UNIVERSITY OF CALIFORNIA,
IRVINE

Are They Present?: Homebound Children with Chronic Illness in Our Schools and the Use of Telepresence Robots to Reach Them

DISSERTATION

submitted in partial satisfaction of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in Education

by

Veronica Ahumada Newhart

Dissertation Committee:
Distinguished Professor Jacquelynne Eccles, Co-Chair
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2018

DEDICATION

To
the students, parents, teachers, classmates, and administrators who took part in this study and generously shared their time, experiences, and ideas.

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CURRICULUM VITAE

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EDUCATIONAL HISTORY

2018	Ph.D.		University of California, Irvine
2016	M.A.	Education	University of California, Irvine
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1993	B.A.	English Language & Literature	Loma Linda University, CA

EMPLOYMENT

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2013-2018 **Graduate Student Researcher, Project Lead/Principal Investigator**

- Virtual Inclusion via Interactive Technologies in the Classroom, an ongoing national multi-case study

2013-15 **Graduate Student Researcher**:

- Technology: Inequality and Opportunity

Public Health

2012-13 **Grant Writer & Consultant**, Summit Healthcare Regional Medical Center

- USDA Distance Learning and Telemedicine Grant

2009-12 **Oral Health Program Director for State of Montana,** Department of Health and Human Services, Family and Community Health Bureau

- Public Health and Safety Division's Federal Accreditation Core Team, Division Administrator Appointee, Domain Leader
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PUBLICATIONS

Refereed Academic Publications

Newhart, V. A. & Olson, J. S. (2017). My student is a robot: How schools manage telepresence experiences for students. *Proceedings of the 34th Annual ACM Conference on Human Factors in Computing System, CHI'17.* https://doi.org/10.1145/3025453.3025809

Newhart, V.A., Warschauer, M., & Sender, L. (2015). Virtual inclusion via telepresence robots in the classroom: An exploratory case study. *International Journal of Learning Technologies*, 23(4). http://escholarship.org/uc/item/9zm4h7nf

Warschauer, M., & Newhart, V. A. (2016). Broadening our concepts of universal access. *Universal Access in the Information Society*, *15*(2), 183-188. https://doi.org/10.1007/s10209-015-0417-0

Published Academic Abstracts/Workshop Papers

Newhart, V.A., Warschauer, M., Olson, J.S., & Eccles, J.S. (2017). Go Home and Get Better: An Exploration of Inequitable Educational Services for Homebound Children. *IDC 2017 Workshop on Equity and Inclusivity at the ACM SIGCHI Interaction Design and Children Conference*. https://escholarship.org/uc/item/8js3h9zc

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Reich, S., Ochoa, W., Gaona, A., Salcedo, Y., Espinoa, G., Newhart, V., & Garrard, W. (2017, April). The Pain of Poverty and Poor English Skills in the Dental Chair: Pediatric Oral Health Disparities. *Paper presented at the biennial meeting of the Society for Research in Child Development*, Austin, TX.

Newhart, V. A. (2014, April). Virtual inclusion via telepresence robots in the classroom. In *CHI'14 Extended Abstracts on Human Factors in Computing Systems* (pp. 951-956). ACM. https://doi.org/10.1145/2559206.2579417

State and Federal Publications

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Dotson, J.A., Buss, A., Frick, D., Carpenedo, D., & Newhart, V.A. (2010). 2010 Maternal and Child Health Needs Assessment. Family and Community Health Bureau, Department of Public Health and Human Services, State of Montana. https://escholarship.org/uc/item/2gr98072

Carpenedo, D., & Newhart, V.A. (2010). 2005-2006 Oral Health Study: Montana Third Grade and Head Start Children. *Oral Health in Montana*. Department of Public Health and Human Services, State of Montana. https://escholarship.org/uc/item/5pq34577

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Newhart, V.A. (2010). Oral Health Education Curriculum for Grades K-5. *National Maternal and Child Oral Health Resource Bulletin XXIII*. Washington DC: National Maternal and Child Health Resource Center. https://escholarship.org/uc/item/04d63118

Manuscripts Under Review and In Preparation

Newhart, V.A. & Eccles, J.S. (2017). Are they present?: Homebound children with chronic illness in our educational system and use of innovative technologies to reach them. *Child Development Perspectives*. (Invited paper)

Newhart, V.A., & Olson, J.S. (2017). Going to school on a robot: A case study to illustrate important design considerations of telepresence robots. (In preparation)

GRANTS, AWARDS, AND FELLOWSHIPS

Research Grants

2017	Institute for Clinical Translational Science Pilot Grant: Biomedical and Health Informatics
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	UC Irvine Class of 2016 Gift Award

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2012 Summit Healthcare Regional Medical Center USDA Distance Learning and Telemedicine Grant

2010 Improving Oral Health in Montana, Grants to States to Support Oral Health Workforce Activities, Health Resources Services Administration

Awards and Fellowships

2017 UC President's Dissertation Year Fellow

2016 UC Public Impact Distinguished Fellow

Cyberlearning 2017: What's next? Making connections to shape the future. Selected Participant Scholar

2015 UC Irvine Faculty Mentor Program Fellow

University of Washington's AccessCyberlearning Capacity Building Institute, Selected Participant Scholar with Travel Award

2014 Association of Computing Machinery (ACM), SigCHI 2014, 2nd Place Winner, Graduate Student Research Competition

2013-16 UC Irvine Graduate Opportunity Fellow

PROFESSIONAL PRESENTATIONS

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2017 "Telepresence robots: Bringing homebound pediatric patients to local schools" Invited Lecturer, PH 194/PH 196: Clinical and Translational Research Preparatory A

"HCI + HRI = Virtual Inclusion" Montana State University School of Computing, Bozeman, MT

"Tele-operated Human Service Robots for Students: Do They Need a Hand?" Los Angeles Unified School District, Assistive Technology Assessors Annual Meeting, Los Angeles, CA

"How Robots are Used in Schools" Newport Elementary School, Newport Beach, CA

“What to Expect from Your Advisor and Faculty Mentors” UC Irvine Graduate Division

“How to Develop Mentoring Plans and Personal Statements” UC Irvine DECADE

“Clinical and Translational Research Preparatory” UC Irvine, School of Social Ecology

2016 “Pediatric Patients Interacting with Robots” Pacemakers in Children and Adults Resource Fair, UC Irvine, School of Medicine, Department of Pediatrics

“Robots in Schools” Invited Lecturer, ED 212: Literacy and Technology

2015 “Telepresence Robots in Education” Dean’s Advisory Board, UC Irvine School of Education.

“Children with Chronic Illness in our Educational System” Integration of Technology in Educational Settings Colloquium with Education Delegation from Nacka Sweden. Irvine, CA.

“Pediatric Patients Interacting with Robots” Pacemakers in Children and Adults Resource Fair, UC Irvine School of Medicine, Department of Pediatrics

“How do Robots Work?” Festival of Knowledge: Innovation and Technology Demonstration, UC Irvine

“Telepresence in real-world contexts” Everyday Telepresence: Emerging Practices and Future Research Directions Workshop. CHI 2015: Crossings. Seoul, Korea. (Participated via telepresence)

2014 “Virtual Inclusion in Traditional Classrooms” Southern California K-12 Assistive Technology Network Annual Meeting, Los Angeles Unified School District. Alhambra, CA.

“Robots in Education” Digital Learning Lab, UC Irvine, School of Education

Invited Lecturer, UC Irvine ED 131: Education Technology
ED 30: 21st Century Literacies

2013 “Disparities in Dental Care for Head Start Children” UC Irvine, School of Education https://doi.org/10.13140/RG.2.2.32463.48808

“Universal Access” Invited Lecturer, ED 250: History of School Innovations and Current School Reform Movements. UC Irvine, School of Education.

“Robots for Students with Chronic Illness” Competitive Edge Research Symposium, UC Irvine, Graduate Division.

Workshop Presentations

Newhart, V.A., Warschauer, M., Olson, J.S., & Eccles, J.S. (2017). Telepresence robots for virtual social and academic inclusion: Can they contribute to improved well-being, health, and social outcomes for homebound pediatric patients? *Pathways to Cures:*

Translational Research Science Presentations. UC Irvine Campus and Medical Center, Institute of Clinical and Translational Science, NIH.

Newhart, V.A. (2016, July). Virtual inclusion via telepresence robots in the classroom. *Presentation at the 23rd International Conference on Learning*, University of British Columbia, Vancouver, BC, Canada.

Newhart, V.A. (2016, March). What are strategies for maximizing the engagement of students with a variety of disabilities who might not typically engage in cyberlearning? *Panel Presenter at The Center for Innovative Research in CyberLearning: AccessCyberLearning Capacity Building Institute*. University of Washington, Seattle, WA.

Newhart, V.A. (2015) Learning via Virtual Inclusion. *UC Irvine Mini-Symposium: Text and Data Mining for Interactive Online Learning*. UC Irvine Data Science Initiative.

Newhart, V.A. (2014). Virtual Inclusion: A Conceptual Framework. *Graduate Research Symposium, UC Irvine Associated Graduate Students.*

TEACHING EXPERIENCE

Higher Education

2013-15 **Teaching Assistant**, UC Irvine

Courses:

- Cognition and Learning in Educational Settings
- Adolescent Development in Education
- Technology: Inequalities and Opportunities

2007-11 **Adjunct Faculty,** University of Montana, Helena

Semester courses taught:

- Introduction to Microcomputers
- Technical Communications
- Human Relations
- MS Office
- Intro to Technical Report Writing
- Professional Office Procedures

1998-2002 **Director and Instructor: Evening English as a Second Language and Adult Literacy Programs**

Workplace Training Curriculum Developer and Instructor

Georgia Northwestern Technical College Calhoun, GA

Schools, K-12

2002-06 **Director of Learning Resources; Assistive Technologies; National Honors Society Adviser**
Ozark Adventist Academy Gentry, AR

1996-98 **English Teacher; Spanish Teacher; Spanish Club Sponsor**
Georgia Cumberland Academy Calhoun, GA

1994-96 **English Teacher; Spanish Teacher; Accounting Club Sponsor; Junior Varsity Basketball Coach**
Gem State Academy Caldwell, ID

LEADERSHIP

Academic/Professional

2017 **UC Irvine Delegate, Federal NIH/NSF Funding Advocacy**, Catalyzing Advocacy in Science and Engineering (CASE), American Association for the Advancement of Science (AAAS) (selected by Vice Provost of Graduate Division as one of only two students from UCI)

UC Irvine Delegate, State of CA Graduate Research Advocacy, University of California Office of the President (UCOP) (selected by Vice Provost of Graduate Division as one of only two students from UCI)

Workgroup Member: Instrumented Spaces, Center for Innovative Research in Cyberlearning (CIRCL) Stanford Research Institute International (SRI). (selected from nation-wide pool of proposals)

2016 **Associate Editor**, The International Journal of Learning: Annual Review, Vol. 23

2015 **Vice-President Administrative Affairs**, UC Irvine Associated Graduate Students

2014-16 **Ph.D. Student Recruitment Committee**, UC Irvine School of Education

2013 **School of Education Representative,** UC Irvine Associated Graduate Students

2013- Present **Journal Referee/Reviewer**:

American Academy of Pediatrics
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International Journal of Technologies in Education

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Centers for Disease Control and Prevention (CDC), Community Transformation Grants Program

Diversity

2015-16 **Leader**, School of Education's Diverse Educational Community and Doctoral Experience (DECADE) Student Council

DECADE Representative, School of Education Steering Committee

2014-15 **Co-leader**, School of Education's Diverse Educational Community and Doctoral Experience (DECADE) Student Council

2014-Present **UC Irvine Graduate Student Mentor**, Competitive Edge Program
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2013-14 **UC Irvine Graduate Student Mentor**, Summer Research Program

Media Coverage

2017 *Fast Company*, Steven Melendez
Thanks to Telepresence Robots, Kids Can Attend School from Home. https://goo.gl/F3SBAj
Coverage of our CHI 2017 paper June 01, 2017

Brigham Young University radio, *Top of the Mind with Julie Rose*
Going to School via Robot. https://goo.gl/adZHsS
Live radio interview Feb 28, 2017 (interview begins ~61:00 and ends ~81:00)

The Conversation, Newhart, V. & Warschauer, M.
How robots could help chronically ill kids attend school. https://goo.gl/EqGYdK
February 16, 2017

2016 *NHK World TV* (Nippon Hōsō Kyōkai, official English name: Japan Broadcasting Corporation)

Documentary: Interacting with Robot Avatars. https://goo.gl/yjnsT7
Initial air date: July 1, 2016

Digital Trends, Luke Dormehl
Robots Could Have a Big Impact. https://goo.gl/p28PYb
September 22, 2016

LANGUAGES

English: native language

Spanish: native language

ABSTRACT OF THE DISSERTATION

Are they present?: Homebound Children with Chronic Illness in Our Schools and the Use of Telepresence Robots to Reach Them

by

Veronica Ahumada Newhart

Doctor of Philosophy in Education

University of California, Irvine, 2018

Professor Mark Warschauer, Chair

Telepresence robots allow for virtual inclusion of homebound children with medical conditions in traditional classrooms. However, while a growing body of research examines different uses of telepresence robots, little is known about the overall effect this practice may have on children or the schools they are attending. My dissertation explores our understanding of this phenomenon by investigating what we know about homebound children in the U.S. educational system, highlighting the inequality of current educational services, providing an in-depth evaluation of recent interactive technologies used in schools, and reporting results from three different studies.

The first study evaluates five cases in depth. These cases center on five homebound children, collecting data from the homebound children and their parents, teachers, classmates, and school administrators. I found three consistent themes in this study—the power to overcome isolation, classmates' treating the robots as the children themselves, and supportive talk by all participants of the homebound child's future.

The second study focuses on the teachers and administrators who have experienced the robot in their classroom or school. I found that although the technology has benefits, it also presents some unique challenges. The technology does provide inclusion for the child, but the teacher and classmates are now visible in the home and the home is visible in the school. Parents, teachers, and administrators need to collaborate and work together to address these possible breaches of privacy.

The third study examines the design features that matter for the robots used by children in school. It is not enough to study the innovative use of this technology and the impact on learners. The research must also represent their needs to the technology industry for design and production of improved technologies. This study reports the participant experiences behind the recommendations and then summarizes the technical needs for the robot to fulfill the specific needs of children in schools.

Together these three studies provide new insights into the benefits and challenges of telepresence robot use in the classroom. The collective findings from these three studies provide learner-centered, policy-relevant, and industry-leading information that empowers educators, users, and technology developers.

INTRODUCTION

Telepresence robots allow homebound children with medical conditions to be virtually included in traditional classrooms. The term "virtual inclusion" is used to characterize an educational practice that allows a homebound student to interact with classmates, teachers, and other school personnel as if the student were physically present. Telepresence robots may provide the means for improved educational services compared to the traditional home instruction services now offered these students. However, while a growing body of research examines different uses of telepresence robots (e.g., in hospital and corporate settings), little is known about the overall effect this practice may have on homebound children attending school via the robot. My dissertation explores the impact that virtual inclusion may have on this population by investigating what we know about homebound students with medical conditions in the U.S. educational system. In addition, my dissertation highlights the inequality of current educational services afforded to this population, provides an in-depth evaluation of recent interactive technologies used in schools (e.g. telepresence robots, Skype, teleconferencing, online schools) for this population, and reports results from my national multi-case study on homebound student use of telepresence robots to attend school.

