (95%) and individual (95%) activities. She spent most of her time addressing specific classroom students rather than the entire group. There were also instances where she strayed from her tasks and began experimenting with the controls of the HSPP (e.g. zooming in and out when she should have been reading from her workspace screen).

The hospital student in Group 4 assumed a leadership role with his peers. He spent a great deal of time explaining to his group members how to accomplish certain

tasks using different programs (e.g. copy and paste in Microsoft Word). Consequently, he spent comparably less time doing individual activities than group or one-to-one activities. He also spent a smaller portion of time doing one-to-one activities since he tended to address the entire group instead of a single person.

Figures 27-29 graph the average occurrences of the three activity types (group, one-to-one, individual) for all groups over a span of 20 minutes. Since the activity type was rated as either occurring or not during the time division, the average ratings vary between 0 (not occurring) and 1 (occurring). The threshold between more frequent and infrequent occurrences was therefore assigned at the 0.5 level.

As seen in Figure 27, group activities were common for the first minute before becoming a rare activity type until about the 9-minute mark. The first minute was when the hospital student was exchanging greetings with people in the classroom, prior to the instructor's lecture. During the lecture (1:01-8:00), group activities were rare because the hospital student was mostly listening to the instructor. Occasionally, group discussions would occur when the instructor posed a question to the students. After the 9-minute mark, group activities become more common for the remaining minutes up to the 18-minute mark (mean =0.75, SD =0.50) since the instructor had already given the assignment, and the group was discussing how to complete it. The group discussions also continued while they were working on the assignment up to a point where the hospital students may have decided to work individually or carry out side conversations with a single person (indicated by the dip in group activity at 19:00).

Figure 27: Average Occurrences of Group Activities

The hospital students appeared to be frequently engaged in one-to-one activities (see Figure 28). One-to-one activities remained common throughout most of the 20 minute time span. During the lecture period (1:01-8:00), one-to-one activities were common for all groups (mean =1, SD =0). The occurrence of one-to-one activities fluctuated afterwards during the brainstorming/working period (8:01-20:00), but the mean remained above 0.5. One-to-one activities near the beginning of the period (10:01-12:00) were usually instances where the hospital student was either asking for clarification of their responsibilities or acting as a coordinator and assigning responsibilities to the other group members individually.

Figure 28: Average Occurrences of One-to-one Activities

Individual activities (see Figure 29) were common for all groups during the first minute, but the occurrences became inconsistent afterwards. It was observed that during the lecture time (1:01-8:00), the hospital students were not likely to be participating in individual activities because they were listening to the instructor. However, there was a period of high occurrences of individual activity around the transition from the end of the lecture to the beginning of the working period (6:01-9:00, mean =0.75, SD =0.50). Another period of high occurrences of individual activity was near the end of the 20-minute time span (18:01-20:00, mean =0.75, SD =0.50).

Figure 29: Average Occurrences of Individual Activities

5.1.2 HSPP Actions/Issues

Figure 30 shows the average occurrences for zooming actions over a time span of 20 minutes. Zooming in and zooming out actions were rare occurrences. Group 1 had only one occurrence of each zooming action, Group 2 had three occurrences of zooming in, Group 3 had three occurrences of zooming in and two occurrences of zooming out, and Group 4 had only one occurrence of zooming out. The zooming actions occurred early in the sessions (0:00-8:00) when the students were searching for the instructor and when they were searching for their group members. Once the students found their group members they would pan left or right, but would not zoom in or out afterwards. This is reflected in the absence of occurrences after the 8:00 mark.

Figure 30: Average Occurrences of Zooming Actions

Figure 31 shows the percentage of time divisions spent by the hospital students on reading actions. The hospital student in Group 2 was the only one to read from the communication screen (19%). This occurred because her group members were sharing a combination of hand-written, drawn, and electronic documents. This likely resulted in less frequent use of the workspace screen (60%) than the other groups (85%, 100%, and 100% for Groups 1, 3, and 4 respectively) since all the other groups shared electronic documents only.

Figure 31: Percentage of Time Divisions Spent for Reading Actions

Figure 32 shows each time period that reading occurred from the communication screen for Group 2 for the first 20 minutes. As explained previously, only the hospital student from Group 2 read from the communication space. Reading was rated as either occurring (1) or not (0) during each time division.

The hospital student in Group 2 read from her communication screen during the lecture (1:01-8:00). She later read from her communication screen in the 9:01-10:00 time division because she was getting clarification on a printed handout that was used during the lecture. She also read from the communication screen in the 16:01-17:00 time division because she was looking at her group members' drawings.

Figure 32: Occurrences of Reading From Communication Screen for Hospital Student in Group 2

Figure 33 shows the average occurrences of reading from the workspace screen over a time span of 20 minutes. At least half of the hospital students were reading from the workspace screen during the lecture (1:01-8:00). When they did, they were reading electronic versions of the handout being used in the lecture during the 2:01-6:00 time span (mean =0.75, SD =0.50). After the lecture (8:01-20:00), almost all of the hospital students were reading from the workspace screen for the remainder of the time span (mean =1, SD =0). The only exception was with Group 2 during the 14:01-15:00 time division. During this minute, the hospital student did not interact with the workspace screen at all because she was talking with her group members.

Figure 33: Average Occurrences of Reading From Workspace Screen

Figure 34 shows the average occurrences of getting attention actions over a time span of 20 minutes. Getting attention actions occurred infrequently (less than one per time division) up to the 12:00 mark. The fewest number of getting attention actions occurred during the 4:01-7:00 time span (mean =0.25, SD =0.50). Afterwards, the number of getting attention actions were more frequent (at least one per time division) and peaked at the 17:00 mark (mean =3.00, SD =0.82).

Figure 34: Average Occurrences of Getting Attention Actions

Figure 35 shows the average occurrences of technical issues over a time span of 20 minutes. Occurrences of this factor were rare (less than one per time division) because the groups did not report all technical issues even though the video of the session recorded several instances of audio issues that were either unnoticed, or not sufficiently detrimental to their task success. Technical issues did not occur very frequently as shown by the numerous zero occurrences in the graph. Technical issues in the beginning and during the lecture (0:00-8:00) were mostly related to audio quality. Technical issues during the brainstorming/working period (8:01-20:00) were related to students having difficulties with the application sharing feature. This was especially prevalent in the 12:01-15:00 time span (mean = 0.25, SD =0.50).

Figure 35: Average Occurrences of Technical Issues

5.1.3 Gamepad Errors

Figure 36 shows the occurrences of button and limit errors for the first 20 minutes of the collaboration session. Gamepad errors were also a rare occurrence: Group 1 and Group 4 had no gamepad errors, Group 2 had only one limit error, and Group 3 had four limit errors and only one button error. For Group 3, three of the four limit errors and the button error occurred within the first two minutes of using the HSPP. The hospital student in Group 2 committed the limit error during the 11:01-12:00 time division.

Figure 36: Occurrences of Gamepad Errors

5.1.4 Task Success

Figure 37 shows the average occurrences of complete task successes over a time span of 20 minutes. No groups had any occurrences of task failures. The occurrences of partial task success were due to the hospital student delegating an assigned task to another group member. Task successes in the beginning (0:00-8:00) were the result of the hospital student completing simple instructions given by the instructor and other students (e.g. looking at objects, answering questions). Task successes during the brainstorming/working period (8:01-20:00) were the result of the hospital student answering questions, completing their assigned portions of the task, and making the decision for the group regarding which song to storyboard.

Partial successes occurred much less frequently than complete successes (mean =0.25, SD =0.50) and only during the brainstorming/working period (8:01-20:00) when students were being assigned tasks by other group members.

Figure 37: Average Occurrences of Task Successes

5.1.5 Presence Measures

Figure 38 shows the average occurrences of positive and negative communication interactions over a 20-minute time span. There were few positive occurrences of Communication Interaction for the first six minutes (two or less per time division). The hospital students were mostly listening to the instructor during this time period, and occasionally asked or answered questions. After the first six minutes, positive occurrences of Communication Interactions greatly outnumbered negative ones, peaking at the 16:01-17:00 time division (mean =6.50, SD =1.3).

Negative occurrences of Communication Interaction remained very low throughout. The average negative occurrences never exceeded 0.5 (SD =0.58) and was usually either 0.25 (SD =0.50) or 0. Negative occurrences were typically a result of sarcasm where the hospital students were making unnecessary or unhelpful comments.

Figure 38: Average Occurrences of Communication Interactions

Figure 39 shows the percentage of time divisions spent on positive and negative Concentration. Half of the hospital students were able to exhibit signs of positive Concentration during all time divisions. The hospital students in Group 1 and Group 2 were unable to achieve positive Concentration during all time divisions (91% and 93% respectively) because they either ‘tuned out’ or were engaged in horseplay, which also explains the higher percentages for negative Concentration (24% and 22% respectively).

Figure 39: Percentage of Time Divisions Spent on Concentration

Figure 40 shows the average occurrences of positive and negative Concentration over a 20-minute time span. Nearly all groups had positive occurrences of Concentration for the entire 20-minute time span. The only exceptions were the 0:00-1:00 and 5:01-6:00 time divisions where the average occurrence was 0.75 (SD =0.50).

Negative instances of Concentration did not occur until the 4:01-5:00 time division. The average occurrences was low (mean =0.25, SD =0.50) when not zero, peaking only once in the 5:01-6:00 time division (mean =0.50, SD =0.58).

Figure 40: Average Occurrences of Concentration

Figure 41 shows the average occurrences of positive and negative Initiative over a time span of 20 minutes. Positive occurrences of Initiative fluctuated for the greater part of the time span. Positive Initiative occurred steadily during the 7:01-11:00 time span (mean =0.75; SD =0.50 @ 7:01-8:00, SD =0.96 @ 8:01-11:00). This time span included the conclusion of the lecture period (1:01-8:00) and the beginning of the brainstorming/working period (8:01-20:00).

Negative occurrences of Initiative only appeared in the 8:01-10:00 time span (mean =0.25, SD =0.50). All of the negative occurrences were from Group 4. The hospital student was not as closely supervised by the instructor during this time span, and likely was less motivated to take initiative at the beginning of the brainstorming/working period (8:01-20:00).

Figure 41: Average Occurrences of Initiative

5.2 Post-Study Questionnaire

5.2.1 Forced-Choice Questions

For the opinions coded as positive/negative, 1 was used for very positive, and 5 for very negative. For the opinions coded as agree/disagree, 1 was used for strongly agree, and 5 for strongly disagree. When we examine the categorical responses for each question in the post study questionnaire we find some predictable results but also some surprising ones. Figure 42 displays the students' opinions of the HSPP. No significant differences were found between any responses for any questions.

All of the students responded positively or very positively to their overall impression of the classroom end (mean =1.67, SD =0.49). Eight of 12 (67%) responded that they were pleased and four (33%) responded that they were very pleased overall. The majority of the students expressed satisfaction with the audio and video quality (mean

=2.17, SD =1.27; mean =2.50, SD =1.00). Eight of 12 (67%) responded positively to the audio quality and seven of 12 (58%) responded positively to the video quality. Fewer students responded negatively. Three of 12 (25%) responded negatively to the audio quality and only one of 12 (8%) responded negatively to the video quality.

Students also responded positively to the esthetic appearance of the classroom unit. Five of 12 (42%) responded positively to the colour of the classroom end, and three (25%) responded negatively (mean =2.67, SD =1.07). Ten of 12 (83%) participants reacted positively to the size and shape while only one (8%) was negative about those features (mean =2.25, SD =0.62).

Figure 42: Students’ Opinions on Classroom End of HSPP

Figure 43 shows the students’ opinions on their sessions. Eleven of 12 (92%) reported that the group was successful in their task and only one (8%) did not agree (mean =2.00, SD =0.74). Ten of 12 (83%) participants reported that the classroom end

was not distracting to the group while only one (8%) participant believed the classroom end was distracting (mean =3.83, SD =0.72). Eight of 12 (67%) agreed that everyone was equally involved in the session, and one (8%) disagreed (mean =2.25, SD =0.87). Nine of 12 (75%) stated that having the classroom end in the room was the same as having the hospital student in the room, and one (8%) stated that it was not the same (mean =2.25, SD =0.75). Ten of 12 (83%) responded that the group grew accustomed to having the classroom end in the room, and two (17%) were neutral (mean =2.00, SD =0.60).

Examining the categorical differences for questions related to having the HSPP in the classroom, there was a significant difference between categories for the question “PEBBLES was distracting to the group” ($\chi^2 [12, 3] =16.0, p <0.05$) and for the question “PEBBLES in the room was the same as having a person in the room” ($\chi^2 [12, 3] =11.3, p <0.05$). The majority of students (75%, mean =2.25, SD =0.75) agreed with the latter statement and a majority of students (83%, mean =3.83, SD =0.72) disagreed with the former statement.

A cross-tabs analysis was used to determine the relationship between the important factors of HSPP. These factors included audio and video quality, student opinions of their task success, and distraction. There was a significant interaction between impressions of audio and video quality ($\chi^2 [12, 9] =21.5, p <0.05$). Students who were satisfied (67%, mean =2.17, SD =1.27) with the audio quality appeared to be satisfied with the video quality as well (58%, mean =2.50, SD =1.00). There was also a significant interaction between the students’ opinions of their success with their tasks and how distracting the classroom end was ($\chi^2 [12, 6] =12.6, p =0.05$). Students who reported that their group completed their task successfully (92%, mean =2.00, SD =0.74) also

appeared to be likely to respond that they thought the classroom end was not distracting (83%, mean =3.83, SD =0.72).

Figure 43: Students' Opinions on HSPP Experience

Figure 44 shows the hospital students' opinions with regards to using the hospital end. Due to small-n, chi-square analysis was not performed to find any significant differences between category responses of the hospital students. Opinions were divided with respect to the range of the classroom camera. Two of four (50%) were satisfied and two (50%) were dissatisfied (mean =3.00, SD =1.16). All four of the hospital students indicated they were satisfied with the onscreen controls to direct the classroom end (mean =1.75, SD =0.50). Two of four (50%) indicated they found the hospital end easy to use and two (50%) were neutral (mean =2.25, SD =0.96).

Figure 44: Hospital Students' Opinions on Using HSPP

Figure 45 shows the hospital students' opinions regarding their sessions. Two of four (50%) believed that the using the controls did not impede their ability to concentrate on their tasks and two (50%) were neutral. Three of four (75%) indicated they were unable to see everybody with the camera at the classroom end. Three of four (75%) stated that they missed being with the rest of their group members. Three of four (75%) agreed that they were a part of all of their group's decisions and one (25%) disagreed. Three of four (75%) indicated that the hand at the classroom end was useful for getting attention and one (25%) disagreed.

Figure 45: Hospital Students' Opinions on HSPP Experience

There was a significant difference between impressions of video quality and how well the group integrated with the classroom end ($\chi^2 [12, 6] = 14.0, p < 0.05$). Those who responded positively to the video quality appeared to agree with the statement that they became accustomed to being with the classroom end. There was a significant difference between impressions of the size and shape of the classroom end and how well the group integrated with the classroom end ($\chi^2 [12, 4] = 10.8, p < 0.05$). Those who responded positively to the size and shape of the classroom end appeared to agree with the statement that they integrated well with the classroom end.

There was also a significant difference between the students' impressions on the distraction of the classroom end and whether they believed that everybody in the group was equally involved in the task ($\chi^2 [12, 9] = 18.2, p < 0.05$). Students who agreed that

everyone in the group was equally involved appeared to be more likely to respond that the classroom end was not distracting to the group.

There was a significant difference between the students' computer use and their opinion of having the classroom end in the room being similar to having the hospital student in the room ($\chi^2 [12, 6] = 14.0, p < 0.05$). It appeared that students who used a computer at least four times per week were more likely to agree that having the classroom end in the room was similar to having the hospital student in the room.

5.2.2 *Open-Ended Questions*

Figure 46 shows the positive and negative occurrences for the descriptive analysis of the open-ended questions. The Video, Easy to Use, Presence, Collaborating, and Communicating categories had more positive than negative occurrences. The Audio category had an equal number of positive and negative occurrences. The User Interface and Application Sharing categories had more negative than positive occurrences. The Presence and Communicating categories were the only ones with no negative occurrences.

Figure 46: Positive and Negative Occurrences from Results of Descriptive Analysis

CHAPTER 6: DISCUSSION

The research questions presented in Chapter 4 provide one set of criteria for evaluating the effectiveness of the HSPP: (1) ease of use; (2) supporting students in completing tasks; and (3) providing telepresence. A small-N design facilitated a closer study of the behaviour of the users as they participated in various activities with the HSPP. The small number of participants resulted in a weak statistical power and therefore few statistical analyses were carried out, but presented an opportunity to study behavioural trends in detail.