Chronic Illness Population

Every year, large numbers of K-12 students are not able to physically attend school due to chronic illnesses. Chronic illness is a disease lasting, or expected to last, at least three months and having some impact on the child, such as functional impairment or a greater than expected need for medical attention given a child's age (Perrin, Ayoub, & Willett, 1993). In my study, functional impairment experienced by all participants was a medically necessitated inability to physically attend school. In my dissertation, I use the term "homebound" for children who are not physically able to attend school due to symptoms, treatments, or recovery from illness but whoare cognitively able to participate in their school's general education curriculum.

Advancements in the medical field are improving the prognosis for many childhood illnesses. Cutting edge technological innovations in pediatric medicine have allowed for reclassification of diseases once considered fatal or terminal (e.g., cancer, heart disease, kidney disease) to be categorized as chronic illnesses (Sexson & Madan-Swain, 1993). In the United States, the number of children with at least one chronic illness has grown dramatically in recent years. Although numbers vary depending on methods and definitions, by any estimate the scope of this problem is enormous. Epidemiologic studies suggest that as many as 1 out of 4 children (i.e., 25%) in the U.S., or 15 to 18 million children age 17 years and younger, suffer from a chronic health problem (Van Cleave, Gortmaker, & Perrin, 2010; J. H. van der Lee, Mokkink, Grootenhuis, Heymans, & Offringa, 2007). However, having a chronic health problem does not necessarily mean that the health problem affects the child's academic performance. Cox and colleagues (2008) estimated that approximately 17% of all students under the age of 18 suffer from a chronic illness that affects their performance in school. This figure is helpful in understanding that a large group of children with chronic illness experience academic challenges but it does adequately not represent the number of children with chronic illness who experience a disruption in school attendance. Earlier research that looked at the effects of chronic illness on school attendance estimated that 4.4

million children, (i.e., 6.5%) of all children under the age of 18, have a chronic condition severe enough to disrupt school functioning (Graff & Ault, 1993; Kaffenberger, 2006; Newacheck & Halfon, 1998; R. J. J. Thompson & Gustafson, 1996). These figures are helpful in understanding how this population has been represented in the literature but do not provide enough information to estimate the number of homebound children in the US. For the purposes of my dissertation, I needed more recent data that could provide a better estimate of homebound children in the US or, at least, children who experience a severe disruption in academic attendance due to chronic illness or medical conditions.

To gauge the size of this population with more recent data, I reviewed figures from the (2016) US Census and 2016 National Health Interview Survey (2016). US Census figures (2016) estimate the total US population to be 323,127,513. Of that population, Census figures estimate the child population (i.e., persons under 18) to be 22.8% with 6.2% of that figure under the age of 5 years. To align Census figures with NHIS school absence data for children 5-17 years, I removed the number of children under 5 years of age from the total number of children under 18 years of age. This results in an estimation for the percent of children in the US who are school-aged to be 16.6% or 53,639,167 children in 2016. The National Health Interview Survey (2016) estimates that 4.2% of children in this age group (i.e., 5-17 years) missed 11 or more days of school and .5% did not attend school at all due to illness. Based on NHIS estimates, the number of school-aged children in 2016 who missed significant amounts of school (i.e., 11+ days of school) due to illness would be approximately 2,260,000 and the number who did not attend school at all due to illness would be approximately 268,000.

The NHIS provides general averages for all children who miss school due to any acute or chronic illness. The NHIS does not allow for categories above 11+ days (i.e., over 2 weeks of school). Children who miss more than 11+ days of school are grouped together as this grouping fits the purposes of the NHIS in determining how many children experience a severe disruption in academic attendance due to illness. This grouping is helpful in estimating how many children overall have their school attendance severely affected by illness. However, at the individual level, there is great variation in the total number of days missed for each child due to severity of condition and recovery. For children dealing with severe illnesses, such as cancer or heart disease, the time away from school is much greater than 11+ days. Childhood leukemia offers an example--it is estimated that children with leukemia miss 40 days of school per academic year and have inconsistent attendance during the following 3 years after diagnosis (Prevatt, Heffer, & Lowe, 2000).

As the number of children who are homebound due to illness continues to increase, we have a growing population of survivors who need adequate educational services. With improved medical care, most will most likely survive into adulthood. We need educational services that provide academic and social benefits necessary for optimal development. Homebound students' long-term academic and social outcomes matter for both their personal and societal benefit.

Current Educational Services

When some children are diagnosed with a chronic illness (e.g., cancer, heart failure), they are suddenly removed from a social context that constituted four to six hours of their daily lives. Prior research states that home instruction services have not changed much since the 1930s (Holmes, Klerman, & Gabrielson, 1970). Holmes and colleagues found the first documented use of homebound educational services in the U.S. occurring in the 1930s as a service for pregnant students in New Haven, CT (*Instructions for the Home Teacher*, n.d.). Traditional services then consisted of an instructor visiting the home along with instructional materials. Current home instruction services also provide a teacher or tutor to visit the home. However, schools may also send packets of papers and make-up work home with siblings, family members, or the home instruction teachers. The amount of home instruction services provided to homebound students depends on the school system. After interviewing 16 school administrators and 20 teachers in 5 states, I found that services typically consist of four to five hours of at-home instruction per week with home instruction services being delivered by a contract instructor or tutor.

To date, there is very little literature on the academic and social effectiveness of home instruction services in the US. Indeed, guidelines for this service do not exist at the federal level. At the state and district levels, guidelines vary widely as to the number of home instruction hours each student receives, the qualifications of instruction providers, and the process for accessing these services. With this lack of structure at federal and state levels, it is difficult to evaluate the efficacy of these services because the implementation varies so widely. However, the standard 4-5 hours of weekly home instruction cannot substitute for regular participation in the classroom environment and does not provide a way for students to experience social interactions with peers.

Homebound students may access other educational services outside of home instruction such as online schools, video conferencing, hospital schools, etc. However, to date, neither our federal or state departments of education track homebound students who use alternative educational services due to illness. My dissertation explores these alternative services and identifies interactive technologies that may provide a broad spectrum of educational services to these students.

Technology

Interactive technologies may provide a solution to this problem, but very few studies have been conducted to evaluate their effectiveness. In my dissertation, I review existing interactive technologies that have been used to meet the needs of these students. Recent advancements in technology have produced affordable, off-the-shelf telepresence robots. This affordability has created increased opportunities for schools and districts to allow these robots to be used by homebound students. For my dissertation, I conducted a national multi-case study on the use of telepresence robots to virtually include homebound students in their local schools.

For my research, I use the concept of virtual inclusion to describe an educational practice that allows a student to attend school through interactive technologies (e.g., a mobile telepresence robot) in such a way that the student is able to interact with classmates, teachers, and other school personnel as if the homebound student were physically present. This presence consists of the user's compelling sense of being in a mediated space and not where the physical body is (Gerrig, 1993; Kim & Biocca, 1997; Minsky, 1980). This is in contrast to earlier research that has used the term "virtual inclusion" to examine the social distribution of access and uptake of information and communication technologies (ICTs) for young people from lower income households and communities (Sinclair & Bramley, 2011). Sinclair and colleagues (2011) explored concepts of universal access to bridge digital divisions in the general population. Virtual inclusion in my research is an inclusive educational practice that provides the homebound student a physical presence (i.e., telepresence robot) in school via a virtual means (i.e., internet connection to the robot). The homebound student's ability to 1) successfully pilot a robot in the school environment on their own and 2) communicate in real-time (both receiving and transmitting) with teachers and classmates are significant components of virtual inclusion.

To understand virtual inclusion via telepresence robots, one must understand how telepresence robots operate. Figure 1 shows four commercially available robots: VGo, Double, Beam, and Ava. In a broad sense, telepresence robots aim to provide social interaction between humans (Kristoffersson, Coradeschi, & Loutfi, 2013). In my research, the use of telepresence robots aims to provide academic and social interactions between homebound children and their school communities. Telepresence robots are not traditional videoconferencing solutions where two or more people meet using specially equipped rooms or computers. In a school setting, a telepresence robot allows for virtual inclusion by enabling the student to be in virtual attendance (i.e., present) in a distant location (i.e., the classroom/school) and have the agency to move around as if s/he were physically there.

Figure 1. Double, VGo, Beam, Ava Robots

The robotic unit has a screen to project the student's face, is mobile, and is remote controlled by the student—the student controls the robot from home, the hospital, or while traveling (e.g., long drives to the hospital) as long as there is Wi-Fi connectivity. After the robot is placed in the classroom and the homebound student logs in to the system, the student can see, hear, talk, interact, 'raise a hand' (via flashing lights), and have access to any accessible location in the school. This mobile access is similar to that of a student in a wheelchair. The unit is recharged every night and provides a two-way, secure, real-time connection for the student that typically lasts most of the school day.

Research Objectives

An objective of this dissertation is to explore our understanding of children who are homebound due to medical conditions and the educational services afforded to them. To fully understand this population and how virtually including them in their local schools may provide improved educational services and more equitable social and academic benefits, I provide an extensive literature review on 1) what is known about this population in the US; 2) current educational services for this population; and 3) interactive technologies that have been used to serve this population.

Another objective of my dissertation is to explore telepresence robots as a possible solution for addressing this inequity. To evaluate this technology as a possible solution, several questions had to be answered: 1) how are the robots used and is there any evidence of virtual inclusion?; 2) how are school systems making the decision to use the robots and how does the link between home and school affect privacy?; and 3) what features should the robot have to facilitate learning and inclusion?

Dissertation Overview

In order to answer these questions, I conducted a qualitative, national multi-case study of homebound children who were using or had used telepresence robots to attend local schools. The results from this study are presented in three papers. Publication #1 (Newhart, Warschauer, & Sender, 2016) explored the experiences of five cases of children attending school on a telepresence robot, where each case includes data collected on the experience of a homebound student, the teachers, the classmates, and the administrators. Findings revealed that most (i.e., four out of five) of the children enjoyed using the robots to attend school. One student enjoyed aspects of using the robot but not the overall experience and returned the robot to the district. Even though not all the children enjoyed using the robot, educators did not feel it was any more work to have them in class via robot than in person. Teachers shared that they enjoyed having the homebound students in their classrooms. In the classroom, there was also strong social acceptance of the robot as a classmate. Teachers, classmates, the homebound child, and parents consistently talked of the homebound child's future as a central reason for use of the robot. It is unclear if encouraging talk of the future occurs with traditional home instruction as classmates and teachers may not be part of the discourse. However, all cases in this study were able to remain in grade via use of the robots. These findings implied that the telepresence robots appear to be a promising solution to address the needs of this population.

Publication #2 included four additional cases for a total of 9 cases. This publication describes the experiences of 22 educators both before deployment of a robot in their schools and during robot use in their schools. Educator experiences were more complex than student experiences given the many tiers of educators. This group of educators consisted of single classroom teachers, teachers who taught in teams, principals, social workers, district administrators, and information technology (IT) personnel. Although there were a number of findings, they were organized under three main categories: 1) who was included in the decision to offer the robot to a student; 2) the issues of privacy now that there was a digital bridge between home and school; and 3) how to make adoption for teachers easier.

Paper #3. Paper #3 is under development and will be submitted to a journal for peer review in the near future. This paper analyzes data from 19 cases to evaluate user interface and robot design features from user-centered perspectives. Three categories of users were identified: 1) homebound children; 2) teachers; and 3) classmates. In order to provide the strongest support for design recommendations, this paper contains data from every round of data collection from September 2013 through June 2017. Findings from this study suggest that there is not one ideal commercial robot on the market today for this practice. I also found that Wi-Fi connectivity was the most cited frustration with the deployment of the telepresence robots used in this study. All participants, their teachers, and their classmates cited frustration with the connectivity of the robot. They did not like the remote student "turning off." Additional findings were organized under four analytic frameworks: 1) learner-centered; 2) teacher-centered; 3) classmate-centered; and 4) homebound controller-centered.

The rest of the dissertation is organized as follows: Chapter 1 presents a review of relevant literature for children with chronic illness, current educational services, interactive technologies, and telepresence. Chapter 2 describes the research methodology. Chapter 3 presents detailed findings on homebound students experiences from Publication #1. Chapter 4 presents findings on educator experiences with deploying and utilizing telepresence robots in their schools in Publication #2. Chapter 5 provides findings and recommendations on the robot design features that matter for learning in Paper #3. To conclude my dissertation, Chapter 6 reviews significant findings, challenges, and suggestions for future research.

CHAPTER 1

LITERATURE REVIEW

In this chapter, I review related work in four research areas: homebound children with chronic illness, education, interactive technologies that have been used in schools for this population, and telepresence. Federal and state data sets lay the foundation for understanding the size of this population in the U.S. Prior research on the effects of severe disruption to academic attendance highlights both short- and long-term negative effects of missing large amounts of school. I reviewed literature on interactive technologies that have been used for school attendance as possible solutions to this problem. To highlight a promising solution, I reviewed relevant research on telepresence and telepresence robots. All four of these research areas provided the structure for exploring the benefits and challenges of using telepresence robots for virtual inclusion of homebound children.

1.1. Children with Chronic Illness

The population of children with chronic illness is growing as diseases that were once fatal are now successfully treated. Children survive at much higher rates than 20 to 30 years ago (Halfon, Larson, & Russ, 2010; Mokkink, Van Der Lee, Grootenhuis, Offringa, & Heymans, 2008). As a result of these increased survival rates, millions of children and adolescents in the United States now live with chronic illnesses and medical conditions including type 1 and type 2 diabetes, cancer, sickle cell disease, asthma, and chronic pain (Compas, Jaser, Dunn, & Rodriguez, 2012). Childhood cancer is a condition that provides strong representation of the increased survival rates and growing numbers of children with chronic illness who are absent from school for long periods of time. For childhood cancer alone, cancer survival rates have shown great improvement from a 40% survival rate in the 1950s, to 59% in 1975, to 80% in 2002 (Robison et al., 2009). Childhood cancer prevents children from attending school due to symptoms before diagnosis, during illness, treatments, and recovery. It is estimated that in 2014, an estimated 15,780 new cases of childhood cancer were diagnosed, approximately 1 in 285 children were diagnosed with cancer before age 20 years, and approximately 1 in 530 young adults between the ages of 20 and 39 years is a survivor of childhood cancer (Ward, DeSantis, Robbins, Kohler, & Jemal, 2014). These numbers reflect a large population of children who experience physical segregation from their schools for long periods of time and social isolation during critical developmental years (Newacheck & Halfon, 1998). Although an average of 15,780 children in the U.S. face a cancer diagnosis every year, thousands more face other debilitating illnesses that result in students being homebound (Ward et al., 2014).

Even though the population of homebound children is quite large and expected to grow, we lack an effective way to gauge the size of this population. At the federal level, data from the Center for Medicaid Services (CMS) can only provide incidence rates of children with chronic illness but not how many of these children experience a severe disruption to school attendance. General health data from the NHIS, National Institutes of Health or Centers for Disease Control are available to provide incidence rates on most illnesses but these data also do not report the severity of the condition or if the illness interferes with school attendance and learning. At the state and local level, schools also do not consistently collect or record data on this population as children who stop attending school due to illness may be transferred to another department, district, or are withdrawn from their local school.