6.1 Ease of Use

Based on the frequency of errors committed, the frequency of technical issues, and the responses in the post-study questionnaire, the HSPP could be deemed easy to use. None of the hospital students responded negatively when asked about the ease of use (see Figure 44). This is somewhat surprising given the complexity of system and that two monitors were used.

The gamepad interface appears to be an easy method to control the classroom end. This result is similar to those found with the elementary version of PEBBLES where a student was able to use a physical gamepad with relative ease [129]. The high school students committed very few gamepad errors and when they did, they occurred in the early stages of the sessions, and rarely reoccurred in the later stages of the sessions. Cumulatively, the groups committed only five gamepad errors during the 20-minute time span, and only two of the groups were responsible for them. All the users responded positively to the controls being onscreen instead of a separate physical device, and the onscreen controls did not seem to interfere with their work. As seen in Figure 45, none of

the hospital students believed that using the onscreen gamepad impeded their ability to concentrate on their tasks.

This result was not surprising given the level of computer experience among the participants. The students were more comfortable with using computers in general, and (by extension) more comfortable learning new computer programs that have a similar look and feel to those with which they have experience (e.g. Windows menus, commands, shortcuts). Since the HSPP uses a software interface that is common to many Windows programs (e.g. Paint), students with computer experience were expected to find little difficulty in learning to use it.

In addition, the on-screen control interface was designed to match the control tasks that students were required to accomplish, and it was based on a physical interface that has been successful with the elementary version of PEBBLES [122]. Interfaces that match a user's tasks have been shown to be the most effective interfaces [100, 131], and it appears that the onscreen control interface has accomplished this goal.

The addition of a workspace screen proved to be invaluable since the hospital students were spending a majority of their time interacting with the workspace screen (see Figure 31). None of the hospital students reported having any problems with managing two screens simultaneously even though an earlier study [124] suggested that students might have difficulty managing multiple screens. It is possible that the experimental setup used in the earlier study had a haphazard appearance (e.g. more basic hardware implementation) compared to the carefully arranged setup for this thesis, and may have negatively affected the users' impressions and ability to work in this early study. The physical arrangement of the screens in the studies conducted for this thesis

allowed the students to switch their attention between the screens in a natural way (looking side-to-side between screens). There is also the possibility the results of the earlier study have become outdated as children are becoming exposed to computers and electronics at an earlier age.

The majority of technical issues were related to confusion with application sharing (52%), and analysis of the responses to the open-ended questions revealed that students had difficulty with the application sharing feature (see Figure 46). Possible reasons for this were that application sharing was a new concept to the students, that was difficult to integrate into their existing work practices, and that the limited time allotted for the training sessions did not allow the feature to be explained and understood in enough detail.

One way to address the difficulties with the application sharing feature is to increase the training time and focus on this feature. Typically, elementary PEBBLES training sessions last longer than 15 minutes. Only a few students in the HSPP studies were in favour of a longer training session, and one suggested creating an instructional video for first-time users of the HSPP. As with the gamepad errors, after the initial difficulties with application sharing were encountered, the students were able to learn how to use this feature, and by the end of their collaboration sessions, were using it with relative ease.

Comparing the results shown in Figures 35 and 37, there does not appear to be any correlation between the occurrences of task successes and technical issues ($r=0.20$, $p>0.05$). However, further research is required to determine if technical issues negatively affect the ability to complete tasks because technical issues would be expected to prevent

a person from being able to complete tasks since their concentration would be divided between tending to their tasks and addressing technical issues.

The natural and intuitive interface using two screens combined with the hospital students' experience with computers allowed them to use the HSPP with relative ease. There were very few gamepad errors, and the technical issues associated with the application sharing feature could be reduced by paying particular attention to the feature in future training sessions.

6.2 Supporting Task Completion

The ability to complete tasks was measured by determining if the student met the criteria for successful completion of a task: Initiation, maintenance, and successful closure of the task [15]. Successful completion of a task required all three criteria to be satisfied. The success level and related task were noted only when the outcome of the task assignment had occurred (i.e. they completed it, they passed it to somebody else, they gave up). As seen in Figure 37, there were no failures and the few partial successes occurred only during the brainstorming/working session (8:01-20:00). The hospital students were also able to achieve over five times more complete successes than partial successes. The groups combined for a total of 23 complete successes and four partial successes during the 20-minute time span. All partial successes were the result of the hospital students delegating their tasks to others.

One reason for the relatively high number of complete successes might be that the HSPP had sufficient functionality to support the students in completing their tasks (e.g. real-time communication, visual information, application sharing). Other reasons might be that the assigned tasks were simple and easy for the students to complete, being with

friends kept them motivated, or novelty factor (i.e. they were enthusiastic because it was their first time being exposed to the technology).

One-to-one interactions that occurred during the brainstorming/working period (8:01-20:00) depended on the working approach of the group. Groups that divided tasks and assigned each group member responsibilities were less likely to have one-to-one interactions since the hospital student was working independently and addressing questions to the group (to gather ideas quickly) rather than a specific person. Groups that worked collectively on the task also appeared to rarely have one-to-one activities (mostly for side conversations). One-to-one interactions also occurred when students were dividing their tasks into individual parts, and would likely be more frequent in situations where a student may be experiencing difficulty and requires more intensive, personal attention (e.g. working with a teacher). However, in general, there were few one-to-one interactions in these studies and it is difficult to determine how this type of interaction influences usability or presence. More research is required to understand the impact of one-to-one interactions in the context of the HSPP.

As seen in Figure 38, there were very few instances of negative Communication Interaction. Possible reasons for the negative occurrences being rare are that the students treated the collaboration session as an actual classroom situation instead of just a simulation, the group members were friends with each other so there would be little reason for negative occurrences, and it was a result of the students' learned behaviour (i.e. they were taught to be polite and respectful to others).

Many of the positive occurrences of Initiative were produced by the hospital student in Group 1. As a result of being one of only two group members, she frequently

exhibited positive Initiative by quickly volunteering to ask and answer questions, and initiating the application sharing process.

All of the negative occurrences of Initiative were from Group 3. The remote student appeared hesitant to share her ideas at the beginning of the brainstorming/working period (8:01-10:00). For example, she was not interested in suggesting a song for her group to storyboard and had to be persuaded to contribute several times by her other group members. This may have been a result of the hospital of the instructor not paying the remote student enough attention during this time span, and thus she was likely less motivated to take initiative. Surprisingly, her group members' impressions of her presence were not affected; one reported the HSPP was not distracting, and both believed the HSPP was the same as having the hospital student in the room with them. However, her group members' opinions were divided on whether or not they were successful in completing the group's assignment.

When the hospital students reported technical issues such as audio problems or difficulty with the application sharing feature, the groups would break their focus and concentration on their work tasks, and focus on addressing the technical issues. Similarly, signal latency caused breaks in concentration because the hospital student and group members had to wait for unnatural disruptions in conversations to pass in order to avoid unnecessarily repeating themselves or talking over each other [90].

These unplanned breaks lasted for varying amounts of time (from approximately 10 seconds to one minute of discussion time). The hospital student in Group 1 would quickly comment on audio problems, and then continue where she left off in her conversations. The classroom students in Group 3 and Group 4 would spend a short

period of time (approximately less than one minute) discussing the technical issue, but one of the group member's would remind the others of their original assignment. The signal latency in Group 2, however, caused the classroom students to focus intensely on the technical issue, and required the intervention of the instructor before regaining focus on their assignment.

As indicated in Figure 40, negative instances of Concentration were scarce compared to positive instances which were nearly constant. This result, in conjunction with the small number of partial task successes and absence of task failures (see Figure 37), indicated that although there were some breaks in concentration, they were not frequent enough or long enough in duration to cause a negative impact on the groups' ability to succeed in their work/academic tasks.

As mentioned previously, the majority of technical issues were related to confusion with the application sharing feature (52%). Twenty percent of the other technical issues were related to connection issues, and the remaining 28% were related to audio quality. The students struggled with making their applications visible to each other, and then managing control of the shared applications. However, the technical issues did not appear to have a serious effect on the groups' ability to complete their tasks since there were no task failures and only a few partial successes occurring during the brainstorming/working session.

In the force-choice and open ended responses to the post-study questionnaire, the students appeared to be very satisfied with the HSPP. The majority responded positively to the video and audio quality (as seen Figure 46), and there were no reports of any concerns with signal latency, some of the most common barriers to the acceptance of

videoconferencing [89]. Serious issues with video and audio quality and signal latency could have negatively affected the ability of the students' ability to complete tasks by causing breaks in concentration and conversation, and frustrating the students.

The hospital student should be given any classroom handouts ahead of time to ensure that they do not struggle with taking notes and operating the classroom end simultaneously. This caveat was identified by observing the hospital student in Group 2 when she asked why the classroom students had received a handout and she had not (there was an electronic version she was unaware of), and the comments from one of the students in Group 3 who inquired about the use of only electronic documents. Managing documents was not a focus of this thesis and no special management tools were available to support this activity. Future development of HSPP should consider electronic and paper-based methods for note-taking, and ensuring that remote students have access to school based documentation.

The majority of the students indicated that their groups completed their task successfully (92%, mean =2.00, SD =0.74). It also appeared that those who believed that they were successful were likely to respond that the classroom end was not distracting (χ^2 [12, 6] =12.6, $p < 0.05$). This result indicated that the classroom end was successful at supporting their tasks without causing serious disruptions. This result is also linked with how the HSPP was able to provide telepresence for the hospital and classroom students to enable them to participate in group and one-to-one activities, and to facilitate positive occurrences of the presence measures.

6.3 Telepresence

The hospital students participated in all of the different activity types (as seen in Figure 26) with the exception of Group 1 (they had only two people, and by definition were unable to carry out any group activities). The large number of group (71% of time divisions) and one-to-one activities (50%) during the brainstorming/working period (8:01-20:00) indicated that the group members were comfortable with using the HSPP, and had enough social presence that supported working together rather than working alone. Social presence came from interactions with others during the collaboration session (doing group and one-to-one activities) which convinced them that they were present.

For Group 1, it is likely there was telepresence despite not having any group activities because it was possible that the smaller group created a more personal sense of social presence than the larger groups (e.g. Groups 2, 3, and 4). The hospital student in Group 2 stated that she believed that she was being ignored, and not being included when the group was making decisions. This may have occurred because the classroom group consisted of all males who seemed to be more interested in talking among themselves rather than working on the assignment as a team. The remote student was female and did not seem to want to interfere with this discussion. Whether this was a normal behaviour for this student, or whether HSPP was interfering with her ability to participate was not determined in this study. Nevertheless, towards the end of her collaboration session, she was an active participant in her group's discussions and held the group's collective interest when she spoke, since the group had divided the work and were concentrating on her part.

As shown in Figure 34, getting attention actions increased in frequency over time. One possible reason for this is that the hospital student was listening to the instructor initially, and then tried to gain the attention of the other group members during the brainstorming/working period (8:01-20:00). Reasons for getting attention included asking for clarification, wanting to provide input to an ongoing discussion, and commenting on the work in progress. Surprisingly, the students rarely used the HSPP hand for getting attention, and relied on interrupting the current speaker. When questioned about this behaviour, the hospital students claimed that they were unsure of how the hand would appear when activated. This could mean that the hospital students felt self-conscious about the appearance of the classroom end, and by association, their own appearance. This issue may require further investigation because if the high school students are concerned about their appearance mediated by the HSPP, they may be reluctant to use it if they feel they are being represented negatively.

As seen in Figures 41, 43 and 45, the number of positive events far outnumbered the negative events for all three presence measures (Communication Interaction, Concentration, and Initiation) suggesting that the hospital students had a presence in the classroom and that their peers had a presence with them in their isolated location. This was an indicator of the notion of presence as transportation [20] in that all of the students were under the impression that the physical presence of the HSPP was the same as having the hospital student in the room, and the hospital students were able to look around the classroom and hear their friends' voices.

As seen in Figure 41, there was a low frequency of positive occurrences followed by a large increase in the frequency of positive occurrences of Initiative during the 8:01-

16:00 time span (100% increase). This was an indicator that the hospital students were taking a more active role in the group by either initiating discussions or anticipating the group's actions as time progressed. The change in the occurrences of Initiative may also have been a result of the hospital student becoming accustomed to the technology and the user interface.

An interesting observation on the presence measures is that negative occurrences of Communication Interaction and Concentration did not necessarily indicate a lower sense of presence. In certain cases, negative occurrences were a positive indicator of co-presence. For example, if group members became distracted from or bored with their tasks, they would engage in light-hearted joking and horseplay with the hospital student. Even though these were counted as negative occurrences of on-task behaviour, they reinforced social presence between the students. This happened because the students saw each other as friends as well as classmates, and the casual banter that was unrelated to their current situation enriched the social experience [20]. A similar interaction between a hospitalized student and his/her classmates would likely have a beneficial effect on the hospitalized student's emotional well-being [121].

Another sign of social presence was observed as the hospital students were usually facing the communication space when they were speaking with their classmates rather than looking at other visual stimuli such as the workspace screen or the environment. In addition, they rarely read a document held-up in front of the camera in the communication space. Some exceptions occurred when the hospital student was looking at the controls on the workspace screen, and when the student was occupied with typing and reading from the workspace screen. Although the video camera was vertically

displaced from the center of the screen (i.e. direct eye-to-eye contact was not possible in our configuration as the students would seem as though they were looking down if they were looking directly at the screen – see Figure 47), the students continued to address the screen instead of the camera. This is similar to speaking at a person’s face rather than speaking directly into certain areas about their head (e.g. eyes, ears, mouth). It is possible that they were looking at the communication screen to determine the other person’s reactions via facial expressions and gestures; both are factors that contribute to a greater sense of social presence [20].

*Figure 47: Eye Position with Respect to Local and Remote Monitors.
Eye position with respect to local monitor (left) and remote monitor (right)
when looking at camera (a) or looking at local monitor (b)*

This evidence of co-presence was echoed in the responses regarding level of agreement with the statements “PEBBLES in the room was the same as having a person in the room” (75%, see Figure 43), and the large number of positive comments regarding presence (8 positive, 0 negative, see Figure 46). Some examples of the positive comments were, “I liked being able to be with the group live”, and “We could just talk like the other person was in the room.”

A related finding from the video analysis was the change in behaviour towards the classroom end. Initially, commands would be given to the hospital student to move specific parts of the hardware or attend to specific aspects of the software. The nature of these commands changed from addressing technical components to addressing the classroom end as a physical surrogate. An example of this occurred for Group 2. One of the classroom participants initially asked the hospital student to “point your camera over here”. In the later stages of his session, he no longer referred to the camera, but instead asked the hospital student to “look” in certain directions. This change in behaviour is reflected in the results of the post-study questionnaire where 75% of the students said that having the HSPP in the room was similar to having the hospital student in the room, and 83% said that the group grew accustomed to being with the classroom end. This finding provides evidence of an increased presence for the hospital students despite not being physically present with the rest of their groups.

One issue that could have a negative impact on co-presence is how the classroom end does not fully mimic the physical capabilities of the human body. The limited rotation arc of the classroom end (70°) does not reflect the actual range of natural rotation of the human neck. Humans have peripheral vision and mobility which is non-existent for the classroom end among other things.

Figure 48 is a model of presence factors and how they can influence the experience of presence on users. The presence conceptualizations reside at the highest level in the model and are defined by the presence measures used in this thesis. The features of HSPP, in-turn, influence these measures. The shaded boxes indicate measures and features that have a greater impact on presence. However, the extent of this impact

remains to be quantified. No direct relationships are shown for the presence measures and features because they work together in order to influence the sense of presence experienced by the hospital and classroom students.

Figure 48: Presence and HSPP Presence Measures and Features

The model of presence used here only represents the social and virtual presence concepts among the many that have been suggested in the literature because they are the concepts that seem to apply best to the HSPP. Social presence refers to experiencing presence through social interactions with other people at a remote location. Virtual presence refers to experiencing presence through the computer-mediated representation of the remote environment. These two forms of presence are based on the concepts of presence as social richness and transportation [20] where social richness refers to social

interactions, and transportation refers to the sensation of being transported to another place.

The concept of presence as social richness can be influenced by the communication and collaboration activities with other people. Common social conventions such as greeting acquaintances and gesturing are considered communication activities, and turn-taking and accomplishing tasks are considered collaboration activities. The concept of transportation can be influenced by a physical presence at a remote location. The classroom end of the HSPP gives the hospital student a remote physical presence in the classroom. These influences are the most dominant presence factors supported by the HSPP, and they are measured using the various categories presented in Chapter 5.

The effect of the HSPP features on the presence factors are determined by the HSPP presence measures in concert. Examining the effect on presence of each individual feature of the HSPP would not be very useful at this point since the features of the HSPP work together to contribute to affect presence. The presence measures offer a mechanism for examining the effects of the HSPP system in terms that are relevant to presence theory.

Positive occurrences of the communication interaction measure are an indication of presence through the communication and collaboration factors. If a person is contributing actively during a brainstorming session, she is demonstrating a positive presence. Negative occurrences of the communication interaction measure can also be counted as indicators of presence through the communication factor, but not the collaboration factor. If a person is being overly loud and disruptive, she has an obvious

undesirable presence since she is not being helpful and disturbing normal communication and work processes.

Positive occurrences of the concentration measure are an indication of presence through the communication and collaboration factors. By staying focused on tasks, the hospital students were able to make meaningful contributions to discussions and assigned tasks. Negative occurrences of the concentration measure can be an indicator of presence if the hospital student is distracted from their work by events in the classroom. In this case, the events have a presence with the hospital student.

Positive occurrences of the initiative measure are an indication of presence through the communication measure and possibly the collaboration measure. When a person is the first to speak up or answer a question, she is likely to be noticed. If what she says is helpful or constructive, then she is also helping with the collaborative process. Negative occurrences of the initiative measure are not an indicator of presence.

Positive instances of communication interaction and initiative indicate increased presence by definition. Positive occurrences of communication interaction indicate that a person understands what is being discussed and contributes positively to the discussion. Positive instances of initiative are only possible if a person feels socially engaged with remote events.

Frequent occurrences of tasks being successfully completed are an indication of presence through the communication and collaboration factors. Not all successful tasks require collaboration but they do require effective communication in order to receive the tasks, complete them correctly, and then acknowledge their completion. A large number of failed tasks may not be an indicator of decreased presence since the student may

experience difficulty in completing tasks regardless if they were physically present in the classroom or not.

Frequent occurrences of group and one-to-one activities are an indication of presence through the communication, collaboration, and physical presence factors. The physical presence of the classroom end contributes to the physical presence factor since the classroom students can see which direction the hospital student is facing, and whether or not they were paying attention or aware of classroom events. They can also see the physical movement of the classroom system which provides the classroom students with a sense of a physical entity in their work space. Any instances of group activities and one-to-one activities indicate increased presence by definition.

Occurrences of individual activities are weakly related to all three presence factors because individual activities are not commonly associated with communicating or collaborating with others, or having a physical presence. However, for the collaboration sessions presented in this thesis, individual activities do not necessarily imply a lack of presence. For example, a student may be working independently on an assigned part of a task. In this example, the student is working alone, but in order to complete her task properly, the student must have a presence in order to be acknowledged by whoever assigned the task, be able to understand the person who assigned the task (i.e. communicate), and since her task is part of a larger task, she is required to maintain an awareness that she is still collaborating with her group.

HSPP actions are related to all three presence factors. Zooming actions indicate that the hospital students believe they have a physical presence in the classroom because zooming actions imply that something or someone of interest in the classroom has caught

their attention. Reading from the workspace typically occurs while they are working on a file or using the application sharing feature which necessitates collaboration. Attempts to get attention are related to communication and physical presence because activation of the HSPP hand provides a physical mechanism for gaining attention. If that attempt is acknowledged by people in the classroom, the hospital student can then be able to speak and be heard. However, a large number of HSPP actions may also be an indicator of decreased presence if the student becomes bored or socially disengaged and performs many HSPP actions for amusement.

Technical issues mostly influence the communication and collaboration presence factors negatively. Issues with the audio or video quality prevent the students from communicating naturally, hence diminishing their presence. Issues with the application sharing feature limit the students' ability to collaborate with each other, again diminishing presence. However, we cannot necessarily confirm nor deny the reverse relationship using the HSPP because manipulating and testing each of these measures independently was beyond the scope of this thesis. For example, having high audio or video fidelity does not necessarily translate into increased presence.

Gamepad errors have the potential to influence all three presence factors. Committing any errors creates the possibility that communicative and collaborative processes can be disrupted because the result of the gamepad error can cause people to become distracted, breaking their train of thought while concentrating, or introducing unexpected breaks in conversations. Unexpected or irregular movement of the classroom end as a result of gamepad errors can also result in a decreased physical presence if the motions do not appear to be natural (which they usually are not).

Audio quality, video quality, ease of use, and user interface are features that appear to have a greater impact on presence. Audio quality is essential since it is one of the primary modes of communication. Video quality is less important than audio quality, but becomes crucial if audio quality is poor. Ease of use is related to user interface and both have an impact on presence. A complex videoconferencing system has the same negative impact on presence as a complicated user interface. A user's sense of presence decreases if she is constantly consulting a reference source in order to accomplish a task with a feature of the system.

6.4 Attitudinal Differences

The significant differences in response to the attitudinal questions in the post-study questionnaire mentioned in section 5.2 included questions on computer use, audio/video quality, esthetics, and student's opinions of task success, distraction/integration of the classroom end and group involvement. The significant differences encompassed several themes, and some are interrelated. The most common themes were: (1) How the classroom end served as a physical surrogate for the hospital student's presence, (2) How distracting the HSPP was, and (3) How the group became accustomed to the HSPP.

The purpose of the classroom end was to provide the hospital student with a presence in the classroom. In this thesis, a physical surrogate for the hospital student was used. The students who agreed that the physical presence of the classroom end was identical to the physical presence of the hospital student (75%, mean =2.25, SD =0.75) were more likely to be using computers at least four times each week (83%, mean =3.33, SD =0.78; χ^2 [12, 6] =14.0, $p < 0.05$), and were less likely to find the classroom end

distracting (83%, mean =3.83, SD =0.72; χ^2 [12, 6] =14.0, $p < 0.05$)). This was probably a result of the students' comfort level with using computers since the HSPP uses a familiar computer interface.

The students who agreed that the group became accustomed to the HSPP (83%, mean =2.00, SD =0.60) were also more likely to respond positively to the video quality (58%, mean =2.50, SD =1; χ^2 [12, 6] =14.0, $p < 0.05$), and to the size and shape of the classroom end (83%, mean =2.25, SD =0.62; χ^2 [12, 4] =10.8, $p < 0.05$). These results may have occurred because the video quality allowed the students to see each other clearly enough, and the students may also have believed that the size and shape of the classroom end was unobtrusive. These significant results illustrated how the HSPP was able to provide a physical surrogate for the student that did not create a disruptive presence in the classroom.

The students who agreed that the HSPP was not distracting (83%, mean =3.83, SD =0.72) were also more likely to state that they thought their group was successful at completing their tasks (92%, mean =2.00, SD =0.74; χ^2 [12, 6] =12.6, $p = 0.05$). If the HSPP had been a distraction to the students, they would likely not have been able to remain focused on their tasks. Consequently, they would probably have had a lower opinion of their task success. In effect, the design of the HSPP (i.e. video and physical design) seems to have given the groups the impression that the hospital student was present with them in the classroom, and they were under the impression that it helped them to complete their tasks.

Based on these results, it would seem that the HSPP served as a synchronous communication and work system that was relatively easy to use and allowed the hospital

students to establish an effective presence in their remote working environment (the classroom). The classroom students responded favourably towards the HSPP, and their behaviour towards the classroom end changed from viewing it as a collection of hardware to interacting with it as though the hospital student was actually present. However, there were limitations to the research that prevent these results from being applicable to the general high school student population.

6.5 Limitations of Research

One next step in this research would be to address some of the difficulties the students experienced (e.g. with reconsideration of the usefulness of infrequently used features such as application sharing). Most of the students struggled with the application sharing feature because they could not use it effectively despite being exposed to it during the training session and having step-by-step instructions provided onscreen. The training offered in this study and HSPP user interface was insufficient as the students required assistance from the researchers in order to understand and use the application sharing feature. Further research involving HSPP will need to either simplify the feature or place more emphasis on the feature during training. Should difficulties persist, then the usefulness of the feature should be compared with the frustration it generates to determine whether or not it should be retained in future versions of the HSPP.

The features of the HSPP that were rarely used were the whiteboard application and the HSPP hand. Seldom use of the whiteboard application was probably related to the difficulty with the application sharing feature since it relied on sharing the program in order to be useful. In almost all instances of sharing drawings, the students resorted to using Paint instead of the whiteboard. This was probably due to that fact that the two the

students were more familiar with the Paint program interface, and the functionality was similar enough to the whiteboard application that they could easily use the more familiar application to accomplish their drawing tasks. As with the application sharing feature, the utility of the whiteboard feature must be reconsidered.

The HSPP hand was rarely used because the hospital students claimed they were unsure how it would appear to the classroom students. Use of the HSPP hand was not critical for the collaboration sessions in this thesis since they were intimate settings. However, there would be cause for concern if the hand was not being used in more formal settings since the hospital students' favoured method of getting attention, interrupting verbally, would be unacceptable in the highly structured and formal setting of the classroom.

The exclusion of the hospital student in Group 2 appeared to be an anomaly, since none of the other hospital students appeared to be excluded, and one was even purposely included in group discussions when she appeared disinterested (Group 3). Regardless of whether or not this was an anomaly, the exclusion of the hospital student was a concern because it appeared that the HSPP was not able to provide her with sufficient presence among her peers. This student could have been excluded for several reasons: 1) the classroom group was all male and may have excluded this student regardless of her location; or 2) it could have been that this student was naturally shy; or 3) it could have been the HSPP. If the issue were to occur again in later studies, similarities could be drawn between groups to isolate the causes of exclusion.

While the results discussed in this thesis provide some positive indicators of the success of the HSPP in providing telepresence for remote high schools students, there are

some important limitations of this work. A small dataset (i.e. small number of subjects) allowed the behaviour of the high school students to be studied and presented in greater detail. However, it also limited the types of statistical analyses permitted and external validity of the results. As a result, few statistical analyses were carried out and those results had limited applicability.

In addition, some of the data was not included in the analysis due to the different times allotted to the groups for their collaboration session. As a result, video data outside of the 20-minute time period could not be averaged for all of the groups since there was no data for some. Group 2 had the longest time of 67 minutes, but the second longest period of time was less than half of that; only 33 minutes for Group 4. This presented a problem because although 20 minutes appeared to be a sufficient period of time to capture the lecture and brainstorming/working events, it did not accurately reflect all of the events that would have occurred if all of the groups had equal or more similar times. For example, the hospital student in Group 2 had many short bursts of occurrences of positive communication interaction while the other groups had prolonged periods instead. This is not evident from mere inspection of the results in Figure 38.

A larger dataset may have mitigated the effects of different times and different group sizes, and reduced the influence of any one individual's performance on the results (increasing validity of the results and reducing variance). However, the purpose of the study in this thesis was to examine usability issues and presence trends of a very early prototype and not to provide definitive answers to specific statistical hypotheses. Small-n studies are often employed in the initial stages of design to assess initial user reactions and do not require a large number of resources [132]. [64] suggests that the data from

small-n studies might present a more accurate description of the impact of a controlled variable by being able to closely observe individual behaviour. They suggest that behavioural effects can potentially be masked by averaging the results of larger sample sizes. The study was successful in identifying reactions and effects caused by the telepresence of the hospital students via the HSPP.

Using a larger dataset presents interesting opportunities for further analysis. It would allow the issues of application sharing, rarely used features, and exclusion to be explored further, and if the dataset could be organized by group size, the results could lead to a suggested maximum workgroup size. Using a larger dataset would also introduce greater variation in the subjects which could be beneficial for external validity [133].

In my study, attempts were made to reduce any effects of gender by randomly assigning males and females to different roles. However, differences in performance, presence experiences, and interaction styles may have been a result of gender differences which could have an impact on the design of the system. For example, an all-male classroom may have resulted in some uneasiness with the lone female hospital student, which was the case in Group 2. This uneasiness may have caused her to be less assertive than usual, lowering the number of positive occurrences of the communication interaction and initiative measures, which would have indicated a lower degree of presence. These types of studies might be useful for studying the sociological effects of technology. This would also require a long-term study in order to observe *behavioural changes effected by* the HSPP.

A second limitation was the use of a laboratory setting (i.e. controlled and closely monitored environment). A laboratory setting made it uncertain whether or not the recorded data were a result of natural behaviour or if the students altered their behaviour in a way that would satisfy the researchers. In addition, because of the need to control many of the environmental, social and task variables such as potential for distractions, and position of the HSPP close to the classroom group, the setting did not closely represent a school/hospital setting where the HSPP would actually be used. In an actual setting, the students would be seated in desks arranged in rows instead of around a meeting table, there would be other students in the room, there would be other ongoing classes nearby, the school's public address system could interrupt the class, fire alarms could be set off, and the students would be doing several tasks that may or may not require a group.

The third limitation of the research was the short duration of the collaboration sessions. The groups were assigned only one very specific group task. An actual high school environment would require several tasks in several subjects throughout the day. Finally, the student would need to do their homework after the classes, and possibly collaborate with other students outside of class. The research did not account for any events external to the single specific task assigned for the collaboration session.

There were also hardware limitations. The HSPP was an early prototype and not much effort was spent on an integrated and visually attractive industrial design. For the classroom end, the physical unit, the mixer, and the computer existed as separate pieces instead of being fully integrated into a single unit. For the hospital end, a typical desktop computer arrangement was used with an additional monitor. As a result, each individual

piece would need to be transported separately between classrooms. Physical mobility was not a crucial issue for this thesis since the students were not asked to move the HSPP and the hospital students were not separated from the classroom by a large distance.

Despite its imperfect appearance, the HSPP used all of the principle components of the elementary version of PEBBLES such as the mobile “head” of the classroom end, the HSPP hand for gaining attention, the two screens for separating the workspace and communication space, the cameras, speakers and microphones for conducting the videoconference, and the audio mixer for maintaining audio quality. Quality of the hardware appeared to be sufficient based on the students’ positive responses, although the audio quality could probably be improved by acquiring a better audio mixer for the classroom end. Future studies might require an improved industrial design if mobility is to be tested, or the study participants express concerns about the appearance of the HSPP.

The design of the HSPP was developed using a “survival of the best fit” design procedure described by [134] and as such was sufficient for the studies conducted in this thesis. It was based on the needs analysis conducted in an earlier study investigating the academic and social activities of high school students [124], and desirable features of existing videoconferencing systems (as highlighted in Figure 17). The limitations of the elementary version of PEBBLES were resolved by matching the strengths of existing videoconferencing systems with the social and academic needs of high school students.

Matching the strengths of existing videoconferencing systems with desired functionality filtered out possible features which were considered insufficient or “least fit”. This led to a design which was considered to be “the best fit” in Darwinist terms: A

system possessing the strengths of its predecessors, few of their weaknesses, and ideally suited for its intended environment.

CHAPTER 7: CONCLUSION

In this thesis, an early prototype of a communication system was designed and constructed to link hospitalized high school age students with their regular classroom. The system was designed by a research team where one member was responsible for developing the software and the interface, other members were responsible for the mechanical assembly of the HSPP, and I was responsible for developing the assembly code for controlling the robotics for the system.

After the HSPP had been constructed, testing with high school students was required in order to examine how presence factors implemented through the HSPP affect the ability of high school students to experience telepresence, and to accomplish typical tasks required of those students. I was responsible for designing and conducting the laboratory studies. The studies served an additional purpose of determining what elements can contribute to a seamless videoconferencing system that supports the academic and social needs of high school students and enables them to take an active role in their classroom.

The research questions to be addressed in this thesis were:

- 1) Is the HSPP easy to use?
- 2) Can the HSPP support students in accomplishing assigned academic tasks?
- 3) What aspects of telepresence are supported by and can be applied to the HSPP for the hospitalized student and his/her classmates? Telepresence for the purposes of this thesis is defined by using the notions of presence as social richness, and as transportation [20].

The laboratory-based case studies with the HSPP generated results that provided some positive evidence for each of these questions. In these studies, groups of high school students worked together to complete a collaborative assignment with one of the group members located in a separate room from the others to simulate a hospitalized

student. Observations from the videotapes and analyses of student's responses to a post-study attitudinal questionnaire indicated that the HSPP was relatively easy to use, and student's were able to complete some collaborative tasks in a simulated classroom environment.