1.2. Education

1.2.1. Academic disruption

Prior research has found that for homebound students, extended absence from the classroom has negative and both educational and social consequences because students may fall behind in instruction, feel isolated from their peers, and experience loneliness and depression (Bennett, 1994; Weitzman, 1986). As the population of homebound children continues to grow, the effects of being removed from their school communities is becoming more evident. To evaluate the effects of chronic illness on academic achievement, Champaloux and Young (2015) examined the association between types of chronic health conditions reported during childhood and adolescence and their impact on educational attainment. Using the National Longitudinal Survey of Youth—Cohort 1997, multivariate logistic regression models were fit to estimate the association between chronic health conditions and educational attainment, adjusting for confounds. Chronic health conditions were defined as a parental or participant report of a chronic health condition. Chronic health conditions were classified into four categories 1) asthma; 2) cancer, diabetes, and epilepsy; 3) heart conditions; and 4) other. Educational attainment was defined as receiving a high school diploma or Graduate Equivalency Degree by age 21, determined from self-report. Champaloux and Young (2015) found that youth who reported having a chronic health condition had higher odds of low educational attainment compared with youth who did not report a condition. Of the four groups in the study, those who were particularly impacted were youth with asthma and those with cancer, diabetes, or epilepsy who had a high number of absences, had repeated a grade, or had high-depressive symptoms score. These findings were consistent with prior literature from Maslow and colleagues (2011) that examined data from the National Longitudinal Survey of Adolescent Health and past literature that supported the relationship between school absences and grade repetition (Brophy, 2006). One potential mechanism leading to low educational attainment may be that students with asthma, cancer, diabetes, or epilepsy may have frequent and/or prolonged absences, which reduces the opportunity to learn and thereby lowers achievement. The prolonged absences experienced by these children not only contribute to their individual academic outcomes but their absences also disrupt their presence in the school community and their contributions to the school culture.

Earlier research has also evaluated the long-term *social* outcomes of prolonged disruption to academic attendance. Comparisons of childhood cancer survivors and their siblings indicate that cancer survivors experience long term social outcomes that include lower rates of marriage, employment, income and educational attainment (Gurney et al., 2009). In evaluating the risk factors for these long-term social outcomes, Gurney et al., (2009) identified prolonged academic disruption as a key risk factor for these outcomes. The disruption in academic attendance caused by a medical condition or treatments creates a disconnect in the child's ability to maintain friendships and advance along with peers through normative social development stages. Note that data on the long-term social outcomes of other illnesses is not readily available as most literature is focused on more concrete outcomes such as survival rates, academic achievement, or improved medical treatments.

1.2.2. Relevant Theories

In order to better understand the effects of severe disruption to academic attendance, I review key theories of child development through an educational lens. In the field of education, our understanding of the impact of chronic illness on children at different developmental levels is essentially theoretical and based on hypotheses drawn from theories of normal child development. A frequently used theoretical approach for evaluating the effects of chronic illness on students is rooted in the cognitive developmental psychology literature. These theoretical frameworks are based on the assumption that certain developmental tasks need to be attained within a given age range. Attainment of these tasks is considered to be the hallmark of healthy growth and development. The assumption is that maturation and experience interact to enable the child to achieve particular tasks and proceed to the next developmental level (Cerreto, 1986; Erikson, 1964; E. C. Perrin & Gerrity, 1984; Piaget & Cook, 1952). Other research suggests that physical, psychological and environmental processes may interfere with the normal sequence of attainments, and chronic illness is perceived to be constitute one such potential threat (Eiser, 1993).

Social-ecology theory is a relevant theory that facilitates exploring the impact that disruption to the normative experience of school attendance may have on homebound children. Social-ecology theory (SET) stresses the role of the social context in determining children's response to disease and treatment (Bronfenbrenner, 2005). The social context can include the child's immediate and extended family, as well as larger societal groups, such as school, neighborhood, and the hospital. The assumption is that the child is at the center of a series of concentric rings, with the outer circles representing larger environments within which the child interacts. The nested circles are the microsystem (e.g., family), mesosystem (e.g., school, where the child interacts), and the exo-system which includes settings where the child does not directly interact but still influence the child (e.g., parents' work colleagues, friends of siblings, etc.) (Bronfenbrenner, 2005).

For homebound students, chronic illness causes a severe change in their mesosystem when the school environment (where they are surrounded by their peers) is removed and replaced with a hospital environment (where they are surrounded by adults). This change in environments reduces the influence of peers within their mesosystem and increases the influences of adults within the meso- and exo- systems (e.g., external influence of the physicians' and medical staff's personal and professional connections). The mesosystem of the school environment is removed when the child is homebound. For my dissertation, I explore the practice of using the robots to maintain the mesosystem of school environment for the homebound children. SET allows for a conceptualization of childhood normative social contexts and provides a strong visual of the gap that is left when the school environment is removed from a child's social experience.

The removal of the school environment is not the only change in social context that homebound children experience. Children with chronic illness are a unique population in that they engage and interact in normative developmental experiences until the symptoms or treatments of their chronic illness remove them from their school environment and thrust them into a new medical environment. Thus, there is the removal of the familiar school environment and the addition of the new, possibly intimidating, medical environment.

For my dissertation, I use a blend of theoretical approaches to evaluate the experiences of these students in our educational systems. In addition to SET, developmental psychological approaches such as Ryan and Deci's self-determination theory provide a framework through which researchers can evaluate the social contexts of learning for children with chronic illness. Ryan and Deci (2002) posit that without meaningful and active participation in familiar and recurring classroom and family routines, children's socio-emotional development can be impaired in many ways, including failure to develop:

- adequate social skills for interacting effectively with peers and non-familial adults,
- mature moral reasoning, adequate self-regulation in complex environments,
- healthy mental health, and
- a comprehensive understanding of social norms and social scripts.

Ryan and Deci's (2002) approach to describing environments that support or thwart effective or healthy functioning lies within self-determination theory and the concept of basic or fundamental psychological needs—the needs for competence, relatedness, and autonomy (Ryan & Deci, 2000). The blend of social ecology and self-determination theories allows for improved understanding of the social contexts in which homebound children may or may not receive the basic human needs for relatedness, competence, and autonomy.

1.2.3. Virtual inclusion

In this paper, the term "virtual inclusion" is used to characterize an educational practice that allows a student to attend school through a mobile robotic telepresence unit in such a way that the student is able to interact with classmates, teachers, and other school personnel as if the student were physically present. Presence is the user's compelling sense of being in a technology mediated space (e.g., the classroom) and not where the physical body is located (e.g. the home). Virtual inclusion parallels the concept of presence as defined by Biocca (1997) and supported by Minsky (1980) in which a remote person feels present in a virtual environment.

1.2.5. Inclusive education

For most children, the basic needs of relatedness, competence, and autonomy are met in the social contexts of attending school. Unfortunately, until recently, there has not been a way to include homebound students in traditional schools. This has resulted in educational systems that reinforce social isolation and physical segregation of homebound children.

Homebound children are not the first population to experience physical segregation from their local school community. Other groups such as children with Down Syndrome, ethnic minorities, and children with physical disabilities have historical records of being excluded from their local schools. In 1970, the federal government mandated inclusive educational practices for children with disabilities through the Individuals with Disabilities in Education Act (IDEA) (U.S. Department of Education, 2006). The IDEA recognized that inclusive educational practices and attending school with peers are key to healthy development and optimal educational outcomes for all children.

Inclusive education is understood as a philosophy that supports and celebrates diversity through the active participation of *all* students in the school culture (Kugelmass & Ainscow, 2004). Other research has found that meaningful and active participation in familiar and recurring classroom and family routines are critically important for both social and socio-emotional development, as well as fulfilling children's basic needs for a sense of belonging and competence (Lerner, 2015; Roeser & Eccles, 2014; R. A. Thompson, 2015)Erwin & Guintini, 2000; Ryan & Deci, 2017).

Most homebound students were cognitively able to learn in traditional classrooms before symptoms and diagnosis of illness preventing their physical attendance and caused them to miss a lot of school. Unfortunately, most children with chronic illnesses such as cancer, heart disease, immunodeficiency disorder, etc. are not considered as having a disability under IDEA because their conditions are not deemed permanent. Childhood cancer, heart disease, kidney failure are perceived to be "curable" and not a permanent disability. Based on this logic, most federal and state policies allow for homebound children to receive similar educational services to traditional children who have a broken leg or other acute illness (e.g., mononucleosis). There is no additional consideration for the significant duration of their illness (months and years, rather than days or a few weeks) and resulting time away from school. Despite the fact that this homebound population does not currently qualify for protection and funding for providing students with disabilities the "least restrictive environment," my dissertation work is guided by the concept and guidelines of inclusive education.

1.2.6. Hospital schools

Instruction services for this homebound population may take place in hospitals for children who are hospitalized for long periods of time. Many children's hospitals have school services within the hospital. However, improvements in medical treatment and decentralized approaches to healthcare mean that a majority of these children spend shorter periods of time in hospital and longer periods of time recuperating or receiving treatment at home or on an outpatient basis (Potas & Jones, 2008). As a result, many homebound students are caught in a gap between the educational services afforded to them by the hospital and the services available to them from their local school. To meet the needs of students in this gap, school systems provide home instruction services.

1.2.7. Home instruction

The number of hours allocated to a student for home instruction services varies according to state and school district recommendations. The Individuals with Disabilities in Education Act (IDEA) and federal regulations do not provide guidance on the need to provide homebound services or how many hours of instruction students should receive (U.S. Department of Education, 2006). Even though the traditional school day consists of 4-6 instructional hours per day for a child to be considered in full attendance and eligible for passing to the next grade level (Zaleski & Colasanti, 2008), homebound services do not operate under the same guidelines.

Every state has different guidelines for home instruction services and for the purposes of this dissertation, a review of California's policies will serve to provide a sample of state-level policies for this population. In order to gauge the size of the homebound population in California, I contacted the California Department of Education. The California Department of Education provides some educational services for students with chronic illness experiencing disruption to academic attendance through the Home and Hospital Instruction (HHI) Program that was housed within the Educational Options, Student Support, and American Indian Education Office until 2014. In 2015, the HHI program was reorganized to fall under the Office of Specialized Programs under Educational Options ("Home & Hospital Instruction," 2017). Until 2015, the state of California did not recognize that homebound student education programs needed administrative oversight that was different from administrative oversight provided to American Indian Education programs for traditional students.

As of 2016, the state contractor that was responsible for Home and Hospital Instruction was also responsible for Continuation High Schools and High Risk Youth and Public Safety. When I contacted this contractor (in 2014 and 2016) to gauge the number of students receiving home instruction services in the state of California, she stated that these numbers are not collected at the state level. She directed me to call each school district to see if they kept records on the number of homebound children in their district. Los Angeles County alone has 80 different school districts. Efforts were made to contact the school districts for population numbers and I was told by every school district I called that I had to contact the schools individually. After a year of trying to research the homebound population numbers in California, I determined this was not feasible.

Assessing the size of this population is not only made difficult by the lack of state and local administrative oversight but also by existing legislation. Disability Rights California highlights that the state of California reimburses schools a full *day* of Average Daily Attendance (ADA) for every *hour* of home instruction services provided to the homebound child. Disability Rights California is a nonprofit disability rights organization that has published online resources for families on the rights of students with significant health conditions. They summarize California's home instruction legislation as follows:

> California law provides that for purposes of computing average daily attendance for students with *temporary* disabilities, each "clock hour" of teaching time devoted to individual instruction counts as one day of attendance. In other words, in order to receive full state funding for a day of attendance, a district need only provide one hour of instruction to that student. The law also says that no student can be credited with more than five days of attendance per week. [Cal. Ed. Code Sec. 48206.3(c).] There is no law requiring districts to provide enough individual instruction to each

temporarily disabled student to enable him to stay current with all his courses and maintain his grades (Disability Rights California, 2012).

California law is clear on what schools must do in order to receive compensation for a full day of attendance for each homebound child. This legislation makes it difficult to track the number of students receiving homebound services because schools that provide homebound services still receive ADA as if the student were still a traditional student in the school. Home instruction teachers or tutors receive monetary reimbursement that may or may not be tracked separately than pay for other work performed at the school.

With limited resources, well-intended educators typically respond to homebound children by providing tutoring and at home services. These home instruction efforts are designed to address the *academic* needs of homebound children. However, being homebound does not solely impact academic achievement. Unfortunately, although home instruction may be able to support some academic achievement, it does not support healthy social and emotional development (Weitzman, 1986). Osterman (2000) argued that schools pay scant attention to the socio-emotional needs of students, individually or collectively and that this is particularly true for students with chronic illness.

What is lacking in the California legislation is mention of what schools must do in order to more fully meet the academic and the socio-emotional needs of these children. The sole focus of the current legislation is school financial reimbursement in the unfortunate case that a student requires (presumed short-term) home instruction services. The academic and social needs of this homebound population are not covered in federal or state home instruction guidelines as these students are viewed as traditional students with "temporary" illness who may resume traditional educational services when they are physically able.

Unfortunately, this mindset and current state legislation prevent these students from receiving necessary services.

1.3. Interactive Technologies

Innovative technological approaches to the problem of homebound students have been limited by the lack of federal and state support of (or even clarity regarding permissible) student attendance via alternative means. In addition, until recently, the technology has not been readily available to offer alternative methods for dealing with academic disruption due to medical conditions—there simply has not been a way to expose these students to social interactions with teachers and peers without great risk to the students' health. The following is an overview of earlier research that highlights some recent technologies that have been introduced to schools and studied for effectiveness in meeting the needs of students who are either geographically isolated or experiencing chronic illness.

1.3.1. Social media

For children with chronic illness, studies have examined the use of texting, email, and social networking sites as technologies to remain connected with their peers (Liu, Inkpen, & Pratt, 2015). Liu and colleagues conducted a small-scale survey with 10 children with chronic illness who were between the ages of 6-18 years. Medical conditions experienced in this sample group included cancer (4), type 1 diabetes (3), Friedreich's Ataxia (1), and both type 1 diabetes and asthma (1). It is not clear in the literature why conditions for only nine children were reported. Researchers also interviewed 15 healthcare professionals and 7 parents of chronically ill children to understand their communication practices and challenges of how these patients stay connected to their peers. They found that due to the nature of their illness and constant hospitalization, pediatric patients often used various communication technologies to stay in touch with friends and try to maintain normalcy in their personal lives. This study is related to my work in that it addresses the use of technology by children with chronic illness to maintain normalcy. However, child participants in this study had a range of chronic illnesses, including illnesses that may not have a significant lifestyle change for patients (Liu et al., 2015). Even though, this study does not differentiate between children who remain in school without disruption to academic attendance or children who are homebound, it still provides valuable insight into the desire for normalcy and the use of technology to achieve it.

1.3.2. Online Schools

Research on K-12 online learning prior to 2012 does not include children with chronic illness as a "special student" group. Watson and colleagues (2011) conducted a review of K-12 online learning federal policy and practice. They found that no state had yet created or allowed a full range of online learning options for students and recommended that states invest in planning for data tracking, transparency, and accountability measures to ensure that online and blended learning provide opportunities and positive outcomes.

This lack of research may have motivated the release of a Request for Proposal in mid-2011 by the U.S. Department of Education Office of Special Education Programs (OSEP), for the establishment of a Center on Online Learning and Students with Disabilities. This request for proposal resulted in the foundation of the Center for Online Learning and Students with Disabilities (COLSD) that expresses a commitment to Universal Design for Learning (UDL) that re-affirms the importance of providing curricular and instructional supports that are able to be represented, acted upon and engaged with by all students. Currently, COLSD is a cooperative agreement among the University of Kansas, the Center for Applied Special

Technologies (CAST), and the National Association of State Directors of Special Education (NADSE) and is focused on four main goals:

1. *To identify and verify trends and issues related to the participation of students with disabilities (SWDs) in K-12 online learning in a range of forms and contexts such as fully online schools, blended or hybrid instruction consisting of traditional and online instruction, and online courses;*
2. *To identify and describe major potential positive outcomes and negative consequences of participation in online learning for SWDs;*
3. *To identify and develop promising approaches for increasing the accessibility and potential effectiveness of online learning for SWDs; and*
4. *To test the feasibility, usability, and potential effectiveness of one or more of these approaches.* (Burdette, Franklin, East, & Mellard, 2015)

However, even though the COLSD subscribes to the 2001 reauthorization of the Elementary and Secondary Education Act (ESEA) which measures, for accountability purposes, the achievement profiles of students receiving public education services online, it still does not recognize students with chronic illness as a population within the school system and does not provide reports on the effectiveness of online educational services for this population (Center on Online Learning and Students with Disabilities, 2012). It is not clear whether online learning schools could provide a feasible alternative to home-bound instruction for children with chronic illness.

After conducting a thorough search through the literature, I was not able to located relevant data or studies to evaluate the effectiveness of online schools for this population. It is not clear whether online learning schools could provide an environment where homebound students could achieve academic success as well as engage in meaningful social experiences.

1.3.3. Video-conferencing

Several studies have explored the effectiveness of teaching and learning via videoconferencing (Hopper, 2014; Hussa, 2012; Comber & Lawson, 2013) but very few have explored the use of this technology for children with chronic illness. The earliest study of real-time video- or tele- conferencing to connect children with chronic illness and their classmates was conducted in Canada via a non-mobile telepresence robot in 2001 through the Providing Education by Bringing Learning Environments to Students (PEBBLES) (Yeung & Fels, 2005). Researchers developed an innovative system that combined videoconferencing with simple robotics to provide high school students with a presence in their classroom from a remote location such as a hospital or home. Case studies were carried out in three different classrooms with use ranging from six weeks to five months. These studies concentrated on evaluating the social, academic, and communication aspects of the system (Fels, et al 2001). Investigators found that in time, the students that used PEBBLES were able to take part in the same tasks as their peers, and participate actively in their classroom without creating any excessive disturbances (Yeung & Fels, 2005). Real-time audio and video communication was valuable in maintaining or establishing connections with peers. However, the PEBBLES robot system was not mobile and needed assistance when moving from one class to another. Students did not have control over their mobility and thus may have incurred implicit social debt to their peers. In recent studies on telepresence robots in the classroom, classmates complained when the mobile telepresence robot lost connectivity and had to be carried or pushed on a cart (Newhart, 2014). It is possible that Yeung et al. did not examine this social debt since mobility was not an option when they implemented the PEBBLES project.

1.3.4. Other

Other digital devices and interfaces such as tablets, computers, Skype, Smartboards, etc. have been used in educational settings; however, there is a lack of formal studies to evaluate these practices in schools for this population. Local news stories and personal accounts exist in publications but database searches have not yielded any studies on the use of these technologies for virtual inclusion of homebound children in their local schools.

1.4. Telepresence

Innovations in technology are not new to education but telepresence highlights a different approach compared to most technological advances in education. Technology in education is an ever-evolving field but technological innovations in education have historically been implemented in a top-down, teacher-centered approach for more than 100 years (Cuban, 1984; 1993). By contrast, the use of robots for children with chronic illness has come to the schools in the opposite fashion. In my investigation of this practice, the robots are being brought to schools in a bottom-up approach—individuals who are concerned about the quality of life of the individual child are introducing them into school systems. The use of robots for virtual inclusion was not introduced to improve school accountability or to assist teachers, the sole purpose was to help an individual child remain connected to school; as reports spread in news articles and by word of mouth about this innovative use of the robot, individuals began advocating for the use of robots.

To understand virtual inclusion via telepresence robot, it is important to understand how telepresence robots operate. Telepresence robots aim to provide social interaction between humans (Kristoffersson et al., 2013) but are not traditional videoconferencing or telepresence solutions where two or more people meet using specially equipped rooms or computers. In a school setting, a telepresence robot allows for virtual inclusion by enabling the student to be in virtual attendance (i.e., included) in a distant location (i.e., the classroom/school) and have the freedom to move around as if s/he were physically there. The robotic unit has a screen to project the student's face (shared identity), is mobile, and remote controlled by the homebound student (giving the student agency)—the student controls the robot from home, the hospital, or anywhere there is Wi-Fi connectivity. After it is placed in the classroom, the homebound student can log in to the system and the student can see, hear, talk, interact, "raise a hand" (via flashing lights), and have access to any location in the classroom and school that would be accessible to a student physically present at school in a wheelchair. The robotic unit is recharged every night and provides a two-way, secure, real-time connection between the student and school that typically lasts most of the school day. Additionally, mobile telepresence robots have a physical presence in the classroom that is missing in other communication devices (e.g., telephonic or video only connections), which, combined with agentic movement, enhances the perception of a social link between the operator and his/her environment (Nakanishi, Murakami, & Kato, 2009).

1.4.2. Telepresence in schools

Prior research with mobile telepresence robots in schools explored the use of these robots for children with severe learning disabilities. Kieron and colleagues (Sheehy & Green, 2011) explored the use of telepresence robots as a way to create a bridge between mainstream and special education classrooms. Two groups of children in the United Kingdom participated in the study: one group consisted of six children from a special school for children with severe learning difficulties and the other group consisted of six children from a traditional school in the same geographic community. Even though the students attended school in the same community, participants did not know each other before the study. Students used the robots to visit the remote classrooms--i.e., the traditional students used the robots to visit the special school and vice versa. The study was conducted in three phases that consisted of semi-structured interviews before use of the robots, observations during use of the robots, and focus groups after students had used the robots. Although all the children enjoyed the experience, the children within the special school saw these devices as a way of accessing environments that they would not be allowed to enter 'in real life.' Mainstream children saw the robots as enjoyable ways of learning about a type of technology which would impact on their future lives (Sheehy & Green, 2011). The vision of the children with severe learning difficulties was that the robots would allow them to interact with the geographical and social environments that they were currently excluded from, whereas children from the mainstream class saw a future in which they controlled the technology itself (Sheehy & Green, 2011).

Homebound children are a blend of both populations represented in this study—they are mainstream students who suddenly experience physical segregation and social isolation from their school and peers. The social norm of their current experience before illness is similar to the mainstream students in that the use of technology holds value for their future. After diagnosis of their illness, the social norm of their current experience is shifted to exclusion from geographical and social environments but on a different level than the students with severe learning difficulties because students with chronic illness are excluded from physical attendance at any school.

1.4.3. Telepresence in medical and corporate settings

A number of papers report on the use of robots in the workplace and healthcare. Lee and Takayama (2011) found that remote workers and colleagues worked as if the remote workers were "really there" in the office and the robots were perceived as useful for both impromptu and planned meetings. Control over volume was difficult, often projecting a louder voice than intended for the setting. Paepcke and colleagues(2011) found that speech volume was an issue in the workplace and remote workers were perceived as "loud." Overall, in these studies, people reacted to the remote person on the robot as if they were physically present, successfully collaborating on projects with informal (hallway conversations) as well as formal interactions (participation in meetings).

Vespa (2005a, 2005b) reported on a preliminary study on usage of tele-rounds in combination with brain monitoring at a neurologic Intensive Care Unit (ICU). Vespa found that response time decreased and the level of face-to-face contact between physician and patients increased. The reduction of travel-time from using the robots was also seen in other studies. Wang and colleagues (2010) also advocated the usage of MRP systems in stroke care as this provided round-the-clock access to stroke experts. Petelin and colleagues (2007) conducted studies in a community hospital and found that consultation time was reduced especially during "off-hours." In addition, they found the use of these robots effective as patients could be seen within 5 minutes instead of the physician travelling for 40 minutes. These studies focused on the effects of bringing physicians to the patients in a more efficient manner but did not evaluate aspects of human social connectedness via the robots.

In my dissertation, I take the view that inclusive educational practices that increase social connectedness are as critical for homebound children as they are for children with disabilities. This increased social connectedness may be possible with the technologies described above that have been used in educational, medical, and corporate settings. Exploring the use of these technologies for the population of homebound children is critical as previous research has found that that severe gaps in school attendance may cause academic and social hardships for these students. Other researchers explore the use of interactive technologies to meet the needs of homebound children but, to date, there have not been many studies on the use of mobile telepresence robots for academic and social learning in traditional schools. Building on the literatures from education, technology studies, and telepresence, my dissertation evaluates the use of telepresence robots as a possible solution to meet the academic and social learning needs of homebound children.

CHAPTER 2

RESEARCH METHODOLOGY

2.1. Phenomenon of Interest

Creswell (1994) defines qualitative research as "an inquiry process of understanding based on distinct methodological traditions of inquiry that explore a social or human problem." My research seeks to explore and understand the phenomenon of homebound children using robots to attend school in real-world traditional classrooms. In order to effectively evaluate this phenomenon, my study is qualitative and exploratory. Creswell (1994) views the role of the researcher as building a complex, holistic picture, analyzing words, reporting detailed views of informants, and conducting studies in their natural settings.

For my dissertation, I chose to conduct a qualitative multi-case study in order to explore the practice of using telepresence robots to attend traditional K-12 schools. I felt a qualitative inquiry to be the best fit for my research as I sought to understand a social problem (i.e., children who are homebound for long periods of time without access to their school communities) in its natural setting (i.e., traditional public schools). The homebound children in my study were homebound due to chronic illnesses but were traditional students before symptoms or diagnosis shifted them to homebound status. As these homebound children were traditional students in attendance at their local schools and had returned to their local school districts via robots, their local school districts were considered the "natural" settings for my studies. Findings resulted from my exploratory study of real-world users in real-world settings where the "phenomenon of interest unfolded naturally" (Patton, 2002).

For my dissertation, I am synthesizing three different papers from my national on-going study. These three papers explored three different aspects of this phenomenon: 1) homebound child experiences; 2) educator experiences; and 3) robot design features. Publication #1 evaluates data collected from 2013-2014 academic year. It contains a total of five cases, with each case consisting of a homebound child and their related parents, teachers, classmates, and administrators. Publication #2 evaluates data collected from the 2013-2016 academic years. It contains data from 9 different cases and evaluates the experiences of 22 educators. Paper #3 evaluates data collected from Fall 2013-Spring 2017. It contains data from 19 cases and evaluates the experiences of 107 total participants with both the user interface and telepresence robot technologies.

2.2. Study Design

The following instruments were created to help generate an understanding of the meaning this phenomenon (i.e., virtual inclusion) has for the participants:

1) school observation protocol

2) home observation protocol

3) topics and sub-questions for the informal interviews of all five groups of participants

a) Homebound child

b) Parents

c) Teachers

d) Administrators

4) focus group questions for

e)classmates

2.3. Research Questions

This study investigated the following research questions:

(1) How are the robots used in classrooms by homebound students, their teachers, and classmates?

(2) What appear to be the effects of robot use on the homebound students, classmates, teachers, and families?

(3) What are the robot design features that matter for learning via virtual inclusion?

2.4. Participants

For each case, there were five groups of participants:

Homebound students: Case study homebound students were invited to participate in an interview in their home or another location chosen by the participant or parent/guardian of the homebound child. Interviews lasted an average of 20 to 40 minutes. Each interview occurred once per participant, was audio recorded, and transcribed. All data was de-identified after transcription, pseudonyms were assigned, and real names were stored separately from anonymized data.

Parents: Parents or guardians of K-12 case study homebound students were invited to participate in an interview in their home or another location, per participant preference, for 20 to 40 minutes. Each interview occurred only once per participant, was audio recorded, and transcribed. All data was de-identified after transcription, pseudonyms were assigned, and real names were stored separately from anonymized data.

Teachers: Case study teachers were observed in their classroom on one occasion during a time when the robot was active. Observations were for a maximum of two hours per classroom when the robot was in use. Observations included classroom teaching and interactions with the robot.

Teachers of case study homebound students were also invited to participate in an interview in their school or another location, at their preference, for 20 to 40 minutes. Each interview occurred only once per participant, was audio recorded, and transcribed. All data was de-identified after transcription, pseudonyms were assigned, and real names were stored separately from anonymized data.

Classmates: Groups of classmates of the homebound case study students were invited to participate in a group discussion for 10 to 15 minutes. Discussions occurred only once per classroom, took place in schools during a school-approved time and were audio recorded. Per teacher preference, instruction time was used for the focus groups. As this study took place in different states, local school policies were followed with regards to assent of classmate participation in the focus groups. The total number of students who participated was collected but no other identifiable data (e.g., names, gender, etc.) was collected during focus group interviews.

Administrators: Administrators of schools and districts of the case study homebound students were invited to participate in an interview in their school or another location, at their preference, for 20 to 40 minutes. Each interview occurred only once per participant, was audio recorded, and transcribed.

2.5. Recruitment

Participants were recruited through school district, hospital, or robot industry contacts who made the initial contact with the parents of homebound students who were using or had used a telepresence robot for virtual inclusion. Contacts at robot companies, school districts, and hospitals agreed to contact potential participants (parents or teachers of students who had already used telepresence robots for virtual inclusion), distribute the UCI Institutional Review Board (IRB) approved flyer, and request their permission to pass on their email address, phone number, or preferred method of contact to the lead researcher. Their involvement was administrative in nature. Participants had the option to either grant permission for their contact information to be shared with me or contact me directly through the contact information on the recruitment flyer. Participants were then contacted via telephone, email, or other method as preferred by the participant. After parents and students agreed to participate in the study they were asked if they were interested in having their school participate in the study. If they agreed, I contacted their school district.

2.5.1. Organizational procedures

School districts: At the school district level, these procedures were followed before school district administrators could contact potential participants (e.g., teachers, principals):

- School districts or schools that were using the technology were contacted via telephone to gauge interest in participating in my study
- I completed the willing school district's external research approval process
- Once school district approval was granted, the school district issued a letter inviting the me to conduct research in their district
- School district invitation to conduct research letter was submitted to UCI IRB along with a formal request to add the school district to my study through the e-modification process; and
- After UCI IRB approval was granted, the school district followed our recruitment process as outlined above.

Hospitals: At hospitals, these procedures were followed before hospital administrators could contact potential participants (e.g., parents, homebound children):

- Hospital administrators that were responsible for distribution of telepresence robots to homebound pediatric patients were contacted via telephone to gauge interest in participating in my study
- After they agreed to participate, hospital administrator agreed to distribute the recruitment flyer; and
- UCI IRB recruitment process was followed as outlined above.

Robot Industry: Robot industry contacts agreed to distribute our UCI IRB-approved flyer to potential participants. The UCI IRB recruitment process was followed as outlined above.

For consistency in data collection, I replicated my study in each set of participants.

2.7. Data Sources

Interviews. All interviews were semi-structured and lasted 20 to 60 minutes. Interview topics included motivation for using the robot, technical aspects of robot use, academic experiences while using the robot, social experiences while using the robot, child's well-being, and general experiences with educational homebound services when applicable. Interviews took place in multiple sites with child/parent interviews taking place in homes, restaurants, and hospitals. Interviews with teachers and administrators took place on school or district campuses or local coffee shops.

Observations and Focus Groups. Observations took place in homes where the child was controlling the robot and classrooms where the robot was deployed and active in the classroom. These observations lasted 45-90 minutes. Observation notes were recorded and analyzed on the same day they took place. Immediately after classroom observations, focus groups were conducted with the classmates, when possible.

Focus groups lasted 7 to 25 minutes and discussions were limited to four questions about the classmates' attitudes and perceptions of attending school with a robot. Open responses were allowed for each question with an average of two to three minutes allowed per response to each question. The homebound children using the robots were present for and actively participated in the focus group discussions.

2.8. Data Analysis

To increase trustworthiness in the data and confirm validity of the processes, Yin's (1994) recommendation to use multiple sources of data was followed. Triangulation, protocols that are used to ensure accuracy and alternative explanations (Stake, 1995), of the data was accomplished by asking similar interview questions of different study participants (i.e., children, parents, professionals), by collecting data from different sources (i.e., children with chronic illness, parents, teachers, classmates, and school administrators), and by using different methods (i.e., interviews, observations, and focus groups). It was expected that the concepts and themes related to the virtual inclusion experiences of the participants would emerge from the multiple sources of data through inductive content analysis, open coding, and the constant comparative method recommended by Glaser & Strauss (1967). Interviews, observation, and classmate focus groups were recorded, transcribed, and coded to identify patterns, similarities, and dissimilarities across the five cases.