There was evidence that the hospital and classroom students experienced presence when using the HSPP. For this thesis, presence was defined as "being there" using the concepts of presence as social realism and transportation. The classroom students seemed to experience presence as transportation because of the appearance and movement of physical surrogate representing the hospital student in their classroom setting. They also seemed to experience presence as social realism by being able to hear changes in the hospital student's speech, and see gestures and facial expressions. The remote student was also able to experience presence as social realism for the same reasons as the classroom students. Presence as transportation for the remote student seemed to result from their ability to look around the classroom with the HSPP and focus on people and objects of interest.

The HSPP seemed to allow the students to communicate, and accomplish some collaborative and individual tasks. Students were able to carry out these tasks by being able to see and hear their classmates clearly and being able to exchange ideas and feedback with each other. The whiteboard application and the application sharing feature facilitated the sharing of ideas by allowing them to share simple sketches and enabling the groups to work together on a common document.

The majority of communication interactions between the hospital and classroom students tended to be natural, positive and appropriate. The students usually remained on

topic, discussing their assigned task and exchanging feedback. The hospital students also exhibited promising signs of initiative by instigating tasks and conversations, thereby increasing the mutual sense of presence by taking an active role in the group. The hospital students appeared to be able to focus on their work for most of the time, and hospital and classroom students reported being able to concentrate on their work without being distracted by the HSPP.

The positive subjective attitudes towards the HSPP and the low number of gamepad errors committed by the hospital students were encouraging. The HSPP appeared to be effective in allowing a hospitalized student to work and communicate with other students and the instructor without many disruptions from the HSPP user interface (other than unpredictable technical issues such as intermittent network failure). The onscreen gamepad interface also appeared to be an effective control method for the high school students to manipulate the classroom end by being easy to learn how to use without being distracting while working. The hospital students did not have many difficulties managing the information on the two display screens although further studies are required to determine whether these results can be replicated in an actual school/hospital situation.

Although the subject numbers were low and the group sizes varied, the results showed that the hospital students appeared to be behaving in a manner that suggested they believed they were present in the classroom. The hospital students were mostly attentive during the lecture period and participated in classroom activities such as asking and answering questions based on the lecture material. They had a role in their groups' assigned tasks by participating in the groups' discussions and later working on the parts

of the tasks for which they were responsible. They also exhibited different working styles suggested by normal group practices and behaviour; some students worked independently while others worked as part of a team effort. In spite of the limited number of applicable statistical tests for the results, observations of the students' behaviours over time provided useful information on the effects of the HSPP on their opinions of their success, and their perception of presence.

An important area of difficulty identifying in this research was the application sharing feature of the HSPP. Most of the students struggled with it because they could not determine how to use it despite being exposed to it during the training session and having step-by-step instructions provided onscreen. The training offered in this study and HSPP user interface seemed insufficient as the students required assistance from the researchers in order to understand and use the application sharing feature. A focus of future studies should be on determining why the students experienced difficulty with the feature, and if the benefits of retaining the feature outweigh the frustration experienced by the students.

7.1 Future Research

Based on the results of the laboratory studies, further evaluation is required to determine the effectiveness of the system with a wider variety of activities and users, and for extended periods of time in a laboratory and actual high school classroom environment. The results of the laboratory studies are promising but the true test of the HSPP will be when it leaves the closely monitored and controlled laboratory setting and is used in loosely controlled field studies in schools and hospitals that can have more unpredictable sources of variability such as types of activity, and distractions.

We would like to examine changes in behaviours and attitudes of real hospitalized students using a similar approach and the instruments used in this thesis (i.e. questionnaires and video analysis). The types of research questions that might be relevant to a field study are: (1) Does the hospital student still experience telepresence (as defined in this thesis), and (2) Does the hospital student benefit (academically and emotionally) from having the live connection to their classmates?

The answers to these questions could be explored through the field studies. An actual classroom environment presents an opportunity to expand the approach used in this thesis further by analyzing changes in behaviours and impressions with the subjects (i.e. instructor and students) over multiple sessions, receiving feedback from actual high school teachers, and adding feedback from parents, caregivers, and hospital staff.

Classroom students in field studies would be participating in a wider range of classroom activities rather than just one collaboration session. Actual hospital students might react differently than the simulated ones in this thesis. Fatigue and malaise stemming from their medical situation were not factors that were considered in this thesis, but would likely play a significant part in student's reaction to HSPP. Instructors might be apprehensive about managing an extra piece of technology with which they were unfamiliar, or may even dismiss it if they were under the impression that HSPP was unnecessary or disruptive.

The research instruments used in this thesis could still be used with some additions. The classroom should also be videotaped to capture changes in behaviour and attitudes of the other students and the teacher. New questionnaires would need to be developed for teachers, parents, caregivers and hospital staff to gather their impressions

of the HSPP. A method to record the workspace screens of both ends would be useful in identifying which applications and features were being used and which were not. Finally, tracking the times spent on various activities might be helpful in developing features geared towards those activities.

No difficulties are expected in finding a high school that can accommodate the technical requirements of the HSPP since most high schools already have classrooms that are wired and connected to the Internet. However, there are several concerns with testing the usability of the HSPP in actual high schools.

One concern is possible vandalism or theft of the classroom unit or its components. Although, the HSPP is made from off-the-shelf components, they are still costly and would require time to purchase and install replacement components. During this time, the hospitalized student would not be able to use High School PEBBLES to connect to their classroom for an indefinite amount of time.

A second concern is the need for the classroom teachers to prepare their lecture materials in advance in order to provide electronic versions to the hospitalized student. This concern was raised by some of the participants who inquired about having all documents and handouts being available in electronic form. The hospital students would need to be made aware of the availability of the electronic documents and taught how to use them effectively.

A third concern is the attitude of the high school teachers. As mentioned, high school teachers may feel apprehensive about allowing the HSPP into their classrooms because they may feel that the technology is foreign to them, or they may dislike it for being disruptive or distracting. In order to alleviate these concerns, they should be

assured that a researcher will be available to address any concerns they might have with the HSPP.

7.2 Future Developments

Some improvements in technical aspects of the HSPP are still needed. Resolution of the audio problems and simplifying the application sharing process are high priorities in order to reduce or eliminate possible frustrations with using the HSPP. The audio problems could be addressed by using a better audio mixer on the classroom end. It was determined that the ALESIS MultiMix 6FX mixer on the classroom end was causing problems while the Shure M267 mixer on the hospital end did not exhibit any obvious problems.

Since the application sharing feature is one of the unique features of the HSPP, the procedure for using it could be simplified by devoting more time to it during the training session. Perhaps spending 20 minutes devoted solely to the application sharing feature might result in fewer problems since application sharing is something that most students are not expected to be familiar with, or do not use on a regular basis. An alternative would be to simplify the interface further in a way that the students will be able to understand easily. Further simplification of the interface could be difficult because of the software developer tools used to create this application cannot support many interface options.

Implementing an automatic speaker location system could reduce the necessity for some control actions [54]. Instead of requiring the student to divide their attention between taking notes and constantly monitoring the teacher's position in the classroom and adjusting the direction of the videoconferencing camera accordingly, an automatic

speaker location system could move the camera automatically. The camera only pans when the speaker approaches the border of camera's vision instead of constantly shifting for even miniscule changes in the speaker's position.

Current videoconferencing cameras are capable of object tracking, but use a colour based algorithm which is unreliable and forces a speaker to avoid wearing certain colours in order to function properly [89]. An alternative solution would be to equip the teacher with a small radio or IR beacon. A microcontroller could then steer the classroom unit to face the beacon using a corresponding radio or IR receiver positioned near the camera lens.

One of the goals of the HSPP is to become a truly mobile and portable system. Although the classroom end was designed to be carried between classes by a single student, the laboratory studies did not verify whether that was possible in a safe and efficient manner. This was not tested because the industrial design of the HSPP was expected to change drastically prior to being deployed in high schools.

The weight of the classroom end still remains an issue since it is still heavy (20 kg) considering that the student responsible for transporting it to and from different classrooms will likely be carrying their own belongings as well. Initial industrial design improvements envision the classroom end being transported on wheels in a similar fashion as rolling luggage (see Figure 49).

*Figure 49: Envisioned Industrial Design for Classroom End of HSPP
(dimensions in mm)*

The computer would be enclosed within the classroom unit instead of being external, the input devices (keyboard, mouse) could be stored in a pocket on the side, and the wheeled design with the retractable handle would enable high school students to easily transport it between classrooms. A slot on the opposite side of the storage pocket could accommodate the attention-getting hand, and the front of the classroom end could still fold down to reveal the communication and workspace screens. Additional carrying handles on the top and sides would make the design easier to lift up and place on a student's desk. Rolling luggage (which the design is based on) comes in a variety of

shapes, sizes, and materials. It would not be entirely impossible to find a suitable sample that could be modified in such a way.

A wireless USB network card could be used to eliminate the need for an ethernet cable and reduce the number of cables leading to and from the classroom end. The circuit presented in Chapter 3 could also be modified to run from a single power supply to reduce the amount of clutter inside. The final weight of the modified system is uncertain. It would be heavier by incorporating the computer into the design, but the wheeled design would also make it easier to transport.

Based on the results presented in this thesis, the HSPP appeared to be an asset to high school students who might be unable to attend their classes regularly. There was mutual presence experienced by the hospital and classroom students as evidenced by their ability to complete simple collaborative tasks despite being physically separate, and the positive behavioural changes they exhibited. However, these results combined with the results of field testing the HSPP could be used to further develop education solutions for high school students who must be away from school for medical or other reasons.

The resulting system design of the HSPP developed in this thesis has shown the value of intelligent modeling with an emphasis on human-machine interaction. New systems that overcome the limitations of prior systems by matching the strengths of these prior systems with the needs of the users can be developed from this type of analysis. In this thesis, the limitations of the elementary version of PEBBLES were overcome. Understanding those limitations combined with studying the strengths and weaknesses of other systems led to a system developed to provide an enhanced remote learning environment for high school students.

APPENDIX A: VIDEO CODECS

Codec stands for “Coder/decoder” and is a device which can be used to compress audio and video signals. Videoconferencing room systems usually have codecs integrated into the devices (camera, communication equipment), and desktop systems usually have codecs in the form of an expansion card [135]. These devices are primarily used to compress the signal received from a camera to a size that is easily manageable for transmission over communication networks. By employing certain mathematical operations, the codec is able to compress a signal to suit a particular bandwidth. For example, a 500 Mbps video signal could be compressed by a codec to 192 kbps for an ISDN connection. The tradeoff for being able to compress a signal is that the received video signal has lower fidelity than the original signal as a result of applying the codec; a higher fidelity signal requires more bandwidth.

Codecs can be categorized as being lossy or lossless. A lossless codec is able to compress and then decompress data without any differences between the data before and after compression. One method of accomplishing lossless compression/decompression is examining the data and eliminating redundancies during compression. During decompression, the algorithm reconstructs the redundancies that were eliminated during the compression process by approximation. If the approximation is identical to the original data, the codec is lossless. Otherwise, it is lossy.

Since video data requires more bandwidth than audio data, this appendix focuses on video codecs. The principles of the video codecs are also applicable to audio compression. Some of the more popular video codecs being used for videoconferencing are: H.261, H.263, and MPEG.

H.261

H.261 is a video coding standard that is part of the ITU H.320 and H.323 standards for ISDN and IP videoconferencing respectively [136]. The H.261 codec compresses data to fit a bandwidth in multiples of 64 kbps [137]. Since ISDN lines are usually grouped, the bandwidth is proportional to the number of ISDN lines (e.g. 2 lines = 128 kbps, 6 lines = 384 kbps).

H.261 specifies a minimum quality level for images at a resolution of 176 x 144 (QCIF) and 7.5 fps. The highest resolution is 352 x 288 (CIF) and the maximum frame rate can vary anywhere above 7.5 fps [137].

H.261 was the first international standard developed using the block Discrete Cosine Transform (DCT) and motion compensation [75]. Figures 49 and 50 show the block diagrams for the implementation of the encoder and decoder respectively.

Figure 50: H.261 Encoder [138]

Figure 51: H.261 Decoder [138]

H.263

H.263 is a further development of the H.261 method and is specified for low bandwidth below 64 kbps. H.263 is a part of the ITU H.324, H.320, and H.323 standards for POTS, ISDN and IP videoconferencing respectively [136].

The codec can be configured for a lower data rate or better error recovery [139]. In addition, the H.263 encoder can limit the number of bits created by coding any single frame to be less than the maximum value specified by the parameter BPPmaxKb which is measured in units of 1024 bits. This parameter varies for different video formats and can be seen in Table 7.

Table 7: Maximum Number of Bits per Frame for Each Video Format [140]

Source Format	BPPmaxKB
Sub-QCIF	64
QCIF	64
CIF	256
4CIF	512
16CIF	1024

MPEG

Moving Pictures Expert Group (MPEG) is a standard developed by an expert group of the International Organization for Standardization (ISO) [96]. It was originally developed as MPEG-1 for creating video CD's (VCD's) with VHS video quality.

There are three types of frames defined for MPEG that are organized in groups of pictures (GOP): I frames, P frames, and B frames. I frames (JPEG encoded single frames) are distributed throughout the video stream to permit random access for video-editing purposes. P frames only code the difference between the previous P or I frame. B frames can be coded by the difference between the previous or the following P or I frame (whichever is better). The typical GOP structure consists of 15 frames beginning with one

I frame followed by a sequence of B and P frames (e.g. IBBPBBPBBPBBPBB) [138]. With recorded video, there are no issues with the GOP structure. However, in a real-time system, B frames can cause processing delays since they depend on both the previous and following frame.

An extension of the MPEG-1 standard, MPEG-2, was specially developed for digital TV and DVD's which makes it more suitable for high resolution video

MPEG-4 was designed with the aim of developing video coding for extremely low data transfer rates (< 64 kbps). The MPEG-4 codec has better compression than MPEG-2, but there is a lack of compatible hardware for MPEG-4 [138].