Coding. Coding is a heuristic—an exploratory problem-solving technique without specific formulas to follow (Saldaña, 2008). Miles and Huberman (1994) state that coding is analysis while others (Basit, 2003) attest that coding and analysis are not synonymous. For this study, coding was viewed as a crucial aspect of analysis--data were coded both during and after collection as an analytic tactic (Miles & Huberman, 1994). Codes were developed as the data were coded and, as recommended by Hatch (2002), patterns were viewed not just as stable regularities but also as varying forms. Patterns and themes were characterized by similarity, frequency, and correspondence. The data also underwent several cycles of coding to generate relevant categories, concepts, and themes. Initial coding was performed on transcripts and different parts of the data (i.e., text) following Glaser and Strauss' (1967) description of open coding where tentative labels are applied to sections of data and these labels are later classified under common concepts or categories as the data undergoes multiple rounds of coding. A list of the code words for each transcript was compiled and compared across the individual cases. This allowed for checks to ensure that a code was used consistently throughout the transcripts. During these steps, notes were taken and recorded of emerging codes, the ideas they represented, and relationships between codes. The themes and concepts that emerged from the analysis were repeatedly compared with the transcripts to ensure their validity. The constant revision of the material allowed for some codes to be subsumed under broader and more abstract categories.

Open coding was part of the analysis that pertained specifically to the naming and categorizing of phenomena through close examination of the data. Following recommendations from Corbin and Strauss (1990) additional analysis closely examined, compared for similarities and differences, and created new questions about the phenomena as reflected in the data.

Publication #1: For Publication #1, I followed open coding procedures and conducted a deep analysis of RQ1 and RQ2 with a focus on the experiences of the homebound child. As I coded, I let themes emerge from the data. After the initial round of open coding, where tentative labels were applied to sections of data and these labels were later classified under common concepts or categories, I noticed repeat mentions from all participant groups, including the adults, about the homebound child's future and repeated references to "when s/he comes back…." All mentions, across the groups, of the child's future were grouped together as "discourse_future." I also noticed that the classmates made repeat positive references to having the homebound child back in school. The homebound children also consistently answered the question, "What do you like most about using the robot?" with a reply about seeing their friends. Positive references about having the homebound child in class and the homebound child enjoying his friends were placed in category, "social_positive." The classmates and teachers also consistently referred to the robot by the name of the homebound child and shared details of the homebound child's experiences in school. During the third round of coding the interview and focus group transcripts, I (not the people interviewed) was the only one using the word "robot." All participant mentions of the homebound child as a person or a robot were categorized as "child_human" or "child_robot." A list of the code words for each transcript was compiled and compared across five cases where each case consisted of a homebound child and related parents, teachers, classmates, administrators. This allowed for checks to ensure that a code was used consistently throughout the transcripts. Resulting themes for Publication #1 were 1) overcoming isolation; 2) social acceptance (anthropomorphizing of the robot); and 3) consistent references to the academic and social future of the homebound child.

For Publication #1, coding was performed with a homebound child-centered focus. Interviews from parents, teachers, classmates and administrators were coded in relation to their experiences with having the homebound child in the classroom via the telepresence robot. Throughout the multiple rounds of coding, several categories emerged in relation to teacher and administrator experiences that were not relevant to the homebound-child experience and did not contribute to the above-mentioned findings. I was finding that educators were experiencing completely separate issues than the homebound children or classmates. During this time, I began to notice that while many schools were open to using the robots, there were also many schools who were resistant to using the robots. After I was contacted to be an expert witness in a lawsuit against a school district who had refused to allow a student with Marfan's syndrome to attend school via robot, I decided to analyze the data to evaluate the experiences of the educators.

Publication #2: The findings from my pilot study along with the resistance of some schools to allow this practice resulted in new questions. For Publication #2, we created a subset of research questions under RQ2:

RQ 2.1 What line of decision making in the school system leads to successful adoption of the telepresence robot?

RQ 2.2 What issues arise because the classroom and the home (or hospital) are now accessible to the other via the telecommunications link?

RQ 2.3 What would make the adoption smoother for teachers?

To answer these questions, I added four new cases and followed open coding procedures to conduct a deep analysis of the data with a focus on the experiences of educators. As I coded, I let themes emerge from the data. After the initial round of open coding, I continued to conduct multiple rounds of coding to analyze emerging categories as they pertained to the experiences of educators. A list of the code words for each transcript was compiled and compared across nine cases where each case consisted of a homebound child and related teachers and administrators (i.e., educators). Educator experiences were as complex as student experiences due to the many levels of educator positions. The different levels of educators included single classroom teachers, teachers who taught in teams, principals, counselors/social workers, district administrators, and instructive technology personnel. Resulting coding categories for Publication #2 were 1) the decision-making process; 2) the bridge between home and school; and 3) how to make adoption for teachers easier.

Paper #3: After the addition of 10 cases (for a total of 19 cases) to my study, feedback on extreme frustration over connectivity and technical issues continued to emerge. Over a four-year period, frustrations with the technology were not decreasing but remained at consistent levels with the majority of participants throughout the study commenting on these issues. I conducted an in-depth analysis of the existing data to address RQ3. Paper #3 evaluates the technical features that matter for these children in a school setting.

To answer the question, "What are the robot design features that matter for learning via virtual inclusion?" data was continually analyzed every year and underwent multiple rounds of coding. With every new batch of cases, I saw some consistent patterns across cases (e.g., all cases reported frustrations with connectivity) and also saw new emerging patterns (e.g., difficulty viewing smartboard displays). Coding resulted in in four categories: 1) the homebound child on the computer or tablet; 2) homebound child on the robot in the classroom; 3) classmates interacting with homebound child via the robot; and 4) the teacher interacting with the homebound child via robot. Under these four categories, the data was organized by tasks that the student expected to accomplish, the tasks the teacher was expected to accomplish and the tasks the classmates expected of the homebound child via the robot. Paper #3 resulted in an in-depth evaluation of robot design features under these four categories for both the VGo and Double robots. Evaluation of existing features was based on participant feedback. Recommendations for improved design features were supported by participant feedback, existing literature, and observations.

CHAPTER 3

VIRTUAL INCLUSION VIA TELEPRESENCE ROBOTS IN THE CLASSROOM: AN EXPLORATORY CASE STUDY

Newhart, V.A., Warschauer, M., & Sender, L. (2015). Virtual inclusion via telepresence robots in the classroom: An exploratory case study. *International Journal of Learning Technologies*, 23(4). doi: 10.18848/2327-0144/CGP/v23i04/9-25

Abstract

Every year, large numbers of students are not able to attend school due to illness. Extended absence from the classroom has negative and overlapping educational and social consequences as students may fall behind in instruction, feel isolated from their peers, and experience loneliness and depression. School districts sometimes provide individual tutors who can make occasional home visits but such tutoring cannot substitute for regular participation in the classroom environment. Telepresence robots may provide a way for students to remain connected to their schools, classmates, teachers, and maintain or develop critical social relationships via virtual inclusion. A total of 61 participants were included in this study. Semi-structured interviews were conducted with 5 homebound children, 5 parents, 10 teachers, 35 classmates, and 6 school/district administrators. While the robot was deployed, one home observation, two classroom observations and two focus group sessions were conducted. This study is a small-scale exploratory case study that examined the use of robots to attend school and how schools integrated homebound students via robots into traditional classrooms. Three themes emerged from the coding and analysis of the data: 1) anthropomorphism for social acceptance and normalcy, 2) overcoming isolation

to meet socio-emotional needs, and 3) new experiences that generated talk of an academic future.

Keywords: Telepresence, Education, Inclusion, Human Computer Interaction, Human Robot Interaction

3.1. Introduction

Advancements in the medical field are improving the prognosis for many childhood illnesses and cutting edge technological advancements in pediatric medicine have allowed for reclassification of diseases once considered fatal or terminal (e.g., cancer, heart disease, kidney disease) to be categorized as chronic illnesses (Sexson and Madan-Swain 1993). Chronic illness, as operationalized by Perrin and colleagues (1993), is a disease lasting, or expecting to last, at least three months and demonstrating some impact on the child, such as functional impairment or a greater than expected need for medical attention given a child's age. For this study, a functional impairment experienced by all participants with chronic illness was physical segregation that caused severe academic disruption (i.e., a significant break in academic attendance) and social isolation from peers. In this paper, the term homebound is used for children who are not able to attend school due to symptoms, treatments, or recovery from illness.

Even though attending school with peers and close friends constitutes the bulk of their daily lives, when some children are diagnosed with a chronic illness (e.g., cancer, heart failure), they are suddenly removed from a social context that constitutes four to six hours of their daily lives. Traditional services afforded by our educational systems to children with chronic illness have not changed much, if at all, over the past 80+ years (Holmes, Klerman, and Gabrielson 1970) with the first documented use of homebound educational services in the U.S. occurring in the 1930s as a service for pregnant students in New Haven, CT ("Instructions for the Home Teacher," n.d.). Packets of papers and make up work are sent home with siblings or family members and, depending on the school system, homebound services may be offered that typically consist of four to five hours of at-home instruction per week.

3.1.1. Technology

Innovative approaches to this problem have been limited by the availability of alternative methods for including these children in traditional schools. Until recently, the technology has not been readily available to offer alternative methods for dealing with academic disruption due to medical conditions—there simply has not been a way to expose these students to social interactions with teachers and peers without great risk to the students' health. While valuable work has been conducted on the challenges of geographical distance on teamwork (G. M. Olson, Olson, and Venolia 2009) and the contributions of video conferencing systems (Venolia et al. 2010), mobile robotic telepresence systems have added mobility to the equation. For children with chronic illness, studies have also examined the use of texting, email, and social networking sites as technologies to remain connected with their peers (Liu, Inkpen, and Pratt 2015) and for children with severe learning disabilities, the use of telepresence robots has been studied as a way to create a bridge between mainstream and special education classrooms (Sheehy and Green 2011). However, to our knowledge, there have not been any formal studies on the use of telepresence robots by children with chronic illness for virtual inclusion in real-world mainstream classrooms.

3.1.2. Virtual inclusion

In this paper, the term 'virtual inclusion' is used to characterize an educational practice that allows a student to attend school through a mobile robotic telepresence system in such a way that the student is able to interact with classmates, teachers, and other school personnel as if the student were physically present. Virtual inclusion is possible through the concept of telepresence, as operationalized by Biocca (Kim and Biocca 1997) and others (Gerrig 1993; Minsky 1980), which refers to the user's compelling sense of being in a mediated space and not where the physical body is located. Allowing the student to pilot or navigate a physical presence in an educational environment is a significant component of virtual inclusion for both the homebound student and the classmates. For classmates, earlier studies with a teleoperated robot have shown that children treated it as a living thing and displayed more engagement than adults with the robot (Scheeff et al. 2002). For the homebound student (i.e., operator), Nakanishi and colleagues (2009) found that a physical presence, when combined with movement, enhances the perception of a social link for the operator. This increased level of engagement with the robot and social link for the homebound student provide the critical support necessary for virtual inclusion.

3.1.3. Telepresence

Figure 3.1. VGo Telepresence Robot

To understand virtual inclusion via robot, it is important to understand how telepresence robots operate (Figure 3.1). Telepresence robots aim to provide social interaction between humans (Kristoffersson, Coradeschi, and Loutfi 2013). Telepresence robots are not traditional videoconferencing or telepresence solutions where two or more people meet using specially equipped rooms or computers. In a school setting, a telepresence robot allows for virtual inclusion by enabling the student to be in virtual attendance (i.e., included) in a distant location (i.e., the classroom/school) and have the freedom to move around as if s/he were physically there. The robotic unit has a screen to project the student's face, is mobile, and is remote controlled by the student—the student controls the robot from home, the hospital, or while traveling as long as there is Wi-Fi connectivity (Figure 3.2). After the robot is placed in the classroom and the homebound student logs in to the system, the student can see, hear, talk, interact, 'raise a hand' (via flashing lights), and have access to any location in the classroom and school similar to that of a student in a wheelchair. The unit is recharged every night and provides a two-way, secure, real-time connection for the student that typically lasts most of the school day.

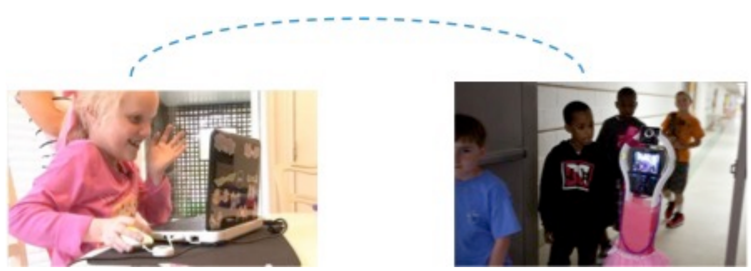

Figure 3.2. Child at home controlling robot at school

3.2. Methodology

To investigate real-world experiences with virtual inclusion, the research team sought a school setting where these robots were distributed by school/district based on student need and not family or community support. The robots require financial resources and students whose parents are able to afford robots or whose communities come together to help purchase a robot for a child may also receive above average social and academic supports that contribute to the success of the robot for academic and social benefits. The research team wanted to explore a level playing field where students received the robots regardless of income level, family background, or social supports. A public school system that had five robots distributed to students with various chronic illnesses was used for this study.

This study sought to explore and understand the phenomena of children with chronic illness using robots to attend school in real-world traditional classrooms. As such, this study was qualitative and exploratory. As a qualitative study, findings resulted from the study of these real-world settings where the "phenomenon of interest unfold naturally" (Patton 2002). As an exploratory case study, the study examined the academic and social contexts of virtual inclusion as well as gained insight into the practice of virtual inclusion via telepresence robots in the classroom and its implications for future research. The study sought to explore the following research questions:

1) How is the robot used in classrooms by homebound students, their teachers, and classmates?
2) What appear to be the effects of robot use on the homebound students, classmates, teachers, and families?
3) Is classroom inclusion via telepresence robot financially and functionally feasible?

3.2.1. Participants

A small-scale exploratory case study was conducted with over 20 hours of interviews, 6 hours of observations, and 2 focus groups. A total of 61 participants shared their experiences during this study: 5 homebound children, 5 parents, 10 teachers, 35 classmates, and 6 school and district administrators (Table 3.1). The children with chronic illness in this study had a range of chronic illnesses including an immunodeficiency disorder (1), cancer (3), and heart failure (1) and were currently using, or had previously used, robots for virtual inclusion. The age range of the children was 6 to 16 years old with 4 male students and 1 female student. In order to conduct a holistic, in-depth study, data was collected from the children with chronic illness, and their parents/guardians, classmates, teachers, and school administrators.