APPENDIX B: ASSEMBLY CODE

hs_peb.asm

```
; High School PEBBLES Motor Controller
; Author: Jason Yeung
; Date: Feb. 10, 2005
; Description: Assembly code based on RS232 Test Interface written
; by
; Peter Luethi. Code has been modified for PIC16F818 chip, and
; keyboard
; echo has been removed and replaced with desired functionality for
; High
; School PEBBLES. Microcontroller accepts RS232 commands in ASCII
; format
; and performs corresponding action:
;
; L = turn head motor left
; R = turn head motor right
; A = activate hand solenoid
; S = stop motor and solenoid
;
; Microcontroller also features left and right limits to prevent
; head
; motor from continuing to turn. Once either limit has been
; activated by
; an external switch, the microcontroller transmits an ASCII code
; which
; is interpreted by the PEBBLES Visual C++ code, and does not allow
; the
; head motor to continue turning in that direction.
;
; D = right limit reached
; G = left limit reached
;
; This program requires the following files (written by Peter
; Luethi) in
; order to compile:
; m_bank.asm
; m_rs096.asm -> changed to configure I/O pins for High School
; PEBBLES
; m_wait.asm
;
; Peter Luethi's original program header can be read below.

;*****
;*****
; RS232 Test Interface
; =====
;
; written by Peter Luethi, 26.03.1999, Dietikon, Switzerland
; http://www.electronic-engineering.ch
; last update: 11.04.2004
;
; V1.02: Fixed copy/paste issue of ISR context store/restore
; (nobody is perfect): Erroneously erased INTCON,INTF
```

```

;           clearing, resulting in endless ISR calling...
;           Re-structured entire ISR and RS232 echo sub-routines
;           (11.04.2004)
;
;   V1.01:      ISR context restore improvements (21.11.1999)
;
;   V1.00:      Initial release (26.3.1999)
;
;   This code and accompanying files may be distributed freely and
;   modified, provided this header with my name and this notice
remain
;   intact. Ownership rights remain with me.
;   You may not sell this software without my approval.
;
;   This software comes with no guarantee or warranty except for my
;   good intentions. By using this code you agree to indemnify me
from
;   any liability that might arise from its use.
;
;   SPECIFICATIONS:
;   =====
;   Processor:      Microchip PIC 16F84
;   Clock Frequency: 4.00 MHz XT
;   Throughput:     1 MIPS
;   Baud Rate:      depends on the module included
;   Code Size of entire Program: ca. 224 instruction words
;   Required Hardware:      MAX 232
;
;   DESCRIPTION:
;   =====
;   Developed and tested on PIC 16F84, executeable on all interrupt
;   featured PICs.
;   Program handles all aspects of
;       Transmission (Register TXD) and
;       Reception (Register RXD) through interrupt.
;   The microcontroller sends feedback of received characters back to
;   the terminal window.
;*****
;***** COMPILATION MESSAGES & WARNINGS *****
;   ERRORLEVEL -207      ; found label after column 1
;   ERRORLEVEL -302      ; register in operand not in bank 0
;***** PROCESSOR DECLARATION & CONFIGURATION *****
;   PROCESSOR 16F818
;   #include "pl6f818.inc"
;   ; embed Configuration Data within .asm File.
;   __CONFIG    _CP_OFF & _WDT_OFF & _PWRTE_ON & _XT_OSC
;***** MEMORY STRUCTURE *****
;   ORG      0x00                      ; processor reset vector
;   goto     MAIN
;   ORG      0x04                      ; interrupt vector
;   goto     ISR                      ; Interrupt Service Routine (ISR)
;***** PORT DECLARATION *****
;   #define    TXport      PORTA,0x00 ; RS232 output port, could be

```

```

#define      TXtris      TRISA,0x00  ; any active push/pull port
;***** CONSTANT DECLARATION *****
      CONSTANT BASE = 0x20          ; Base address of user file
registers
;***** REGISTER DECLARATION *****
      FLAGreg      equ    BASE+d'2'
      #define      RSflag      FLAGreg,0x00          ; RS232 data reception
flag

      TXD      equ    BASE+d'3'      ; TX-Data register
      RXD      equ    BASE+d'4'      ; RX-Data register

      W_TEMP      equ    BASE+d'5'      ; context register (ISR)
      STATUS_TEMP equ    BASE+d'6'      ; context register (ISR)
      PCLATH_TEMP equ    BASE+d'7'      ; context register (ISR)
      FSR_TEMP equ    BASE+d'8'      ; context register (ISR)

;***** INCLUDE FILES *****
      #include "C:\Jason's Work\PIC Programming\SerialV4\m_bank.asm"
      #include "C:\Jason's Work\PIC Programming\SerialV4\m_wait.asm"
      #include "C:\Jason's Work\PIC Programming\SerialV4\m_rs096.asm"

;***** SUB-ROUTINES *****
RSservice
      movlw 'L'
      subwf RXD,0
      btfsc 03h,2
      goto TurnL ; received command to turn head left
      movlw 'S'
      subwf RXD,0
      btfsc 03h,2
      goto StopMotor ; received command to stop all motors
      movlw 'R'
      subwf RXD,0
      btfsc 03h,2
      goto TurnR ; received command to turn head right
      movlw 'A'
      subwf RXD,0
      btfsc 03h,2
      goto Wave ; received command to wave hand
      goto endServ ; received erroneous command
StopMotor
      bcf PORTB,1
      bcf PORTB,7
      goto endServ
TurnL
      bcf PORTB,5
      bsf PORTB,6
      bsf PORTB,1
      goto endServ
TurnR
      bcf PORTB,6
      bsf PORTB,5
      bsf PORTB,1
      goto endServ
Wave
      bsf PORTB,7

```

```

endServ      bcf    RSflag                ; reset RS232 data reception flag
              bsf    INTCON,INTE ; re-enable RB0/INT interrupt
              RETURN

```

```

;***** INTERRUPT SERVICE ROUTINE *****

```

```

ISR

```

```

;*** ISR CONTEXT SAVE ***

```

```

bcf    INTCON,GIE ; disable all interrupts
btfsc INTCON,GIE ; assure interrupts are disabled
goto   ISR
movwf  W_TEMP      ; context save: W
swapf  STATUS,W    ; context save: STATUS
movwf  STATUS_TEMP ; context save
clrf   STATUS      ; bank 0, regardless of current bank
movfw  PCLATH      ; context save: PCLATH
movwf  PCLATH_TEMP ; context save
clrf   PCLATH      ; page zero, regardless of current page
bcf    STATUS,IRP  ; return to bank 0
movfw  FSR         ; context save: FSR
movwf  FSR_TEMP    ; context save
;*** context save done ***

```

```

;*** ISR MAIN EXECUTION ***

```

```

;*** check origin of interrupt ***

```

```

btfsc INTCON,INTF ; check for RB0/INT interrupt
goto   _ISR_RS232 ; if set, there was a keypad stroke
btfsc INTCON,RBIF ; check for PORTB Change interrupt
goto   _ISR_LIMIT ; if set, there was a limit reached

```

```

; catch-all

```

```

goto   ISRend      ; unexpected IRQ, terminate execution of

```

```

ISR

```

```

;*** RS232 DATA ACQUISITION ***

```

```

_ISR_RS232

```

```

; first, disable interrupt source
bcf    INTCON,INTE ; disable RB0/INT interrupt
; second, acquire RS232 data
RECEIVE ; macro of RS232 software reception
bsf    RSflag      ; enable RS232 data reception flag
goto   _ISR_RS232end1 ; terminate RS232 ISR properly

```

```

;*** LIMIT DATA TRANSMISSION ***

```

```

_ISR_LIMIT

```

```

; first, disable interrupt source
bcf    INTCON,RBIE ; disable RB0/INT interrupt
; second, transmit RS232 data
btfsc  PORTB,4     ; check for left limit
goto   LEFTLIM
btfss  PORTB,5     ; check for right limit
goto   _ISR_RS232end2 ; terminate RS232 ISR properly

```

```

RIGHTLIM

```

```

SEND   'D'

```

```

goto   _ISR_RS232end2 ; terminate RS232 ISR properly

```

```

LEFTLIM

```

```

SEND   'G'

```



```

        goto _ISR_RS232end2    ; terminate RS232 ISR properly

        ;*** CLEARING OF INTERRUPT FLAGS ***
_ISR_RS232error
        bsf    INTCON,INTE ; after error, re-enable IRQ already here
_ISR_RS232end1
        bcf    INTCON,INTF ; clear RB0/INT interrupt flag
        goto   ISRend
_ISR_RS232end2
        bcf    INTCON,RBIF ; clear PORTB change interrupt flag

        ;*** ISR TERMINATION (CONTEXT RESTORE) ***
ISRend    movfw FSR_TEMP    ; context restore
        movwf FSR          ; context restore
        movfw PCLATH_TEMP ; context restore
        movwf PCLATH       ; context restore
        swapf STATUS_TEMP,W ; context restore
        movwf STATUS       ; context restore
        swapf W_TEMP,F     ; context restore
        swapf W_TEMP,W     ; context restore
        RETFIE             ; enable global interrupt (INTCON,GIE)

;***** MAIN *****
MAIN    RS232init          ; RS232 Initialization
        clrf  FLAGreg
LOOP    btfsc RSflag       ; check RS232 data reception flag
        call  RSservice    ; if set, call RS232 routine
        goto  LOOP
        END

```

m_bank.asm

```

;    Standard Macros for PIC 16XXX
;    =====
;
;    written by Peter Luethi, 8.1.1999, Switzerland
;    http://www.electronic-engineering.ch
;    last update: 16.02.2003

#define    M_BANK_ID dummy

BANK0 macro                ; select register bank 0
        bcf    STATUS,RP0
        bcf    STATUS,RP1
    endm

BANK1 macro                ; select register bank 1
        bsf    STATUS,RP0
        bcf    STATUS,RP1
    endm

BANK2 macro                ; select register bank 2
        bcf    STATUS,RP0
        bsf    STATUS,RP1
    endm

```

```

BANK3 macro                ; select register bank 3
    bsf    STATUS,RP0
    bsf    STATUS,RP1
endm

;*** Conditional branching ***
; Macros to simplify 'IF THEN ELSE' queries
; Pre:  valid w
; Post: compare w vs. m_val, branch to m_target or not

;branch on equal w and m_val
BEQ  macro m_val, m_target
    sublw m_val
    bz    m_target    ; zero bit set, branch
endm

;branch on not equal w and m_val
BNEQ macro m_val, m_target
    sublw m_val
    bnz   m_target    ; zero bit not set, branch
endm

;branch on greater w than m_val
BRG  macro m_val, m_target
    sublw m_val    ; result = m_val - w
    bnc   m_target    ; no carry if result negative, branch
endm

;branch on equal or greater w than m_val
BREG macro m_val, m_target
    sublw m_val-0x1    ; result = (m_val-1) - w
    bnc   m_target    ; no carry if result negative, branch
endm

;branch on smaller w than m_val
BRS  macro m_val, m_target
    sublw m_val-0x1    ; result = (m_val-1) - w
    bc    m_target    ; carry if result zero or positive, branch
endm

;branch on equal or smaller w than m_val
BRES macro m_val, m_target
    sublw m_val    ; result = m_val - w
    bc    m_target    ; carry if result zero or positive, branch
endm

```

m_rs096.asm

```

;    Modified Feb. 10, 2004 by Jason Yeung
;    Configured I/O pins to satisfy High School PEBBLES requirements
;    Original header by Peter Luethi follows.

```

```

;*****
;
;    RS232 Software Interface for PIC 16XXX

```

```

; =====
;
; written by Peter Luethi, 31.01.1999, Dietikon, Switzerland
; http://www.electronic-engineering.ch
; last update: 14.05.2004
;
; V1.02:      Changed error handling to dedicated ISR termination
label
;      _ISR_RS232error required at the end of the ISR
;      (11.04.2004)
; V1.01:      Clean-up and improvements (30.12.2000)
; V1.00:      Initial release (31.01.1999)
;
; This code and accompanying files may be distributed freely and
; modified, provided this header with my name and this notice
remain
; intact. Ownership rights remain with me.
; You may not sell this software without my approval.
;
; This software comes with no guarantee or warranty except for my
; good intentions. By using this code you agree to indemnify me
from
; any liability that might arise from its use.
;
;
; SPECIFICATIONS:
; =====
; Processor:      Microchip PIC 16F84
; Clock:          4.00 MHz XT
; Throughput:     1 MIPS
; Serial Rate:    9600 baud, 8 bit, no parity, 1 stopbit
; Required Hardware: RS232 level shifter (MAX232)
;
;
; DESCRIPTION:
; =====
; Developed and tested on PIC 16F84, executeable on all interrupt
; featured PICs.
; Program handles all aspects of
;      Transmission (Register TXD) and
;      Reception (Register RXD) through interrupt.
;
; Waitcycle for 9600 baud ==> 104 us each bit
;
; Call of implemented procedures with:
;      "RS232init" Initialization
;      "SEND 'c'"  sends character 'c'
;      "SENDw"     sends content of working register
;      "RECEIVE"   macro in ISR: receive from RS232, store in RXD
;
;
; DECLARATIONS needed in MAIN PROGRAM:
; =====
; ORG      0x00                      ; processor reset vector
; goto     MAIN                      ; main program
;
; ORG      0x04                      ; interrupt vector

```

```

;      goto   ISR                      ; Interrupt Service Routine (ISR)
;
;      CONSTANT BASE = 0x0C           ; base address of user file
registers
;      TXD    equ    BASE+?           ; TX-Data register
;      RXD    equ    BASE+?           ; RX-Data register
;
;      #define TXport      PORTA,0x00 ; RS232 output port, could be
;      #define TXtris      TRISA,0x00 ; any active push/pull port
;      ; RS232 input port is RB0, because of its own interrupt flag
;
;      Example code snippet of main program:
;      -----
;      FLAGreg    equ    BASE+d'7'
;      #define    RSflag      FLAGreg,0x00      ; RS232 data reception
flag
;
;      RSservice          ; RS232 service sub-routine
;      movfw RXD          ; get received RS232 data
;      <do whatever you want...>
;      bcf    RSflag      ; reset RS232 data reception flag
;      bsf    INTCON,INTE ; re-enable RB0/INT interrupt
;      RETURN
;
;      MAIN  RS232init      ; RS232 Initialization
;      clrfs FLAGreg        ; initialize all flags
;
;      LOOP  btfsc RSflag    ; check RS232 data reception flag
;      call  RSservice      ; if set, call RS232 echo & LCD display
routine
;      goto  LOOP
;
;      END
;
;      Example code snippet of ISR (to be implemented in main program):
;      -----
;      ;***** INTERRUPT SERVICE ROUTINE *****
;      ISR    <... context save ...>
;
;      ;*** determine origin of interrupt ***
;      btfsc INTCON,INTF ; check for RB0/INT interrupt
;      goto  _ISR_RS232  ; if set, there was a keypad stroke
;
;      <... check other sources, if any ...>
;
;      ; catch-all
;      goto  ISREnd      ; unexpected IRQ, terminate
execution of ISR
;
;      ;*** RS232 DATA ACQUISITION ***
;      _ISR_RS232
;      ; first, disable interrupt source
;      bcf    INTCON,INTE ; disable RB0/INT interrupt
;      ; second, acquire RS232 data
;      RECEIVE          ; macro of RS232 software reception
;      bsf    RSflag      ; enable RS232 data reception flag
;      goto  _ISR_RS232end ; terminate RS232 ISR properly

```

```

;
;      <... other ISR sources' handling section ...>
;
;      ;*** ISR Termination ***
;      ; NOTE: Below, I only clear the interrupt flags! This does
not      ; necessarily mean, that the interrupts are already re-
enabled. ; Basically, interrupt re-enabling is carried out at the
end of   ; the corresponding service routine in normal operation
;        ; mode.
;        ; The flag responsible for the current ISR call has to be
cleared  ;
;        ; to prevent recursive ISR calls. Other interrupt flags,
activated ;
;        ; during execution of this ISR, will immediately be served
upon     ;
;        ; termination of the current ISR run.
;      _ISR_RS232error
;      bsf    INTCON,INTE ; after error, re-enable IRQ already here
;      _ISR_RS232end
;      bcf    INTCON,INTF ; clear RB0/INT interrupt flag
;      goto   ISREnd      ; terminate execution of ISR
;
;      <... other ISR sources' termination ...>
;
;      ISREnd      <... context restore ...> ; general ISR context
restore
;      RETFIE      ; enable INTCON,GIE
;
;
;      REQUIRED MEMORY:
;      =====
;      2 registers: @ BASE+0 - BASE+1
;
;*****
;***** INCLUDE FILES *****
;      IFNDEF      M_BANK_ID
;          ERROR "Missing include file: m_bank.asm"
;      ENDIF
;
;***** HARDWARE DECLARATION *****
;      IFNDEF      TXport
;          ERROR "Define TXport in MAIN PROGRAM."
;      ENDIF
;      IFNDEF      TXtris
;          ERROR "Define TXtris in MAIN PROGRAM."
;      ENDIF
;      MESSG "Default RS232 RXport is PORTB,0x00."
;      #define      RXport      PORTB,0x00 ; Needs to be an interrupt
supervised
;      #define      RXtris      TRISB,0x00 ; port! When modify, set
adequate
;
;      ; flags in INTCON register.