Table 3.1.
Chapter 3 Participant Characteristics (N=61)

Homebound Student Name	Relationship	Sex	Grade When Interviewed	Condition	Interview Location
Samuel		M	5th	Heart	Restaurant (en route to hospital)
	Mother	F	----	---	
	Classmates	--	5th	---	Classroom
	Teacher A	F	----	----	Classroom
	Teacher B	F	----	----	
	Teacher C	F	----	----	
	Principal	F	----	----	School Office
	District Administrator	F	----	----	District Office
Daniel		M	6th	Cancer	Hospital
	Mother	F	----	----	
	Teacher A	F	----	----	School Office
	Teacher B	F	----	----	
	Administrator	M	----	----	
	Principal	M	----	----	School Office
Eileen		F	9th	Cancer	Home
	Mother	F	----	----	
	Teacher	F	----	----	Classroom
David		M	3rd	Immunodeficiency Disorder	Home
	Mother	F	----	----	
	Teacher A	F	----	----	
	Teacher B	F	----	----	
	Teacher C	F	----	----	
Nathan		M	2nd	Cancer	Home
	Mother	F	----	----	
	Classmates	---	2nd		Classroom
	Teacher	F	----	----	Classroom
	Principal	F	----	----	School Office
	Regional Administrator	M	----	----	Automobile

3.2.2 Recruitment

Participants were recruited through the Technology Programs Manager at a district-level technology center who made the initial contact with the parents of homebound children who were using or had used one of the district's telepresence robots for virtual inclusion. If the parents expressed an interest in participating in the study, their contact information was provided to the research team via email. After parents and students agreed to participate in the study, the Technology Programs Manager proceeded to contact teachers and administrators of participating families and the contact information of willing teachers and administrators was also shared with the research team via email.

3.2.3 Interviews

All interviews were semi-structured and lasted 20 to 60 minutes. Interview topics included motivation for using the robot, technical aspects of robot use, academic experiences while using the robot, social experiences while using the robot, child's well-being, and general experiences with educational homebound services when applicable. Interviews took place in multiple sites with child/parent interviews taking place in homes, a restaurant (child was traveling to the hospital), and hospital. Interviews with teachers and administrators took place on school or district campuses except for one administrator interview that took place in a vehicle while he was driving, as per his request.

3.2.4 Observations and focus groups

Observations took place in one home where the child was controlling the robot and in two classrooms where the robot was deployed and active in the classroom. These observations lasted 45-90 minutes with one of these observations taking place in Nathan's classroom and the other, on a different day and location, in Samuel's classroom. Samuel was in school (via robot) for the classroom observation but was traveling to the hospital on the day his home observation was scheduled. Observation notes were recorded and analyzed on the same day they took place. Immediately after classroom observations, focus groups were conducted with the classmates. Focus groups lasted 7 to 25 minutes and discussions were limited to four questions on the classmates' attitudes and perceptions of attending school with a robot. Open responses were allowed for each question with an average of two to three minutes allowed per response to each question. Home and classroom observations were not possible for three cases due to the following reasons: 1) Eileen had returned her robot at the time of the interview, 2) Daniel was receiving treatment at the time of interview, 3) David did not attend school on the day of the interview.

3.2.5 Analysis

To increase trustworthiness in the data and confirm validity of the processes, Yin's (1994) recommendation to use multiple sources of data was followed. Triangulation, protocols that are used to ensure accuracy and alternative explanations (Stake 1995), of the data was accomplished by asking similar interview questions of different study participants (i.e., children, parents, professionals), by collecting data from different sources (i.e., children with chronic illness, parents, teachers, classmates, and school administrators), and by using different methods (i.e., interviews, observations, focus groups, field notes). It was expected that the concepts and themes related to the virtual inclusion experiences of the participants would emerge from the multiple sources of data through inductive content analysis, open coding, and the constant comparative method recommended by Glaser & Strauss (1967).

Interviews, observation field notes, and classmate focus groups were recorded, transcribed, and coded to identify patterns, similarities, and dissimilarities across the five cases.

Miles and Huberman (1994) state that coding is analysis while others (Basit 2003) attest that coding and analysis are not synonymous. For this study, coding was viewed as a crucial aspect of analysis and data were coded both during and after collection as an analytic tactic. Codes were developed as the data were coded and, as recommended by Hatch (2002), patterns were viewed not just as stable regularities but also as varying forms. Patterns and themes were characterized by similarity, frequency, and correspondence. The data also underwent several cycles of coding to generate relevant categories, concepts, and themes.

Initial coding was performed on transcripts and different parts of the data (i.e., text) following Glaser and Strauss' (1967) description of open coding where tentative labels are applied to sections of data and these labels are later classified under common concepts or categories as the data undergoes multiple rounds of coding. A list of the code words for each transcript was compiled and compared across the individual cases. This allowed for checks to ensure that a code was used consistently throughout the transcripts. During these steps, notes were taken and recorded of emerging codes, the ideas they represented, and relationships between codes. The themes and concepts that emerged from the analysis were repeatedly compared with the transcripts to ensure their validity. The constant revision of the material allowed for some codes to be subsumed under broader and more abstract categories.

3.3. Findings

This process resulted in highlighting three themes critical to understanding the social and academic reality of virtual inclusion for these participants—anthropomorphism for social acceptance and normalcy, overcoming isolation to meet socio-emotional needs, and new experiences that generated talk of an academic future. This process also supported self-determination theory (i.e., a child's fundamental need for competence, relatedness, and autonomy) (Deci and Ryan 1985) as a potential framework for future studies.

3.3.1. Anthropomorphism for Social Acceptance and Normalcy

Anthropomorphism refers to attributing human-like characteristics to non-human agents (Guthrie 1997), and several studies support the idea that human interaction with computers is fundamentally social in nature (C. I. Nass, Steuer, and Tauber 1994; Takeuchi and Katagiri 1999). Previous research has shown that users tend to treat computers and robots as if they were humans without even being aware of it (Luczak, Roetting, and Schmidt 2003) and that users also apply human social categories to computers as well as to robots and they do so relatively automatically (Reeves and Nass 1996; C. Nass and Moon 2000). Throughout this study, both students and teachers began to view the robot as the student after the initial introductory period and frequent references were made to the robot 'attending school,' 'playing in the gym,' 'falling down,' 'singing in the choir,' etc.

Anthropomorphism of the robot was a key contributor to establishing a sense of normalcy for all homebound students interviewed. It allowed for the homebound student to interact with classmates, maintain or establish social connections to their school community, and receive care and support from their friends. The anthropomorphization of the robot and the subsequent acceptance of the robot as a regular member of the classroom seemed to vary between schools. Most schools reported an excited introduction phase followed by a settling of attention and eventual normalcy of the robotic presence.

For Samuel, all three of his teachers felt that the ascription of human qualities to the robot seemed to happen easily for his 5th grade classmates. His teachers reported that the robot was accepted as Samuel almost immediately and that,

Teacher 1: They call it 'Samuel'

Teacher 2: It's 'Samuel'

Interviewer: So they don't differentiate between the robot and 'Samuel'?

Teacher 2: Yeah…It is one person. They don't think anything different

Surprisingly, the removal of human qualities seemed to happen just as effortlessly by Samuel's classmates. After attending school for several weeks as a robot, Samuel was cleared by his physician to attend school for picture day as long as he wore a facemask when not being photographed. He was able to finally meet his new friends in person and his teacher reported that Samuel and his friends got along just like they did when Samuel was in class via the robot. His classmates so easily accepted Samuel in person, that when it came time to take the class picture, they did not want the robot in the picture.

Teacher 2: Yeah, the other day, we had class pictures and so Samuel's mom brought him here and in the class picture was Samuel and the robot and the kids were like, 'Why are they both in there?' (chuckle)

Teacher 3: So, you know, it was . . . 'Why does he take two spots?'

Teacher 1: Yeah (chuckle). 'That's one person…why is he having them both?' And so, they were confused by the fact that they both were going to be in the picture.

The robot lost its value and identity when Samuel was physically present—there was no need to ascribe human qualities to the robot because the actual human it represented was physically present in the room. However, after Samuel went home, he came back to school via the robot that same day and his homeroom teacher recalls that the transition was seamless and class activities resumed as normal.

The ascription of human qualities to the robots was consistent across all five cases with each teacher interviewed making at least one mention of students treating the robot as a 'regular' student. Nathan's teacher reported that 'you may not have noticed, but when we're walking down the hall coming back from book fair, they just ran over and just (laughter) like the robot's a normal, (laughter) a kid.' It was also common across all five cases that students referred to the robots by the name of the homebound student. Daniel's teacher commented that, 'It was always Daniel. It was never the robot. It was always Daniel. They would say in the mornings, 'Is Daniel going to be in class today?' She continued, 'the very first day we had the robot in the classroom, it was like Daniel was back…And so we immediately identified, you know, with just him and it was a more of a – I would say an emotional tie to him rather than like an academic tie.'

This emotional tie and connectedness that teachers and classmates felt towards the student via the robotic presence was consistent in all five cases; however, Eileen also had the experience of attending a class where she did not feel her classmates treated the robot as a 'normal' student. Eileen was the only female student in the study as well as the only high school student. Studies have shown that user gender affects people's reactions toward artificial intelligence robots (Crowell et al. 2009) but there has not been enough research on gender and social acceptance of telepresence robots to evaluate whether being female contributed significantly to Eileen's experience.

For most of the students, the robot either remained in the same classroom or traveled with the same group of students between classes. This increased exposure and interaction with the robot may have contributed to acceptance of the robot for the other students. Eileen reported that she used her robot to attend various classes composed of different students throughout the day. Her experience with normalcy as a student varied from that of the other students in the study but it is not clear whether this variance was due to her gender or due to the level of anthropomorphism and normalcy allocated to the robot by classmates since most of her classmates were exposed to the robot for only one class period during the day.

This difference in normalcy surfaced when Eileen was asked about her favorite class. She named world geography and when asked to explain why that was her favorite class, her response focused on how other students treated her.

Eileen: Well, it's just the people in that class didn't treat me like I was a robot…so I liked it…and like in my 1st period, every single person would stare at me and like crack up laughing if I ran into something …and then like they never got used to it.

Mother: And in that world geography class, they would pick on – you know– they would pick on her, but be like, 'Come on Eileen! What are you doing?' You know, like treated her like a normal person…

The social connection Eileen felt in her world geography class and that other homebound students felt in their classrooms seemed to allow them to enjoy their classes and motivate them to attend school via robot. They were able to experience a social connection even though they were embodied in a mobile robot. The importance of this social connection is supported by self-determination theory and relevant research that has shown that students have three categories of needs: to feel competent, to feel socially attached, and to have autonomous control in their lives (Deci and Ryan 1985; Connell and Wellborn 1991).

While the use of telepresence robots may help students academically by allowing them to participate in classroom lectures and activities, the academic benefits of this form of inclusion may be influenced by the social acceptance of the robot as a classmate. Research by Tsui and colleagues (2011) stresses the importance of informal interactions with telepresence robots in order to improve the effectiveness of robot use during formal interactions. For younger students who attend school for most of the day with the robot and have increased opportunities for informal interactions, acceptance and anthropomorphization of the robot may happen more readily than it would for students who only see the robot for one class period of the day. In this study, social attachment to classmates and a sense of normalcy seemed to be related to the level of anthropomorphism allocated to the robot by classmates.

Anthropomorphization and social acceptance of the robot allowed for most of the students in this study to experience a sense of normalcy and a return to traditional school experiences. However, traditional school experiences are not always positive and there were a few examples of negative actions from peers towards the student via the robot.

Negative actions differ from acts of bullying in that, according to Olweus (1991), 'A person is being bullied when he or she is exposed, repeatedly and over time, to negative actions on the part of one or more other persons' and 'negative action is when someone intentionally inflicts, or attempts to inflict, injury or discomfort upon another.' Olweus (1991), also stresses that in order to use the term 'bullying' there should be an imbalance in strength (an asymmetric power relationship). Bullying of the robot was reported for one student through two separate physical incidents and negative action was reported for one other student through one verbal incident. The reported bullying and negative actions had differential effects possibly due to gender or age.

One student who experienced a negative action, Eileen, eventually returned her robot to the service center and resumed homebound services for all her classes. She stated that she 'didn't like all the attention' that the robot received and reported that a male student asked about her, 'Like, what is that, a vacuum cleaner?' She did not think the student was being intentionally negative but she did not like the attention she received as a robot. She eventually made the decision to return her robot to the service center with the hope of returning to school the following semester as self-described, 'Eileen the human.'

Samuel also experienced negative verbal behavior but his experience was different in that it also included negative physical behavior on more than one occasion. However, he did not return his robot and was actively using the robot at the time of the interview. The first incidence of bullying occurred when he 'ate' lunch with his friends (i.e., he 'sat' the robot at a lunch table with his friends and ate his lunch at home while his friends ate their lunch at school). One of his teachers described the bullying incident and reported that Samuel was eating lunch with his friends when another student walked up and smeared ketchup on Samuel's face/screen. According to the teacher, Samuel was also taunted with 'Why don't you go tell your mama?? Go tell your mama right now…' while his screen was being smeared with ketchup. Samuel did not need to tell his mama because she was home and witnessed the entire incident via Samuel's laptop but he also did not tell his teacher about the bullying. Samuel's teacher remembers that,

> …he came back from lunch with his lights on and I said, 'Yes?' and he said, 'I need you to wipe off my lens.' And so, you know, I took a tissue and cleaned off his lens and I said, 'Ok, is that better?' And he said, 'Yes.'

The teacher was unaware of the bullying until Samuel's mother called the school and reported it. When the teacher was asked how she felt about the bullying incident, she matter-of-factly replied, 'Yeah, I was like well he's getting the full deal right here. The whole shebang…the good and the bad.' This incidence of bullying did not discourage Samuel from attending school via the robot but instead his friends became his 'bodyguards' to protect him during lunch. When the teacher was asked for her views on these social interactions, both good and bad, she reflected on something his mother had told her, 'His mom told me one time what a blessing it [the robot] was because he was literally…very depressed for the past two years.' She continued with her thoughts on Samuel's depression and experiences of being isolated for two academic years versus attending school via robot, 'I think that the benefit … whether it works great or not, just the benefit of him getting to be around other kids when he wouldn't normally get to be around kids is priceless.'

Neither Samuel nor his mother reported the first bullying incident during their interviews but they did describe other negative behavior from a classmate, Mike. Mike would put his hand in front of Samuel's screen to prevent him from seeing. Even after Samuel's mother asked Mike (through the robot) to stop doing that, Mike denied doing it and continued this behavior until an adult at the school noticed what was happening and put a stop to it.

Samuel's attitude towards the bullying and lack of discouragement from it may stem from his mother's perceptions of these behaviors. During our interview, she commented,

> I said, you know, it's just going to happen…when…going to lunch…there's not the teacher or the aide…there's not as much adult supervision. So that tends to be when things happen or when they take him back to the classroom or they're going to recess, you know, because (thoughtful pause) they're ten.

Even though bullying is traditionally viewed as a negative experience, Samuel's teacher and his mother seemed to accept the negative behavior as an unfortunate but normal part of the school experience and typical of being ten years old. When asked to describe the most positive aspect of using the robot, Samuel's mother expressed,

> Mother: Um, like I said, just a sense of normalcy. I mean, he just – he feels more like a ten-year old kid. You know, he's back to complaining about having homework. He's back to – you know, the things that most ten-year olds do…talking about his friends…
>
> Interviewer**:** Complaining about them?
>
> Mother**:** And darn Mike! (laughter) Um, and he's a nice boy. He's a ten-year old boy is what it is.

For Samuel, the negative experiences also allowed for subsequent positive experiences while embodied in the robot. His friends rallying around him and assigning themselves as his bodyguards followed having ketchup smeared on his screen. Having the annoyance of a classmate block his screen gave him something to discuss during our interview while he rolled his eyes, threw his hands up in mock frustration, and laughed with his mother at Mike denying that he was the one blocking the screen. As Samuel described his school experiences, it was clear that he felt a strong social connection to his school and to his friends.

3.3.2. Overcoming isolation to meet socio-emotional needs

Maintaining a social connection to peers has not traditionally been an aspect of home instruction services. Most of the students in this study felt isolated from their peers when they could no longer physically attend school and interact with their friends. This exclusion from school left some students with feelings of loneliness, depression, and isolation. The homebound students did not mention feeling depressed while receiving home instruction before the robot, but parents and teachers made references to the students experiencing 'depression' and displaying a 'lack of interest' when it came to completing school work through homebound instruction.

The educational experiences of the children in this study had a common thread—the use of the robot to remain socially connected. While some parents, teachers, and administrators focused on the academic benefits and better utilization of school resources via the robot, the children had a different focus (Table 3.2). When asked what they liked most about using the robot, all of the homebound children interviewed responded with a variation of 'I get to see my friends.' When asked what they liked least about using the robot, the responses varied greatly from 'nothing really' to connectivity issues, to wishing the robot had arms.

Table 3.2.
What Students Liked Most and Liked Least About Using a Robot

	Like most…	Like least…
Daniel	Seeing my friends	Not physically being there
Nathan	Everyone's nice to you	That I crashed a lot…it keeps coming on and off, on and off. So like we can't do the activity that we were doing…
Eileen	Just talking to my friends	The attention
Samuel	Getting to have a lot of fun with my friends	That it doesn't have arms. Because sometimes…I'll get locked in the room and I can't unlock the door or open it.
David	Mm, you can see your friends	Nothing really

The students' responses to what they liked most about using the robot had a consistent theme of remaining socially connected to their friends and reflected the enjoyment they experienced from being able to maintain that connection. Even though the responses to what they liked least about the robots were not consistent, most of the responses still reflected on their perceived level of social connection. Nathan's response expressed frustration when that connection was severed due to the technical aspects of the robot, Samuel wished he could still open doors to join his classmates, and Daniel wished he could physically attend school again. Eileen did not like the attention she received while embodied in the robot and while her response reflects a social connection she did not enjoy, it is worth noting that she followed this response with the incident of the boy asking if she was a 'vacuum cleaner.' What she liked least about using the robot is also what caused her to stop using the robot. Her virtual inclusion experience was shaped by the social interactions she received while embodied in the robot.

Students with chronic illness have one consistent option to remain academically connected to their school—homebound instruction. The few students who were allowed the option of the robot had varied experiences with homebound instruction and virtual inclusion. These experiences ranged from a 3rd grader who had never attended a traditional school before using a robot to a 2nd grader who transitioned from a traditional student to virtual inclusion without ever using homebound services.

Samuel used homebound services for two academic years and was then able to use the robot the following school year. When I asked his mother to describe her child's experience with virtual inclusion, she stated that she was initially concerned that her son would not be able to attend a full day of school. His energy level and interest in school had dropped off dramatically and she believed he would be able to attend school for maybe 30 minutes to 1 hour a day. She attributed Samuel's energy level and lack of interest in schoolwork to his medical condition.

Once Samuel received the robot, his interest and energy increased and he attended a full day of school (six hours) the first day he used the robot. His mother commented, 'And once he got the robot, I mean, I never in a million years expected him to be able to go to school all day…I just did not expect it. And he went the first day and went all day…' Until she witnessed Samuel's increased energy and instant engagement in school activities, his mother had not realized that her son might have been experiencing depression as a result of his isolation from school and peers.

Mother: there were a lot of things that I didn't think he could, you know, with the progression of the heart condition, we kind of thought that he was just able – his ability to do things was lessening, I guess. There were a lot of things I didn't think he could do and I was attributing it physically. I didn't think he could do what he can now as far as stamina to attend all day. Which I think was maybe a little more of depression.

Samuel transitioned seamlessly from four hours of instruction per week to six to seven hours per day, five days a week. After receiving the robot, Samuel was not only motivated to do well in his regular classes but also auditioned for and made it into the school choir via robot. According to a school administrator, Samuel's music teacher was hesitant about allowing him to audition via robot. After the audition, the teacher reported back to the administrator that Samuel made it into the choir and that 'He has the voice of an angel.' She only heard Samuel sing via the robot.

Daniel also experienced both homebound services and virtual inclusion. He experienced homebound services for one semester shortly after his family relocated to a new school district. Unfortunately, his family's relocation occurred shortly before he was diagnosed with cancer. Even though a robot was available for Daniel to use during his 1st semester of 6th grade, the new school district did not support use of the robot and instead provided traditional homebound services. He and his family were greatly dissatisfied with the homebound services and when Daniel was questioned about his experience with homebound services, he sighed and quietly replied, 'I failed.'

After a semester of homebound services and the negative experience of failing academically, Daniel's family decided to move back to his prior neighborhood where his former school district and teachers agreed to use the robot. After using the robot to attend school for the 2nd semester of 6th grade, and with the full support and help of his teachers, Daniel was able to remain in grade and his mother expressed deep appreciation for the willingness of the school district and the teachers to try this new form of technology for her son. She felt that 'If it weren't for the robot and the school, you know, welcoming it and helping him and everything, he would have failed 6th grade.' His mother was very grateful that her son had achieved some academic success with the robot. However, when Daniel expressed what he liked most about using the robot, he did not mention academics. He responded, 'Just being there, to be there during lessons and stuff and seeing your friends talking to you…and socialize.'

Daniel enjoyed socializing with friends and seemed to feel increased motivation to keep up with his schoolwork when he was using the robot versus when he was utilizing homebound services but use of the robot did not completely remove feelings of isolation. When his mother expressed appreciation for the ease of robot use and how Daniel was able to use it unsupervised, Daniel expressed continued feelings of loneliness.

Mother: …he stays home, and there's times I gotta work and he's home by himself and he does everything by himself. He logs on, he – you know, he goes to school… It's very easy to function…

Daniel: I don't like staying alone.

The robot was Daniel's main form of human contact during the school day but it was not enough to remove feelings of loneliness. When questioned further about the robot and asked if there were any negative aspects about using the robot, Daniel replied, 'No, I don't think so. Other than not physically being there.' Daniel did not enjoy being home alone and he missed not being able to physically attend school.

For all students who attended school before diagnosis and experienced homebound services, the experience of being socially isolated was described in negative terms. The return to the classroom and subsequent social interactions via robot was, at least initially, a positive experience. Even for Eileen, who decided to return her robot, she felt that using the robot to 'hang out' with friends, 'was the fun part.' Social isolation can have negative consequences for students and studies have shown that children with chronic illness who are restricted in their social activities should receive extra attention because they are especially vulnerable for problems in their social development (Meijer et al. 2000). For the majority of the students in this study, the robots seemed to provide a valuable tool for returning to school and experiencing some normalcy as students. However, even this technology did not remove all feelings of isolation. All students who attended school before the robot, like Daniel, expressed a desire to be back in school and physically present with their friends.

3.3.3. New experiences that generated talk of an academic future

New social experiences presented themselves to the homebound students and along with the new experiences came a new discourse about the future of the student. Teachers and administrators made frequent references to 'when s/he comes back' as an important motivator for using the robot. All participants including homebound students, classmates, teachers, parents, and administrators made references to need for the student to be academically prepared when s/he 'comes back to school.' Nathan's teacher commented, 'when he comes back…he's gonna know exactly what we're talking about…I think it will be such a smooth transition for him…'

The virtual inclusion of students with chronic illness not only allowed for the homebound students to engage in new experiences and interactions with peers and teachers as part of their academic experience but it also allowed their teachers and classmates to include the student in the discourse of the classroom and talk of the future. Talk of the homebound student attending class, participating in peer groups, and being prepared academically when s/he physically returned to school became part of the classroom discourse because the student was considered 'present' in the classroom. The student's presence, even though it was via robot, allowed for the student to engage in new experiences that contributed to both discourse and active engagement in their academic future.

3.4. Discussion

The representations of the data that emerged from the analysis provided a set of themes for understanding the experiences of children with chronic illness using telepresence robots to attend school. It is important to emphasize that these results were grounded in the participants' experiences and opinions and may not be generalizable to other groups. They do, however, provide valuable insights into the educational experiences of children with chronic illness utilizing telepresence robots to attend school. Nathan and the other homebound students interviewed for this study are just a small representative sample of a growing population in our educational systems that experience physical segregation and social isolation from school as a routine part of their experience. Exclusion from school is not unique to this population.

Historically, there have been other vulnerable populations that were excluded from our school systems due to the dominant public attitude that traditional schools could not accommodate them or meet their needs. For example, until a few decades ago, for reasons of both law and public opinion, most children with Trisomy 21 were excluded from attending public school. Following passage of the 1975 Individuals with Disabilities in Education Act (IDEA), this situation has changed and the vast majority of children with Trisomy 21 now attend school where they learn to read, make friends, and prepare for greater independence as adults (Buckley and Bird 2000).

More than twice as many children in the U.S. are diagnosed with cancer per year (about 16,000) (Ward et al. 2014) as are born with Trisomy 21 (about 6,000) (Parker et al. 2006), and thousands more face other debilitating illnesses such as heart disease and immunodeficiency disorders (Ward et al. 2014). Though for reasons of health rather than cognitive disability, too many of these chronically ill children are today excluded from school, also with serious negative consequences for educational and social development. This small study suggests that, with new technologies and the right approach, chronically ill students may also be better integrated into public education.

3.5. Implications for Practice and Future Research

The use of robots by children with chronic illness to attend school is a complex issue occupying the intersection of three different fields of research: education, healthcare, and technology. However, there is very little interaction between the professionals in these worlds and the child and family are often left to navigate this intersection on their own. The use of robotic technology allows students to remain connected to their school community while navigating the health care world but, as seen in this study, the use of this technology has also drawn a spotlight to the physical segregation and social isolation experienced by most children with chronic illness.

Innovations in technology (e.g., the robots) are not new to education but this study highlights a different approach than most technological advances in education. Technology in education is an ever-evolving field, but technological innovations in education have historically been implemented in a top-down, teacher-centered approach for more than 100 years (Cuban 1984; 1993). By contrast, the use of robots for children with chronic illness has come to the schools in the opposite fashion. The robots are being brought to schools in a bottom-up approach—individuals who are concerned about the quality of life of the individual child are introducing them into school systems. The use of robots for virtual inclusion was not introduced to improve school accountability or to assist teachers—the sole purpose was to help chronically ill children remain connected to their schools and friends. As information spread about this innovative use of a telepresence robot, individuals began advocating for the use of robots in schools and the technology was introduced into willing school districts (Hooker 2011).

For educators, one of the concerns expressed about this form of technology being brought to schools by individuals is that the robots have gone straight from production to consumer without any study on the impact of robot use on students or the most effective ways to implement this technology in a traditional school setting. In this study, the use of robots for virtual inclusion in the classroom looks promising for children with chronic illnesses but the success of this form of inclusion will vary by setting and participant characteristics. This study took place in rural communities with schools that strongly supported the use of robots in the classrooms. Urban schools or schools with resistant or hesitant school administrators and teachers may produce different outcomes and experiences.

Of equal concern is the issue of teacher preparedness. Since children with chronic illness have traditionally been excluded from their school communities, guidelines do not exist for teachers or schools on how to facilitate virtual inclusion or partner with health care teams to best meet the needs of these students. The partnership between education, technology, and health care teams is a key component to the success of virtual inclusion as the child will no longer be isolated at home but will be an active member of the school community and most educators have had little training on the needs of children with medical conditions in the classroom (Olson et al. 2004). The experiences of the children in this study suggest that professionals in education, technology, and health care need to increase collaborative efforts to provide more opportunities for improved health and social outcomes of a continually growing and vulnerable population of children.

3.6. Conclusion

While no general conclusion can be drawn beyond the experiences of these five children, the impact of remaining connected to their school communities is undeniable. The implications from this small sample are sobering—children with chronic illness and their classmates are strongly affected by physical segregation and social isolation and, until recently, there has not been a way to provide them with inclusive academic and social experiences.

One student comment may have captured the overall attitude of these students towards this experience. While Daniel and his mother were being interviewed at the hospital (per parent request), Daniel did not feel well and his mother suggested that he get some rest. He opted out of the interview and the interview continued with his mother in the hospital room. After a while, Daniel lifted his oxygen mask and called from across the room, 'Hey. I wanna be more a part of the interview.' This desire to participate even though he was not feeling well seemed to capture the spirit of the participants in this study—to be a part of the life that is going on around them. Future studies may provide insight into whether telepresence robots present a valuable means for them to do so.

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CHAPTER 4

MY STUDENT IS A ROBOT: HOW SCHOOLS MANAGE TELEPRESENCE EXPERIENCES FOR STUDENTS

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Abstract

Homebound students, those who can learn but have a serious health issue (e.g. cancer, heart disease, immune deficiency) that prevents physical attendance at school, are now able to go to school using telepresence robots. Telepresence robots are generally video conferencing units on remote-controlled robots. Previous research has shown that using these robots allows homebound students to interact with classmates and teachers as if they are physically present. But, what does this mean for teachers and administrators? We present a qualitative study of 22 teachers and school administrators who worked with telepresent students and 4 who decided against adopting the robot. Our goal was to learn how decisions are made to adopt the robot, what issues arise in its use, and what would make adoption easier. This study contributes new insights on teacher and administrator perspectives on what is needed for effective use of this technology in educational settings.

4.1. Introduction

Due to advancements in pediatric medicine, many previously fatal childhood diseases are now chronic illnesses [5,10,16]. As a result, millions of children and adolescents in the US now live with chronic illnesses such as cancer, sickle cell anemia, asthma, etc. [1]. This has led to a growing population of children who are unable to physically attend school but still need to grow socially and learn. Traditional services for these students consist of 4-5 hours of home instruction per week. Unfortunately, traditional home instruction services are not designed to fully support these students' needs and do not provide any avenue for the students to establish or maintain social connections to their school communities. Studies show that inclusive educational practices result in better outcomes for students [4,9], yet current educational practices reinforce the exclusion of some children with chronic illness from school.

Recently, technology has created the opportunity to include the homebound child in school. Videoconferencing has been used in schools, [6–8] but very few studies have explored the use of this technology for homebound children with chronic illness. Some studies examined a technology solution for hospital-bound children, using a non-mobile telepresence robot, PEBBLES [2,17], shown in Figure 4.1. The "face" of the robot showed the hospital-bound child's face, and the "head" could move to view different parts of the classroom, allowing others to know what the hospital-bound student was looking at. Since PEBBLES did not have independent mobility, it needed assistance when moving from one classroom to another, incurring a social debt to the helpmates.

Figure 4.1. From left to right, PEBBLES, VGo, and Double Robots used in schools

More recently, mobile telepresence robots, originally built to allow adults to work at a distance, have now been introduced into classrooms for homebound children. Both the VGo and Double (shown in Figure 4.1) have videoconferencing on a screen and allow the homebound child to control both the camera and the wheel/s from home. The child can move the robot around the classroom and is also able to go to lunch, music classes, assemblies and even field trips.

Our research on these robots is guided by Deci and Ryan's self-determination theory (SDT). SDT argues that all humans have universal, innate psychological needs (i.e., competence, autonomy, relatedness) and that if these needs are met, people will function and grow optimally. However, in order for humans to actualize their inherent potential, the social environment must nurture these needs. Our research focuses on the social-contextual conditions of telepresence robot use in classrooms. More specifically, we look at how these conditions facilitate learning and contribute to improved well-being for homebound students. In this study, we examine the factors that facilitate the use of this technology from the perspectives of teachers and administrators as these are the people at the front line of implementing this practice in existing school systems. Without these educators, the robots cannot reach the students.