```

```

;***** CONSTANT DECLARATION *****
    CONSTANT LF =      d'10' ; Line Feed
    CONSTANT CR =      d'13' ; Carriage Return
    CONSTANT TAB =      d'9'  ; Tabulator
    CONSTANT BS =      d'8'  ; Backspace

;***** REGISTER DECLARATION *****
    IFNDEF      BASE
        ERROR "Declare BASE (Base address of user file registers) in
MAIN PROGRAM"
    ENDIF

    TEMP1 set     BASE+d'0'    ; universal temporary register
    TEMP2 set     BASE+d'1'

    IFNDEF      TXD
        ERROR "Declare TXD register in MAIN PROGRAM"
    ENDIF
    IFNDEF      RXD
        ERROR "Declare RXD register in MAIN PROGRAM"
    ENDIF

;***** MACROS *****
RS232init macro
    BANK1
    bcf    TXtris           ; set output
    bsf    TRISA,1          ; set L_LIM input
    bsf    TRISA,2          ; set R_LIM input
    clrf   TRISB ; set output
    bsf    RXtris           ; set RS232 input with weak pull-up
    bcf    OPTION_REG,INTEDG ; RS232 interrupt on falling edge
    BANK0
    clrf   PORTB
    bsf    TXport           ; set default state: logical 1
    bcf    INTCON,INTF ; ensure interrupt flags are cleared
    bcf    INTCON,RBIF
    bsf    INTCON,INTE ; enable RB0/INT interrupt
    bsf    INTCON,RBIE ; enable PORTB change interrupt
    bsf    INTCON,GIE ; enable global interrupt
endm

SEND macro S_string      ; "SEND 'X'" sends character to RS232
    movlw S_string
    call SENDsub
endm

SENDw macro
    call SENDsub
endm

RECEIVE macro
    call SB_Wait          ; first wait sub-routine
    btfsc RXport
    goto _RSError        ; no valid start bit
    movlw 0x08
    movwf TEMP1          ; number of bits to receive, 9600-8-N-1

```

```

_RECa call  T_Wait                ; inter-baud wait sub-routine
      btfsc RXport
      bsf   RXD,0x07
      btfss RXport
      bcf   RXD,0x07
      decfsz TEMP1,w              ; skip if TEMP1 == 1
      rrf   RXD,f                ; do this only 7 times
      decfsz TEMP1,f
      goto  _RECa
      call  T_Wait                ; inter-baud wait sub-routine
      btfss RXport              ; check if stop bit is valid
      goto  _RSError            ; no valid stop bit
      endm

;***** SUBROUTINES *****
SENDsub  movwf TXD                ; store in data register
        bcf   TXport            ; start bit
        movlw 0x08
        movwf TEMP1            ; number of bits to send, 9600-8-N-1
        call  T_Wait
_SENDa   btfsc TXD,0x00          ; send LSB first !
        bsf   TXport
        btfss TXD,0x00
        bcf   TXport
        rrf   TXD,f
        call  T_Wait
        decfsz TEMP1,f
        goto  _SENDa
        bsf   TXport            ; stop bit
        call  T_Wait
        call  T_Wait            ; due to re-synchronization
        RETURN

T_Wait   movlw 0x1D              ; FOR TRANSMISSION & RECEPTION
        movwf TEMP2            ; total wait cycle until next
        goto  X_Wait            ; bit: 9600 baud ==> 104 us

;*** When entering this subroutine, ISR context restore has already
consumed some cycles ***
SB_Wait  movlw 0x08              ; FOR RECEPTION of start bit
        movwf TEMP2            ; total wait cycle: 52 us
        goto  X_Wait            ; (=> sampling in the center of each bit)

X_Wait   decfsz TEMP2,f          ; WAIT LOOP
        goto  X_Wait
        RETURN

_RSError clrf   RXD              ; invalid data
        goto  _ISR_RS232error    ; goto RS232 error handling in ISR

```

m_wait.asm

```

;*****
;
; Wait cycle Routine for PIC 16XXX V1.01

```

```

; =====
;
; written by Peter Luethi, 18.01.1999, Dietikon, Switzerland
; http://www.electronic-engineering.ch
; last update: 16.02.2003
;
; V1.01:      Correction of a severe mistake: Programming of the
prescaler
;            affected the entire OPTION_reg including PORTB pullups and
;            INTEDGE configuration. Now only the least significant 6
bits
;            of OPTION_reg are configured, the upper 2 bits are
preserved.
; V1.00:      Initial release (18.01.1999)
;
; This code and accompanying files may be distributed freely and
; modified, provided this header with my name and this notice
remain
; intact. Ownership rights remain with me.
; You may not sell this software without my approval.
;
; This software comes with no guarantee or warranty except for my
; good intentions. By using this code you agree to indemnify me
from
; any liability that might arise from its use.
;
;
; SPECIFICATIONS:
; =====
; Processor:      Microchip PIC 16XXX
; Clock:          4.00 MHz XT
; Throughput:     1 MIPS
;
;
; DESCRIPTION:
; =====
; Developed on PIC 16C84, but executeable on all PIC 16X84, 16C7X,
etc.
;
; Routine performs a "busy" wait.
; Implemented standard delay (@ 4 MHz):
; "WAIT 0x01" is equal to 1 Unit == 1.02 ms
; The assigned standard prescaler for TMR0 is "PRESCstd =
b'00000001'"
; The prescaler is activated by clearing bit 3 of the OPTION
register
;
; Prescalers:
;      b'00000000' == 1:2      ==> 0.512 ms
;      b'00000001' == 1:4      ==> 1.02 ms      (standard)
;      b'00000111' == 1:256    ==> 65.3 ms
;      Waittime = WCYCLE (= timeconst) * prescaler
;
; Call of implemented procedures with:
;      "WAIT xxx"      ; standard
;      "WAITX xxx, yyy" ; extended with specific prescaler
;                      ; WAITX      d'16',d'7' = 1.045 s @ 4 MHz

```



```

;
;
;   DECLARATIONS needed in MAIN PROGRAM:
;   =====
;   "CONSTANT BASE = 0x0C"           Base address of user file registers
;
;
;   REQUIRED MEMORY:
;   =====
;   1 register: @ BASE+0
;
;*****
*****
#define      M_WAIT_ID dummy

;***** INCLUDE FILES *****
    ifndef      M_BANK_ID
        error "Missing include file: m_bank.asm"
    endif

;***** CONSTANT DECLARATION *****
    constant PRESCstd = b'00000001'      ; standard prescaler for TMR0

;***** REGISTER DECLARATION *****
    wcycle      set BASE

;***** MACROS *****
WAIT macro timeconst_1
    movlw timeconst_1
    call WAITstd
endm

WAITX macro timeconst_2, prescaler
    movlw timeconst_2
    call _Xsetup
    movlw prescaler      ; assign prescaler for TMR0
    call _Xwait
endm

;***** SUBROUTINES *****
_Xsetup      movwf WCYCLE          ; assign wait cycle duration
             clrf TMR0
             bank1
             movlw b'11000000' ; set up mask
             andwf OPTION_REG,f    ; clear corresponding bits
             return

WAITstd      movwf WCYCLE          ; assign wait cycle duration
             clrf TMR0
             bank1
             movlw b'11000000' ; set up mask
             andwf OPTION_REG,f    ; clear corresponding bits
             movlw PRESCstd        ; load standard prescaler
_Xwait       iorwf OPTION_REG,f    ; assign prescaler to TMR0
             bank0

_WAITa       bcf   INTCON,2      ; clears TMR0 overflow flag

```

```

_WAITb      btfss INTCON,2      ; checks TMR0 overflow flag, skip if set
            goto _WAITb        ; this is the wait-loop
            decfsz WCYCLE,f      ; repeats the loop according to the
            goto _WAITa        ; assigned wait cycles
            RETURN

```

APPENDIX C: INFORMATION AND CONSENT FORMS

Project Title: Evaluating the Effectiveness of High School P.E.B.B.L.E.S.

Principal

Investigators: Deborah Fels, P.Eng., Ph.D., Ryerson University
Bertha Konstantinidis, B.Sc., Ryerson University
Jason Yeung, B.A.Sc. (supervised by D. Fels), Ryerson University

Consent Form to Participate in Study

Child's Name (if under the age of 18): _____

- ☐ I give permission for my child to participate in the Ryerson University study conducted by the principal investigators mentioned above.
- ☐ I do NOT give permission for my child to participate in the Ryerson University study conducted by the principal investigators mentioned above.

Consent to be Videotaped/Photographed

One (1), one-hour videotape will be taken during this study. The camera for videotaping has a very narrow field of view but we intend to capture all of the participants in the study on videotape. Photographs may also be taken during the sessions and may be included on the PEBBLES web site, www.pebbles.ryerson.ca. Photographs may also be used in information brochures about PEBBLES. The findings will be used for publication and instructional purposes.

I give permission to (check off boxes as appropriate; you may choose to not check off any of these boxes):

- ☐ Allow my child be videotaped during the session.
- ☐ Allow my child be photographed during the session.

In addition, I give permission for the videotapes/photographs to be used for (check off boxes as appropriate; you may choose to not check off any of these additional boxes):

- ☐ Other research projects.
- ☐ Teaching and demonstration in hospitals and schools.
- ☐ Teaching and demonstration at professional meetings outside hospitals & schools.
- ☐ Use on PEBBLES Web Site.
- ☐ Use in brochures about PEBBLES.

Signature of Parent or Legal Guardian: _____

Project Title: Evaluating the Effectiveness of High School P.E.B.B.L.E.S.

Principal
Investigators: Deborah Fels, P.Eng., Ph.D., Ryerson University
Bertha Konstantinidis, B.Sc., Ryerson University
Jason Yeung, B.A.Sc. (supervised by D. Fels), Ryerson University

Consent Form to Participate in Study

Participant's Name (if over 18): _____

- ☐ I agree to participate in the Ryerson University study conducted by the principal investigators mentioned above.
- ☐ I do NOT agree to participate in the Ryerson University study conducted by the principal investigators mentioned above.

Consent to be Videotaped/Photographed

One (1), one-hour videotape will be taken during this study. The camera for videotaping has a very narrow field of view but we intend to capture all of the participants in the study on videotape. Photographs may also be taken during the sessions and may be included on the PEBBLES web site, www.pebbles.ryerson.ca. Photographs may also be used in information brochures about PEBBLES. The findings will be used for publication and instructional purposes.

I give permission to (check off boxes as appropriate; you may choose to not check off any of these boxes):

- ☐ Be videotaped during the session.
- ☐ Be photographed during the session.

In addition, I give permission for the videotapes/photographs to be used for (check off boxes as appropriate; you may choose to not check off any of these additional boxes):

- ☐ Other research projects.
- ☐ Teaching and demonstration in hospitals and schools.
- ☐ Teaching and demonstration at professional meetings outside hospitals and schools.
- ☐ Use on PEBBLES Web Site.
- ☐ Use in brochures about PEBBLES.

Signature of Participant: _____

Project Title: Evaluating the Effectiveness of High School P.E.B.B.L.E.S.

Principal
Investigators: Deborah Fels, P.Eng., Ph.D., Ryerson University
Bertha Konstantinidis, B.Sc., Ryerson University
Jason Yeung, B.A.Sc. (supervised by D. Fels), Ryerson University

Information Form – Participants (under the age of 18)

The purpose of this study is to evaluate a device created to allow a student who is in hospital or at home for an extended period of time to attend school from the hospital or home. This device consists of two computer systems connected together using video-conferencing technology. We will be simulating this situation at Ryerson where one student will be in a separate computer room from the rest of their group in a meeting room. The students in the group will see and interact with the student in the separate room. The student in the separate room will see and interact with students in the meeting room. Students will be asked to work together on a short project involving the storyboarding of a music video.

The system will be controlled by the student in a separate computer room, and supported by the investigators. An investigator will be present at all times when the system is being used.

If agreed to, the participant will be involved for a total time of one hour. The study will take place at Ryerson University. An introduction and training session will be provided to the participants in the form of an in-class discussion and hands-on exercise. The participant will also be asked to complete a short questionnaire before and after the study to give their impressions and opinions on how the system worked for them.

During this study, one part of PEBBLES will be in the computer lab KHW375 with the remote student. The other part of PEBBLES and the group of students will be in KHS363B. One one-hour videotape will be taken during the session. Videotaping will be done to gather data on the interactions between the remote student and the classroom (KHS363B).

Confidentiality

All data will be confidential and will not be published except as summary data. Student names will not be used at any time. All data and videotapes will be used exclusively for research and educational purposes. Parts of the videotapes that show the system in use may be used for teaching purposes or presentations. Videotapes and other data will be kept in a locked location for five years and then destroyed. Photographs may be used on the PEBBLES web site (www.pebbles.ryerson.ca). The findings will be used for publication and instructional purposes.

Project Title: Evaluating the Effectiveness of High School P.E.B.B.L.E.S.

Principal
Investigators: Deborah Fels, P.Eng., Ph.D., Ryerson University
Bertha Konstantinidis, B.Sc., Ryerson University
Jason Yeung, B.A.Sc. (supervised by D. Fels), Ryerson University

Information Form (cont.) – Participants (under the age of 18)

Risks and Discomforts

There are only minimal risks associated with participation in this study involved in the potential discomfort with the amount of effort required to carry out the study tasks of preparing a storyboard for a music video, and with completing the questionnaires associated with the study. These data will only be used to analyze the usability of PEBBLES and inform future versions of it. Only members of the project team will have access to all the data, which will be stored in the project office in a locked filing cabinet.

Expected Benefits

The participant is not expected to benefit personally from participating in this study. However, the results from this research will contribute to the development of a system that will allow a student to attend their classroom while in hospital or at home. The long-term benefits of such a system may be a more consistent and satisfying education for a child who must have a long stay in hospital or at home.

Opportunities for Feedback

Copies of any conference proceedings or publications arising from this research will be available in the school library. We sincerely appreciate your co-operation. If you have any questions or concerns, please do not hesitate to call Deborah Fels at 416-979-5000 ext. 7619 or Jason Yeung at _____ The Ryerson Research Ethics Board may also be reached at 416-979-5042.

Voluntary Participation

I understand that participation is voluntary and that I have the right to withdraw from this project, or from parts of it, at any time by contacting Deborah Fels.

Assent

I was present when _____ read this form and gave his/her verbal assent.

Name of person who obtained assent

Signature

Date

Project Title: Evaluating the Effectiveness of High School P.E.B.B.L.E.S

Principal
Investigators: Deborah Fels, P.Eng., Ph.D., Ryerson University
Bertha Konstantinidis, B.Sc., Ryerson University
Jason Yeung, B.A.Sc. (supervised by D. Fels), Ryerson University

Information Form – Participants (over 18 years of age)

The purpose of this study is to evaluate a device created to allow a student who is in hospital or at home for an extended period of time to attend school from the hospital or home. This device consists of two computer systems connected together using video-conferencing technology. We will be simulating this situation at Ryerson where one student will be in a separate computer room from the rest of their group in a meeting room. The students in the group will see and interact with the student in the separate room. The student in the separate room will see and interact with students in the meeting room. Students will be asked to work together on a short project involving the storyboarding of a music video.

The system will be controlled by the student in a separate computer room, and supported by the investigators. An investigator will be present at all times when the system is being used.

If agreed to, you will be involved for a total time of one hour. The study will take place at Ryerson University. An introduction and training session will be provided to the participants in the form of an in-class discussion and hands-on exercise. The participant will also be asked to complete a short questionnaire before and after the study to give their impressions and opinions on how the system worked for them.

During this study, one part of PEBBLES will be in the computer lab KHW375 with the remote student. The other part of PEBBLES and the group of students will be in KHS363B. One one-hour videotape will be taken during the session. Videotaping will be done to gather data on the interactions between the remote student and the classroom (KHS363B).

Confidentiality

All data will be confidential and will not be published except as summary data. Student names will not be used at any time. All data and videotapes will be used exclusively for research and educational purposes. Parts of the videotapes that show the system in use may be used for teaching purposes or presentations. Videotapes and other data will be kept in a locked location for five years and then destroyed. Photographs may be used on the PEBBLES web site (www.pebbles.ryerson.ca). The findings will be used for publication and instructional purposes.

Project Title: Evaluating the Effectiveness of High School P.E.B.B.L.E.S.

Principal
Investigators: Deborah Fels, P.Eng., Ph.D., Ryerson University
Bertha Konstantinidis, B.Sc., Ryerson University
Jason Yeung, B.A.Sc. (supervised by D. Fels), Ryerson University

Information Form (cont.) – Participants (over 18 years of age)

Risks and Discomforts

There are only minimal risks associated with participation in this study involved in the potential discomfort with the amount of effort required to carry out the study tasks of preparing a storyboard for a music video, and with completing the questionnaires associated with the study. These data will only be used to analyze the usability of PEBBLES and inform future versions of it. Only members of the project team will have access to all the data, which will be stored in the project office in a locked filing cabinet.

Expected Benefits

You are not expected to benefit personally from participating in this study. However, the results from this research will contribute to the development of a system that will allow a student to attend their classroom while in hospital or at home. The long-term benefits of such a system may be a more consistent and satisfying education for a child who must have a long stay in hospital or at home.

Opportunities for Feedback

Copies of any conference proceedings or publications arising from this research will be available in the school library. We sincerely appreciate your co-operation. If you have any questions or concerns, please do not hesitate to call Deborah Fels at 416-979-5000 ext. 7619 or Jason Yeung at 416-979-5000 ext. 7620. The Ryerson Research Ethics Board may also be reached at 416-979-5042.

Voluntary Participation

I understand that my participation is voluntary and that I have the right to withdraw from this project, or from parts of it, at any time by contacting Deborah Fels.

APPENDIX D: PRE-STUDY QUESTIONNAIRE

High School PEBBLES Pre-Study Questionnaire

*The purpose of this questionnaire is to gather information on high school students.
Thank you in advance for taking part in this study. All data will remain confidential.*

1. Personal Code: _____
2. Sex (circle one): **Male** **Female**
3. What grade will you be entering in September 2005? (circle one)
9 **10** **11** **12** **University/College**
4. How often do you use a computer? (circle one)
Less than once/week **1-3 times each week** **4-6 times each week** **Daily**
5. How long have you been using computers? (circle one)
Less than 1 year **1-3 years** **More than 3 years**
6. How long does it usually take you to learn a new computer program? (circle one)
Less than 15 minutes **15 minutes to 1 hour** **More than 1 hour**
7. Please indicate your level of agreement with the following statements:

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
a. You feel comfortable in large groups					
b. You are more of a listener than a speaker					
c. You have no problem talking with strangers					
d. You find it difficult to speak loudly					

8. Have you ever been to a hospital for treatment? (circle one)

Yes

No

If you answered "No" to question 8, skip questions 9 and 10

9. When was the last time you visited a hospital? (circle one)

**Less than 1
week ago**

**Less than 1
month ago**

**Less than 6
months ago**

**Less than 1
year ago**

**More than 1
year ago**

10. How often do you visit a hospital for treatment? (circle one)

Daily

Weekly

Monthly

Yearly

Only one time

APPENDIX E: POST-STUDY QUESTIONNAIRE

High School PEBBLES Post-Study Questionnaire

The purpose of this questionnaire is to gather information on your experience with high school PEBBLES. Thank you for taking part in this study. All data will remain confidential.

1. Personal Code: _____
2. Sex (circle one): **Male** **Female**
3. What grade will you be entering in September 2005? (circle one)
9 **10** **11** **12** **University/College**
4. Please give your ratings for the following features of PEBBLES:

	Very displeased	Displeased	Neutral	Pleased	Very pleased
a. Size & Shape					
b. Colour					
c. Video Quality					
d. Sound Quality					
e. Overall Impression					

5. Please indicate your level of agreement with the following statements
(HOSPITAL STUDENTS ONLY):

	Very displeased	Displeased	Neutral	Pleased	Very pleased
a. Easy to Use					
b. Controls					
c. Camera Range					

6. Please indicate your level of agreement with the following statements:

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
a. The group finished the task successfully					
b. PEBBLES was distracting to the group					
c. Everyone was equally involved in the task					
d. Having PEBBLES in the room was the same as having the person in the room					
e. The group got used to having PEBBLES around					

7. Please indicate your level of agreement with the following statements
(HOSPITAL STUDENTS ONLY):

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
a. Using the controls made it difficult to concentrate					
b. I could see everybody with the camera					
c. I missed being with the rest of the group					
d. I was a part of all the group's decisions					
e. The hand was useful for getting attention					

8. What did you like most about the system?

9. What did you dislike most about the system?

10. Give us any other additional comments:

REFERENCES

- [1] J. P. Molnar. "Picturephone Service - A New Way of Communicating." *Bell Laboratories: Record*, vol. 47, no. 5, pp. 134-135, 1969.
- [2] I. Dorros. "Picturephone." *Bell Laboratories: Record*, vol. 47, no. 5, pp. 136-141, 1969.
- [3] C. Egido, "Video Conferencing as a Technology to Support Group Work: A Review of its Failures," in *Proc. 1988 ACM Conference on Computer-Supported Cooperative Work*, Portland, USA, 1988, pp. 13-24.
- [4] S. Hirsh, A. Sellen, and N. Brokopp. "Why HP People Do and Don't Use Videoconferencing Systems." [Online document], Feb 14, 2005, [cited May 17, 2005], Available: www.hpl.hp.com/techreports/2004/HPL-2004-140R1.pdf
- [5] A. Girgensohn, J. Boreczky, P. Chiu, J. Foote, L. Wilcox, and S. Smoliar, "Supporting Group-to-Group Collaboration in Videoconferences," in *Proc. 35th Annual Hawaii International Conference on System Sciences*, Waikoloa, USA, 2002, pp. 9.
- [6] D. Zotkin, R. Duraiswami, V. Philomin, and L. S. Davis, "Smart Videoconferencing," in *Proc. Multimedia and Expo, 2000. ICME 2000. 2000 IEEE International Conference on*, New York, USA, 2000, pp. 1597-1600.
- [7] Polycom. [Online document], [cited July 28, 2005], Available: <http://www.polycom.com>
- [8] Tandberg. [Online document], [cited July 28, 2005], Available: <http://www.tandberg.net>
- [9] WebEx. [Online document], [cited July 28, 2005], Available: <http://www.webex.com>
- [10] W. A. S. Buxton, "Telepresence: Integrating Shared Task and Person Spaces," in *Proc. Graphics Interface '92*, Vancouver, Canada, 1992, pp. 123-129.
- [11] RACOL. "RACOL: Rural Advanced Community of Learners." [Online document], June 10, 2004, [cited Jan 4, 2005], Available: <http://www.racol.ualberta.ca/>
- [12] Government of Alberta. "Alberta SuperNet." [Online document], 2002, [cited July 5, 2005], Available: <http://www.albertasupernet.ca>

- [13] "RACOL Project Delivers Distance Education to Rural Alberta Schools Through Videoconferencing." [Online document], May 2005, [cited July 25, 2005], Available: <http://www.thejournal.com/magazine/vault/A5318B.cfm>
- [14] T. Sheridan. "Musings on Telepresence and Virtual Presence." *Presence: Teleoperators and Virtual Environments*, vol. 1, no. 1, pp. 120-125, 1992.
- [15] D. I. Fels, L. A. Williams, G. Smith, J. Treviranus, and R. Eagleson. "Developing a Video-Mediated Communication System for Hospitalized Children." *Telemedicine Journal*, vol. 5, no. 2, pp. 193-207, 1999.
- [16] D. I. Fels, L. A. Williams, G. Smith, J. Treviranus, and R. Eagleson, "Creating an Interactive Supply Student," in *Proc. Symposium on Industrial Engineering and Management*, Toronto, Canada, 1998, pp. 86-90.
- [17] People for Education. "2005 Secondary School Tracking Report." [Online document], Mar 30, 2005, [cited Jul 5, 2005], Available: <http://www.peopleforeducation.com/tracking/summrpts/second/05/mar30.pdf>
- [18] C. Heeter. "Being There: The Subjective Experience of Presence." *Presence: Teleoperators and Virtual Environments*, vol. 1, no. 2, pp. 262 - 271, 1992.
- [19] M. Slater. "Measuring Presence: A Response to the Witmer and Singer Presence Questionnaire." *Presence: Teleoperators and Virtual Environments*, vol. 8, no. 5, pp. 560-565, 1999.
- [20] M. Lombard and T. Ditton. "At the Heart of It All: The Concept of Presence." [Online document], Sept 1997, [cited Sept 9, 2004], Available: <http://www.ascusc.org/jcmc/vol3/issue2/lombard.html>
- [21] J. van Baren and W. IJsselsteijn. "Measuring Presence: A Guide to Current Measurement Approaches." [Online document], Mar 23, 2004, [cited Sept 29, 2004], Available: <http://www.presence-research.org/omnipres/D5.pdf>
- [22] M. Lombard, T. B. Ditton, D. Crane, B. Davis, G. Gil-Egui, K. Horvath, and J. Rossman, "Measuring Presence: A Literature-Based Approach to the Development of a Standardized Paper-and-Pencil Instrument." Presented at *Third International Workshop on Presence*, Delft, The Netherlands, 2000.
- [23] T. Sheridan. *Humans and Automation: System Design and Research Issues*. Santa Monica: John Wiley & Sons, Inc., 2002.
- [24] W. Barfield, D. Zeltzer, T. Sheridan, and M. Slater. "Presence and Performance Within Virtual Environments," in *Virtual Environments and Advanced Interface Design*. W. Barfield and I. T. A. Furness, Eds. New York: Oxford Press, 1995, pp. 473-513.

- [25] NASA. "Mars Exploration Rover Mission: Home." [Online document], Jan. 26, 2005, [cited Jan. 26, 2005], Available: <http://marsrovers.jpl.nasa.gov/home/index.html>
- [26] J. Zheng, N. Bos, G. M. Olson, and J. S. Olson, "Trust Without Touch: Jump-start Trust with Social Chat," in *Proc. CHI 2001*, Seattle, USA, 2001, pp. 293-294.
- [27] A. Motluk. "Do games prime brain for violence?" *New Scientist*, vol. 186, no. 2505, pp. 10, 2005.
- [28] "The Honda Humanoid Robots." [Online document], [cited Sept. 1, 2004], Available: <http://www.honda-robots.com/english/html/asimo/frameset2.html>
- [29] "Sony Global - AIBO Global Link." [Online document], [cited Sept. 1, 2004], Available: <http://www.sony.net/Products/aibo/>
- [30] "Sony Global - QRIO." [Online document], [cited Apr. 5, 2005], Available: <http://www.sony.net/SonyInfo/QRIO/>
- [31] C. Breazeal. "Kismet." [Online document], [cited April 5, 2005], Available: <http://www.ai.mit.edu/projects/humanoid-robotics-group/kismet/kismet.html>
- [32] "Repilee R1." [Online document], [cited July 28, 2005], Available: http://ed-02.ams.eng.osaka-u.ac.jp/lab/development/Humanoid/ReplieeR1/ReplieeR1_eng.htm
- [33] Ernest Orlando Lawrence Berkeley National Laboratory. "Berkeley Lab's RAGE Telepresence Robot Captures R&D100 Award." [Online document], July 2, 2002, [cited June 22, 2004], Available: <http://www.lbl.gov/CS/Archive/headlines070202.html>
- [34] L. A. Williams, D. I. Fels, G. Smith, J. Treviranus, and R. Eagleson, "Using PEBBLES to Facilitate Remote Communication and Learning," in *Proc. 41st Meetings on Human Factors and Ergonomics*, 1997, pp. 320-324.
- [35] Novint Technologies. "Haptic (touch enabled) telerobotic control of robots." [Online document], [cited Jan. 26, 2005], Available: <http://www.novint.com/Telerobotics.htm>
- [36] NOVA. "Mini-Andros." [Online document], Nov. 2000, [cited Jan. 26, 2005], Available: <http://www.pbs.org/wgbh/nova/robots/hazard/meetandros.html>
- [37] P. Hoversten. "Robot to map in Chernobyl plant." [Online document], Apr. 23, 1998, [cited Jan. 26, 2005], Available: http://grok.ecn.uiowa.edu/PR/chernobyl/4_23_98USAtoday.html

- [38] A. Agah and K. Tanie. "Multimedia Human-Computer Interaction for Presence and Exploration in a Telemuseum." *Presence: Teleoperators and Virtual Environments*, vol. 8, no. 1, pp. 104-111, 1999.
- [39] J. Casper and R. R. Murphy. "Human-robot Interactions During the Robot-assisted Urban Search and Rescue Response at the World Trade Center." *IEEE Transactions on Systems, Man and Cybernetics - Part B*, vol. 33, no. 3, pp. 367-385, 2003.
- [40] S. Basu. "Futuristic Robot." [Online document], Sept 6, 2000, [cited July 18, 2005], Available:
<http://www.edgereview.com/ataglance.cfm?category=edge&ID=78>
- [41] "Mobile Robot Knowledge Base - iRobot CoWorker." [Online document], [cited Apr. 4, 2004], Available:
<http://robot.spawar.navy.mil/home.asp?item=details&order=&sort=&page=1&cat=plat&sub=UGV&id=52>
- [42] S. Docimo, R. Moore, and L. Kavoussi. "Telerobotic Surgery is Clinical Reality: Current Experience with Telementoring in Adults and Children." *Presence: Teleoperators and Virtual Environments*, vol. 6, no. 2, pp. 173-178, 1997.
- [43] Imperial College. "Medical Robots Start Work at London Hospital." [Online document], May 18, 2005, [cited May 18, 2005], Available:
<http://www1.imperial.ac.uk/medicine/news/p51805.html>
- [44] Associated Press. "U.S. and France Join Forces to Fight Terror." [Online document], Sept. 30, 2004, [cited Jan. 26, 2005], Available:
http://kutv.com/topstories/topstories_story_274203102.html
- [45] J. Blanchette. "Questions in the Online Learning Environment." [Online document], [cited June 17, 2004], Available:
<http://cade.athabascau.ca/vol16.2/blanchette.html>
- [46] Associated Press. "Video Phones: Why is No One Calling?" [Online document], Sept 5, 2000, [cited Sept 1, 2004], Available:
<http://archives.cnn.com/2000/TECH/computing/09/05/picture.phones.ap/>
- [47] Telepresence Systems Inc. "Telepresence: Advancing The Future." [Online document], [cited Sept 1, 2004], Available:
http://www.telepres.com/tsi_advance.shtml
- [48] G. M. Olson and J. S. Olson. "Distance Matters." *Human-Computer Interaction*, vol. 15, no. 1, pp. 139-178, 2000.

- [49] C. Heeter, J. Gregg, J. Climo, F. Biocca, and D. Dekker. "Telewindows: Case Studies in Asymmetrical Social Presence," in *Being There: Concepts, Effects and Measurement of User Presence in Synthetic Environments*. G. Riva, F. Davide, and W. A. IJsselsteijn, Eds. Amsterdam, The Netherlands: Ios Press, 2003, pp. 279-293.
- [50] C. S. Cavanaugh. "The Effectiveness of Interactive Distance Education Technologies in K-12 Learning: A Meta-Analysis." *International Journal of Educational Telecommunications*, vol. 7, no. 1, pp. 73-88, 2001.
- [51] D. Litke. "Virtual Schooling At The Middle Grades: A Case Study." [Online document], [cited June 17, 2004], Available: <http://cade.athabasca.ca/vol13.2/litke.html>
- [52] Transport Canada Training Directorate. "Videoconferencing Technology As A Medium for Distance Learning," Oct. 1993.
- [53] S. R. Aragon. "Creating Social Presence in Online Environments." *New Directions for Adult and Continuing Education*, no. 100, pp. 57-68, 2003.
- [54] T. Sheridan. *Telerobotics, Automation, and Human Supervisory Control*. Massachusetts: The MIT Press, 1992.
- [55] S. A. Bly, S. R. Harrison, and S. Irwin. "Media Spaces: Bringing People Together in a Video, Audio, and Computing Environment." *Communications of the ACM*, vol. 36, no. 1, pp. 27-47, 1993.
- [56] C. S. Steffey. "The Effects of Visual and Verbal Cues in Multimedia Instruction". Doctor of Philosophy in Teaching and Learning dissertation, Virginia Polytechnic Institute and State University, USA, 2001.
- [57] J. J. Baldis. "Effects of Spatial Audio on Communication During Desktop Conferencing". Master of Science in Engineering thesis, University of Washington, USA, 1998.
- [58] F. C. Stromsland. "Perceptions of 4th and 6th Grade Students, Regarding Their Academic Abilities and Achievement, as Related to Participation in Distance Learning Using Interactive Television". Doctor of Education, Seton Hall University, USA, 1999.
- [59] E. Bradner and G. Mark, "Social Presence with Video and Application Sharing," in *Proc. 2001 International ACM SIGGROUP Conference on Supporting Group Work*, Boulder, USA, 2001, pp. 154-161.
- [60] A. Sacau, L. M. B. Gouveia, N. M. Ribeiro, F. R. Gouveia, and F. Biocca, "Presence in Computer-Mediated Environments: A Short Review of the Main

Concepts, Theories, and Trends." Presented at *IADIS International Conference e-Society 2003*, Lisbon, Portugal, 2003.

- [61] M. Slater and A. Steed. "A Virtual Presence Counter." *Presence: Teleoperators and Virtual Environments*, vol. 9, no. 5, pp. 413-434, 2000.
- [62] International Society for Presence Research. [Online document], [cited Sept. 1, 2004], Available: <http://ispr.info>
- [63] B. Witmer and M. Singer. "Measuring Presence in Virtual Environments: A Presence Questionnaire." *Presence: Teleoperators and Virtual Environments*, vol. 7, no. 3, pp. 225-240, 1998.
- [64] K. S. Bordens and B. B. Abbott. *Research Design and Methods: A Process Approach*. 5th ed. Boston: McGraw Hill, 2002.
- [65] M. Usoh, E. Catena, S. Arman, and M. Slater. "Using Presence Questionnaires in Reality." *Presence: Teleoperators and Virtual Environments*, vol. 9, no. 5, pp. 497-503, 2000.
- [66] M. Meehan, B. Insko, M. Whitton, and F. P. Brooks, "Physiological Measures of Presence in Virtual Environments." Presented at *4th International Workshop on Presence*, Philadelphia, USA, 2001.
- [67] W. A. IJsselsteijn and H. d. Ridder, "Measuring Temporal Variations in Presence." Presented at *Presence in Shared Virtual Environments Workshop*, Ipswich, UK, 1998.
- [68] S. Whittaker and B. O'Conaill. "The Role of Vision in Face-to-Face and Mediated Communication," in *Video-Mediated Communication*. K. E. Finn, A. J. Sellen, and S. B. Wilbur, Eds. New Jersey: Lawrence Erlbaum Associates, 1997, pp. 23-49.
- [69] Reuters. "S. Korea/Japan venture unveils 3G video phone roaming." [Online document], June 26, 2002, [cited Nov. 18, 2004], Available: <http://sg.biz.yahoo.com/reuters/nseo137154.html>
- [70] University of Calgary. "Telehealth." [Online document], May 2, 2005, [cited Sept. 1, 2005], Available: <http://www.fp.ucalgary.ca/telehealth/Glossary.htm>
- [71] M. Sportack, F. C. Pappas, E. Rensing, J. Konkle, C. R. Smith, D. Welk, and D. Short. *High-Performance Networking Unleashed*. Indianapolis: Sams, 1997.
- [72] W. D. Sincoskie. "Viewpoint: broadband ISDN is happening—except it's spelled IP." *IEEE Spectrum*, vol. 34, no. 1, pp. 32-33, 1997.

- [73] M. Brain. "How DSL Works." [Online document], [cited Jan. 11, 2005], Available: <http://computer.howstuffworks.com/dsl.htm>
- [74] M. Brain. "How Cable Modems Work." [Online document], [cited Jan. 11, 2005], Available: <http://computer.howstuffworks.com/cable-modem.htm>
- [75] International Telecommunication Union. [Online document], [cited Sept 14, 2005], Available: <http://www.itu.int/home/>
- [76] S. Benford, C. Greenhalgh, G. Reynard, C. Brown, and B. Koleva. "Understanding and Constructing Shared Spaces with Mixed-Reality Boundaries." *ACM Transactions on Computer-Human Interaction*, vol. 5, no. 3, pp. 185-223, 1998.
- [77] "Megaconference Jr." [Online document], 2005, [cited Jul. 6, 2005], Available: <http://megaconferencejr.org>
- [78] NASA. "NASA LIVE." [Online document], [cited Jul. 4, 2004], Available: <http://live.larc.nasa.gov>
- [79] "Pairing and Sharing: Round 2." [Online document], [cited Aug. 2, 2005], Available: <http://www.cranfordschools.org/ps2/index.html>
- [80] D. O'Connor. "Application Sharing in K-12 Education: Teaching and Learning with Rube Goldberg." *TechTrends*, vol. 47, no. 5, pp. 6-13, 2003.
- [81] M. J. Heath and D. Holznagel. "Interactive Videoconferencing: A Literature Review." [Online document], Oct. 2002, [cited June 22, 2004], Available: <http://neirtec.terc.edu/K12vc/resources/litpolicy.pdf>
- [82] T. Sheridan, "Eight Ultimate Challenges of Human-Robot Communication," in *Proc. Robot and Human Communication, 1997. RO-MAN '97. Proceedings., 6th IEEE International Workshop on*, 1997, pp. 9-14.
- [83] A. Xu, W. Woszczyk, Z. Settel, B. Pennycook, R. Rowe, P. Galanter, J. Bary, G. Martin, J. Corey, and J. R. Cooperstock. "Real-Time Streaming of Multichannel Audio Data Over Internet." *Journal of the Audio Engineering Society*, vol. 48, no. 7, pp. 627-641, 2000.
- [84] A. J. Sellen. "Remote Conversations: The Effects of Mediating Talk with Technology." *Human-Computer Interaction*, vol. 10, no. 4, pp. 401-444, 1995.
- [85] N. Bos, D. Gergle, J. S. Olson, and G. M. Olson, "Being There Versus Seeing There: Trust via Video," in *Proc. CHI 2001*, Seattle, USA, 2001, pp. 291-292.

- [86] J. S. Olson, G. M. Olson, and D. K. Meader, "What Mix of Video and Audio is Useful for Small Groups Doing Remote Real-time Design Work?" in *Proc. CHI '95*, Denver, USA, 1995, pp. 362-368.
- [87] G. Bell. "The Lack of PC-based Video-Telephony: How I Lost A Technology Bet." [Online document], May 9, 2002, [cited May 25, 2005], Available: http://research.microsoft.com/~gbell/TR_2002_49_Why_I_Lost_A%20Bet_on_Video_Telephony.htm
- [88] P. Jeffrey. "Videoteleconferencing: Why is it Disadvantageous for Group Collaboration." [Online document], Jan 1998, [cited May 12, 2005], Available: <http://www.ece.ubc.ca/~phillipj/papers/videoteleconferencing.pdf>
- [89] J. Cooperstock, "Engaging Technolog(ies) for Effective Interaction." Presented at *ED-MEDIA 2005*, Montreal, Canada, 2005.
- [90] A. H. Anderson, C. O'Malley, G. Doherty-Sneddon, S. Langton, A. Newlands, J. Mullin, A. M. Fleming, and J. V. d. Velden. "The Impact of VMC on Collaborative Problem Solving: An Analysis of Task Performance, Communicative Process, and User Satisfaction," in *Video-Mediated Communication*. K. E. Finn, A. J. Sellen, and S. B. Wilbur, Eds. Mahwah, New Jersey: Lawrence Erlbaum Associates, 1997, pp. 133-155.
- [91] C. Dero. "Webcam Buying Guide." [Online document], [cited Aug. 2, 2005], Available: http://www.futureshop.ca/learnmore/BuyersGuide/en/computers_peripherals_webcam.asp?logon=&langid=EN
- [92] "Microphones." [Online document], [cited Aug. 2, 2005], Available: <http://www.sweetwater.com/shop/live-sound/microphones/buying-guide.php>
- [93] "Mixers." [Online document], [cited Aug. 2, 2005], Available: <http://www.sweetwater.com/shop/live-sound/mixers/buying-guide.php>
- [94] C. Dero. "Speaker Buying Guide." [Online document], [cited Aug. 2, 2005], Available: http://www.futureshop.ca/learnmore/BuyersGuide/en/audio_speakers.asp?logon=&langid=EN
- [95] H. H. Baker, N. Bhatti, D. Tanguay, I. Sobel, D. Gelb, M. E. Goss, J. MacCormick, K. Yuasa, W. B. Culbertson, and T. Malzbender, "Computation and Performance Issues In Coliseum: An Immersive Videoconferencing System," in *Proc. Eleventh ACM International Conference on Multimedia*, Berkeley, USA, 2003, pp. 470-479.

- [96] Moving Pictures Expert Group. [Online document], [cited Aug. 2, 2005], Available: <http://www.chiariglione.org/mpeg/>
- [97] H. H. Baker, N. Bhatti, D. Tanguay, I. Sobel, D. Gelb, M. E. Goss, W. B. Culbertson, and T. Malzbender. "Understanding performance in coliseum, an immersive videoconferencing system." *ACM Transactions on Multimedia Computing, Communications, and Applications*, vol. 1, no. 2, pp. 190-210, 2005.
- [98] B. O'Conaill, S. Whittaker, and S. Wilbur. "Conversations Over Video Conferences: An Evaluation of the Spoken Aspects of Video-Mediated Communication." *Human-Computer Interaction*, vol. 8, no. 4, pp. 389-428, 1993.
- [99] J. Coates and R. Sutton-Spence. "Turn-taking patterns in Deaf conversation." *Journal of Sociolinguistics*, vol. 5, no. 4, pp. 507-529, 2001.
- [100] W. A. S. Buxton, A. J. Sellen, and M. C. Sheasby. "Interfaces for Multiparty Videoconferences," in *Video Mediated Communication*. K. E. Finn, A. J. Sellen, and S. B. Wilbur, Eds. Hillsdale, New Jersey: Lawrence Erlbaum Associates, 1997, pp. 385-400.
- [101] K. Fischer and T. Tenbrink. "Video conferencing in a transregional research cooperation: Turn-taking in a new medium," in *Connecting Perspectives. Videokonferenz: Beiträge zu ihrer Erforschung und Anwendung*. J. Döring, H. W. Schmitz, and O. A. Schulte, Eds. Aachen: Shaker, 2003, pp. 89-104.
- [102] B. O'Conaill and S. Whittaker. "Characterizing, Predicting, and Measuring Video-Mediated Communication: A Conversational Approach," in *Video-Mediated Communication*. K. E. Finn, A. J. Sellen, and S. B. Wilbur, Eds. New Jersey: Lawrence Erlbaum Associates, 1997, pp. 107-132.
- [103] H.-P. Dommel and J. J. Garcia-Luna-Aceves. "Floor Control for Multimedia Conferencing and Collaboration." *Multimedia Systems*, vol. 5, no. 1, pp. 23-38, 1997.
- [104] J. Chattoe, P. Leach, and R. Riesenbach. "Ontario Telepresence Project." [Online document], [cited June 17, 2004], Available: http://www.dgp.toronto.edu/tp/techdocs/Final_Report.pdf
- [105] "Hydra." [Online document], [cited Aug. 3, 2005], Available: <http://www.dgp.toronto.edu/OTP/Techdocs/Hydra.html>
- [106] P. Dourish and S. Bly, "Portholes: Supporting Group Awareness in a Distributed Work Group," in *Proc. SIGCHI Conference on Human Factors in Computing Systems*, 1992, pp. 541-547.

- [107] "Portholes." [Online document], [cited May 16, 2005], Available: <http://www.dgp.toronto.edu/OTP/Techdocs/Portholes.html>
- [108] AT&T. "Train of Thought - 1970 The Picturephone." [Online document], [cited Dec 1, 2004], Available: <http://www.research.att.com/history/70picture.html>
- [109] M. Mehlmann. *When People Use Computers: An Approach to Developing an Interface*. New Jersey: Prentice-Hall, 1981.
- [110] J. Nielsen. "Heuristic Evaluation," in *Usability Inspection Methods*. J. Nielsen and R. L. Mack, Eds. New York: John Wiley & Sons, 1994, pp. 25-62.
- [111] J. S. Angiolillo, H. E. Blanchard, E. W. Israelski, and A. Mané. "Technology Constraints of Video-Mediated Communication," in *Video Mediated Communication*. K. E. Finn, A. J. Sellen, and S. B. Wilbur, Eds. Hillsdale, N.J: Lawrence Erlbaum Associates, 1997, pp. 51-73.
- [112] J. S. Olson, L. Covi, E. Rocco, W. J. Miller, and P. Allie, "A Room of Your Own: What Would it Take to Help Remote Groups Work as Well as Collocated Groups?" in *Proc. CHI '98*, Los Angeles, USA, 1998, pp. 279-280.
- [113] C. A. Maxwell and R. Jayavant, "Digital images, compression, decompression and your system," in *Proc. WESCON/94. 'Idea/Microelectronics'*, 1994, pp. 144-147.
- [114] A. Shah, D. Staddon, I. Rubin, and A. Ratkovic, "Multimedia over FDDI," in *Proc. 17th Conference on Local Computer Networks*, Minneapolis, USA, 1992, pp. 110-124.
- [115] "Kyocera Visual Phone VP-210." [Online document], Oct 5, 1999, [cited July 12, 2005], Available: <http://www.atip.org/Akihabara/prod/enhmob/kyocera/vp-210/>
- [116] D. M. Grayson and A. F. Monk. "Are You Looking at Me? Eye Contact and Desktop Video Conferencing." *ACM Transactions on Computer-Human Interaction*, vol. 10, no. 3, pp. 221-243, 2003.
- [117] W. Huang, J. S. Olson, and G. M. Olson, "Camera Angle Affects Dominance in Video-Mediated Communication," in *Proc. CHI 2002*, Minneapolis, USA, 2002, pp. 716-717.
- [118] H. Ishii, M. Kobayashi, and K. Arita. "Iterative design of seamless collaboration media." *Communications of the ACM*, vol. 37, no. 8, pp. 83-97, 1994.
- [119] M. Billinghurst and H. Kato, "Real World Teleconferencing," in *Proc. CHI '99*, 1999, pp. 194-195.

- [120] Smart Technologies. "Smart Board." [Online document], [cited Jan. 4, 2005], Available: <http://www2.smarttech.edu.com/st/en-US/Products/SMART+Boards/default.htm>
- [121] D. I. Fels, P. Weiss, J. Treviranus, and G. Smith, "Videoconferencing in the classroom: Children's attitudes," in *Proc. CybErg 1999*, 1999, pp.
- [122] A. Cheetham, C. Young, and D. I. Fels, "Interface Development for a Child's Video Conferencing Robot," in *Proc. IEA2000HFES 2000 Congress*, San Diego, USA, 2000, pp. 380-383.
- [123] D. I. Fels and P. L. Weiss. "Toward Determining an Attention-Getting Device for Improving Interaction During Video-Mediated Communication." *Computers in Human Behaviour*, vol. 16, no. 1, pp. 189-198, 2000.
- [124] J. Yeung, B. Konstantinidis, and D. I. Fels, "Remote Work System for High School Students," in *Proc. ED-MEDIA 2005*, Montreal, Canada, 2005, pp. 891-898.
- [125] R. J. Cowan, M. L. Hennessey, C. V. Vierstra, and P. D. Rumrill. "Small-N Designs in Rehabilitation Research." *Journal of Vocational Rehabilitation*, vol. 20, no. 3, pp. 203-211, 2004.
- [126] M. B. Miles and A. M. Huberman. *Qualitative Data Analysis: An Expanded Sourcebook*. 2nd ed. Thousand Oaks: Sage Publications, 1994.
- [127] D. I. Fels, J. K. Waalen, S. Zhai, and P. L. Weiss, "Telepresence Under Exceptional Circumstances: Enriching the Connection to School for Sick Children," in *Proc. Interact 2001*, Japan, 2001, pp. 617-624.
- [128] P. L. Weiss, C. P. Whiteley, J. Treviranus, and D. I. Fels. "PEBBLES: A Personal Technology for Meeting Educational, Social and Emotional Needs of Hospitalized Children." *Personal and Ubiquitous Computing*, vol. 5, no. 3, pp. 157-168, 2001.
- [129] D. I. Fels and P. L. Weiss. "Video-mediated Communication in the Classroom to Support Sick Children: A Case Study." *International Journal of Industrial Ergonomics*, vol. 28, no. 5, pp. 251-263, 2001.
- [130] D. Garson. "Reliability." [Online document], [cited Aug. 16, 2005], Available: <http://www2.chass.ncsu.edu/garson/pa765/reliab.htm>
- [131] W. Buxton. "Human Input/Output Devices," in *Technology Forecast: 1995*. M. Katz, Ed. Menlo Park, C.A.: Price Waterhouse World Firm Technology Center, 1994, pp. 49-65.

- [132] Statistics Canada. "Sampling Error." [Online document], Aug. 17, 2005, [cited Sept. 16, 2005], Available:
<http://www.statcan.ca/english/edu/power/ch6/sampling/sampling.htm>
- [133] Statistics Canada. "Probability Sampling." [Online document], Aug. 17, 2005, [cited Sept. 16, 2005], Available:
<http://www.statcan.ca/english/edu/power/ch13/probability/probability.htm>
- [134] D. Meister and T. P. Enderwick. *Human Factors in System Design, Development, and Testing*. Mahwah: Lawrence Erlbaum Associates, 2002.
- [135] J. A. Sprey. "Videoconferencing as a Communication Tool." *IEEE Transactions on Professional Communication*, vol. 40, no. 1, pp. 41-47, 1997.
- [136] G. Paul, Jr., "An Overview of Videoconferencing Technology," in *Proc. MILCOM 97*, Monterey, USA, 1997, pp. 205-212.
- [137] Sun Microsystems. "Sun Global Glossary." [Online document], [cited Aug. 30, 2005], Available: <http://docs.sun.com/app/docs/doc/805-4368/6j450e60h?a=view>
- [138] P. Symes. *Video Compression Demystified*. New York: McGraw-Hill, 2001.
- [139] D. Turaga and T. Chen. "Fundamentals of Video Compression: H.263 as an Example," in *Compressed Video Over Networks*. M. T. Sun and A. R. Reibman, Eds. New York: Marcel Dekker, 2001, pp. 3-34.
- [140] "H.263 Introduction." [Online document], Mar. 23, 1999, [cited Aug. 30, 2005], Available:
<http://www.cmlab.csie.ntu.edu.tw/cml/dsp/training/coding/h263/introduction.html>