In our initial study, five students found themselves fully capable of using the robot, offering them feelings of competence and autonomy, two of the three universal and innate psychological needs that are central to psychological health and well-being [11,13,15]. All students claimed to feel included in class; classmates referred to the robot by the homebound child's name as opposed to calling it a device or a robot. And, parents noted significant increases in their children's interest and happiness at being with their friends, fulfilling the third need for psychological health and well-being, relatedness [15]. In one striking case, before a child was offered the robot, his mother attributed the child's decreasing energy level to his worsening heart condition. She even worried that he wouldn't have enough energy to use the robot. But from the first day of going to school on the robot, he attended school 6-7 hours a day, five days a week. He was not only motivated to do well in his regular classes, but he also auditioned for and made it into the school choir using the robot. The child's earlier low energy was later attributed to depression. In addition, the teachers consistently talked about the child returning to school, which gave the homebound child hope and motivation to do well.

This case study also provided information about what features of the robot, originally designed for use by adults in an office setting, would better fit the needs of children in a classroom with classmates and teachers [12]. We highlight some of these design feature recommendations in this paper, as it is important for educators to understand some of the most common challenges to using this technology in schools. Key to robot functioning is Wi-Fi connectivity, which is often spotty when the child is driving the robot in the school halls. Batteries are occasionally limited, requiring the child to interact only from the docking station. A better solution for connectivity would involve equipping the robot with a hotspot.

The robot's audio is key; video is secondary to its presence in the classroom, but essential for the homebound child to see. A wide field of view is important especially in navigation. The user interface for the homebound child was not a problem, since both the VGo and Double use a mouse, track pad, or arrow keys to move. The interface is simple, but one child complained of pain in his finger from hitting the arrow key so much throughout the school day. We recommend a game interface for movement, something most children are familiar with. A number of other recommended features emerged in these cases and the full paper [12] contains many more details and the incidents that drove the recommendations.

Questions remain, however, about the settings in which these robots reside: The school and the home. The previous literature does not cover how the ***school*** should make decisions about allowing a child to come to school on a robot, what to do about the fact that schools are now ***connected*** to spaces outside the school, and what features would help the ***teachers***, who are already burdened with work, to accommodate the student attending school via robot. Schools are complex social settings where many different groups (e.g., teachers, students, administrators, and parents) interact to shape a child's life experiences. There is no research to inform the creation of guidelines for how to make the decision to offer the telepresence robot to a homebound student for school attendance. There is also no research that reveals the special issues surrounding the bridge from school to an outside place, the home or hospital. As the telepresence robot industry expands into schools, the information provided to educators varies by robot manufacturer. In order to successfully support the use of this technology for vulnerable students who are homebound, the HCI and education communities must pioneer the efforts to establish guidelines for educators based on formal objective studies. By interviewing teachers and school administrators, we sought to explore practices and design features that would help make adoption easier. This paper focuses on the following three questions:

- What line of decision making in the school system leads to successful adoption of the telepresence robot?
- What issues arise because the classroom and the home (or hospital) are now accessible to the other via the telecommunications link?
- What would make the adoption smoother for teachers?

4.2. Methodology

We conducted interviews of 14 teachers and 8 administrators in 9 different schools who had experience with telepresence robots being used by homebound students to attend schools. The homebound students were in the following grades: K, 2, 3, 5, 6, and 9. In addition, we interviewed 2 administrators and 2 teachers who explored the use of the robots and declined to use them, one even after having purchased it. All interviews were semi-structured and lasted 20 to 60 minutes. Interview topics included the administrative decision-making process for allowing a robot in school, how the robot was introduced to the school and classmates, teacher/administrator perspectives on robot use, and any reports of resistance to using the robot.

Interviews were recorded, transcribed and coded to identify patterns, similarities, and dissimilarities across the cases. We used open coding with iterative labeling of sections of data with testing of the labels across all data sets until they settled into a consistent set [3]. The constant revision allowed for some codes to be subsumed under broader and more abstract categories.

4.3. Results

Although there were a number of findings, we focus on the three research questions: The decision making process that led to successful adoption, the issues that arise because the robot provides a "bridge" between the classroom and the home or hospital, and ideas that would make the adoption smoother for teachers.

4.3.1. The Decision Process

Three major stakeholders were identified in all successful cases of robot deployment—parents, teachers and administrators. Any one of the stakeholders could veto the adoption. In the 9 schools where we conducted interviews, a school district administrator initiated 3 of the robots, a hospital administrator initiated 3 of the robots, 1 was initiated by a teacher, 1 by a former teacher, and 1 by a parent.

Getting Parent Support

All participants agreed that for the homebound student to use the robot, parent support was key. Administrators and teachers could initiate the idea, but the full support and cooperation of the parents/guardians was credited for success. All 22 participants who accepted the robot were strong supporters of the technology and were "excited," "thrilled," and "happy," that the child would be able to attend school via robot.

Gaining Board Approval

Once parents approved of the use of the robot for their child, district or school board approval was required. One school principal took a creative approach to gaining support from her district board. To demonstrate the potential of the robot as a participant in a learning environment, she attended the district board meeting via the robot. She rolled in as a robot and participated throughout the entire meeting as she normally would. She then made the formal request for one of her students to attend school via the robot. After the board gave her an "eye test" (i.e., made her go to the back of the room and read the board) and a "hearing test" (i.e. also made her go to a back corner of the room to see if she could still hear them), they approved the use of the robot.

Getting Teacher Support

Having parental support and district approval are two steps on the road to deploying a robot for a student. The third step is gaining support from teachers who will be interacting with the robot on a daily basis. Although all teachers were enthusiastic about the robot, one teacher reported feeling "nervous" and a little "scared." When questioned what motivated her to move ahead and do it, she replied, "I knew it was what he [her student] needed, so I did it." Her hesitations centered on being physically responsible for the robot and not knowing how to control it.

In schools where the decision was made to NOT use the robots, privacy concerns were cited as the main reason. In one school where two teachers were offered the opportunity to use a robot for a 1st grader with cancer, the teachers were strongly resistant. The student had been in their classrooms before diagnosis and they were not willing to reintroduce him to the classroom via the robot. Their main cause for resistance was fear that use of the robot would also allow the mother and other adults in the home to witness what happened in the classroom; posts about what they heard or saw might be made on social media sites. They knew that the mother of the child was active on Facebook and not always in positive ways. At another school, the deployment of a purchased robot was postponed indefinitely due to administrator concerns over a similar fear of the child's mother having access to the classroom and posting what she saw or heard on social media. We elaborate on this point in the next section about the "bridge" between classroom and home or hospital.

4.3.2 The Bridge Between Home and School

The robots used for students to attend school were off-the-shelf robots designed for use in offices and medical settings in the adult world. The only privacy/security features are the login password, an encrypted link, and the inability to video or audio record. There is nothing that ensures that only the student is seen in the classroom or that others in the home or hospital cannot see the classroom. One principal felt that her teachers needed what she called "safe space," echoing the major concern of the schools that did not adopt the robot.

Once the telepresence bridge between home and school is made, then aspects of the home (other children, dogs, parents, their objects and tidiness, etc.) are visible in school. Likewise, the bridge may allow for more people than just the homebound student to see and hear what is happening in school. Privacy of both settings is potentially violated.

Safe Space for Teachers and Classmates

One school created a safe space for teachers and classmates by requiring the at-home parent or adult to fulfill all the requirements and follow the school guidelines for a parent volunteer in the classroom. School administrators did not want to be excessively restrictive with the homebound parent so they transitioned the parent into the existing school structure of a classroom aide. By officially taking this role, it allowed the at-home adult to effectively 'enter' the classroom. In this role, the adult needs to be trustworthy and working within the parameters of school and teacher expectations to maintain student privacy and not discuss, verbally or online, what is observed in the classroom. In addition to officially becoming a classroom aide, the at-home parent/adult also had to agree that when the homebound student was attending school, the student would be seated where no one else in the home could view the classroom. We recommend that, when others are present in the home, the student wear headphones so others cannot hear the teacher or classmates and that the homebound student self-mute to minimize home noises from disrupting the class.

Safe Space for Homebound Students and Families

Viewed from the reverse direction on the bridge, classmates, teachers, and other school personnel now have access to the remote student's home. Most school children do not visit the homes of all their peers but the robots create an open bridge straight into that child's living room, dining room, bedroom, etc. It is just as important to have a safe space for the homebound student where items that are viewed or conversations that are overheard are not repeated or commented on. The VGo screen is fairly small and not much can be viewed beyond the student's head but other robot models, including the Double, have larger screens and may provide increased views of household items and people. In addition to visuals coming through the screen, sounds come through speakers and classmates in our study were aware of siblings, pets, and general household noises. An administrator made the recommendation that a curtain or screen be used behind the at-home student to prevent classmates and school personnel from seeing personal objects and to free parents from the pressures of "having visitors" view their house every day.

4.3.3. How To Make Adoption Easier for Teachers

Most educators have had little training on the needs of children with medical conditions in the classroom [14]. Teachers in our study were also not given much training on the function of the robot and no instruction on how to deal with the social complexities of the robot. One of the teachers who was excited to try it found herself "afraid to touch it" after it arrived. She was not sure what all the buttons were for or if she would inadvertently disconnect the student. One substitute teacher was unaware that a student would be logging in to the robot and turned it off against the homebound student's wishes. This prompted the homebound student to say he "hated" her. Most teachers found the physical robot fairly easy to accommodate in the classroom, not requiring any special arrangements beyond what a student in a wheelchair would need.

Experience with the robot led to a number of suggestions for design changes, which are detailed in Newhart and Olson [12]. Key for the teachers was the fact that the battery life was not sufficient for the student to stay connected for six hours of the day and to have the full mobility they needed. Inadequate battery life required intermittent docking throughout the school day. And, the Wi-Fi connectivity was often lost at router transition points, requiring the robot to be moved by hand to the next area. A teacher mentioned that "in between the hallways there were dead spots so that we would have to like push the robot a little to get it going again."

The VGo is equipped to announce its presence when it is first connected and its departure when disconnected. These announcements were annoying when they occurred because the robot inadvertently disconnected and then reconnected during lessons. This occupancy awareness feature could be replaced with a visual feature that goes on when the robot is occupied and turns off when it is not.

One frustration with everyday tasks for the teacher was that if there was a handout like a quiz or worksheet that was not delivered to the student at home in their box with the upcoming week's-worth of material, it was difficult to include the homebound student in the exercise. One student cleverly helped the homebound student take a quiz by putting on earphones to hear the homebound student's answers as she read the questions to him. The ability to fax material back and forth would be a welcome addition.

The placement of the camera near the projected eyes on the face of the robot was important for keeping the student engaged, especially younger ones. One teacher reported that she made every attempt to keep the remote student engaged by "looking at his eyes and making sure he saw my eyes." When questioned about this practice she said it was what she did for all of her 2nd graders.

Several teachers expressed worry that they would be held responsible for any damage to the robot. To continue the theme of "safe space" for the teachers and increase teacher buy-in, administrators should make clear that the physical and financial responsibility for the robot lies with the school or district and not the individual teacher. Of all 14 teachers interviewed, no one knew who paid for the robot, who paid the monthly robot access fee, or who paid for the student's laptop or tablet. Transparency on financial responsibility of the program may ease teacher worries about an expensive piece of technology that is being placed in their classroom.

Schools should have clear guidelines on the selection criteria for use of the robot in order to provide equitable access to the technology. Once selection is made, how a robot is introduced to the school should be tailored along parent and student preferences. While a large production at a school assembly where the robot is rolled out and introduced to the entire school may suit some students, other students do not like being in the spotlight. One student in our study returned her robot because she "didn't like all the attention." The robot physically represents the student in her school community; how she meets and engages with peers should also socially represent the student.

4.4. Recommendations

From the descriptions above, we have recommendations for the social practices surrounding the adoption of the telepresence robot for including a homebound child in class.

4.4.1. For the parents

We know that the parents' cooperation and support of the robot's use is key. Sometimes the parent has to be the initiator, advocating because they believe that having their child attend school on a robot will contribute to their child's well-being [15].

We recommend that the parent and child place the computer that the child will be using in a location that does not violate the household's privacy. Often this is the dining room or a study, not in the living room where there is a lot of traffic and visibility. We recommend that the child communicate with headphones and a microphone so that the classroom activities are not broadcast to others in the household and household activities are not broadcast to the classroom. Privacy is important for both home and school.

In addition, we recommend that the parents go through training as a classroom aide, so that they are aware of what appropriate behavior is for adults in the classroom. In particular, they are not to breach the privacy of their child, the teacher, or their classmates on social media. In many ways, the parent who is near the homebound child on the computer is like a parent attending the class.

4.4.2. For the school administrators

The school administrators should bring the parents and teachers together to make the decision of whether the homebound child can attend school on a robot. Together, they will come to an understanding of the ground rules as well as the responsibilities and opportunities available. By working it out, they can become a model of inclusion for others.

The school administrators should make sure that the robot's communication path between the school and the home is encrypted, and that the parent has gone through training as a classroom aide. In addition, school administrators should take physical and financial responsibility for the robot, and communicate that to teachers.

School administrators should also plan for equitable access to the technology and how to introduce the robot to the school community and perhaps to the parents of classmates. Some homebound children welcome the attention; some do not. The robot introduction should include the needs and wishes of the parents, homebound children, and teachers.

4.4.3. For the teachers

Like the parents and administrators, successful adoption requires the teachers' buy-in. But to make the teachers comfortable, they need the assurances from the school administrators that they are *not* responsible if something happens to the robot.

The teachers should be informed about the homebound student's capabilities and schedule. Some homebound children are undergoing therapy treatments, for example, and will need lesson schedules adapted for them when possible.

Teachers need to be trained on how to operate the controls on the robot itself. They need to know how to adjust the speaker volume, how to turn it on and off, how to move it if it gets disconnected, and how to dock it for power. These instructions should remain in the classroom in case a substitute teacher comes and needs to work with the robot.

Before formal introduction of the robot in the classroom, the child should have a special session with the teacher to determine the best placement of "the desk" so the child can see and be seen, hear and be heard adequately. If the child needs to move from room to room, this early session can include a guided tour of where they have to go (e.g. to the music room or the lunch room) and the student should be provided with a map of the school. The student can plot on the map where the connectivity is spotty so the teacher is aware of problem areas and the student can avoid those areas until the connectivity issues are resolved.

To support the inclusion of the child in spontaneous new lessons that involve handouts or quizzes, the school and the home should include fax machines or comparable transmission of tangible documents.

4.5. Conclusions

There is mounting evidence that using a telepresence robot to include homebound children in school is important for their social as well as academic development. In other papers, we have focused on the experience of social inclusion of the child, and design recommendations for modifying a robot so that it is a better fit for children in schools. In this paper, we focused on what school professionals can do to make the appropriate decisions about whether to attempt this intervention, and if so, what to do to prepare. Teachers and parents need adequate training on the technology and provision of safe spaces both in the home and school. We believe through better understanding of teacher and administrator perceptions and attitudes, more children with chronic illness will have the opportunity to experience school attendance via robot. Providing the opportunity for this practice is the first step towards conducting future studies to evaluate the effectiveness of this practice and improve the standard of educational services afforded to homebound students.

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CHAPTER 5

GOING TO SCHOOL ON A ROBOT: ROBOT AND USER INTERFACE DESIGN FEATURES THAT MATTER FOR LEARNING IN SCHOOLS

Recently, telepresence robots have been introduced as a way for students who are homebound due to illness or chronic condition to experience a much richer learning experience than the typical home instruction services for 4-5 hours a week. Telepresence robots are videoconferencing units attached to a mobile robot base that a child can control from home. Because currently available telepresence robots were designed for use by adults in corporate or medical settings, they are not necessarily a fit for children in school settings. We carried out a study of 19 such students, interviewing and observing them as well as their parents, teachers, administrators, and classmates. We organized our findings along the lines of the various tasks and settings the child was in, developing a ***learner-centered analytic frame,*** then ***teacher-***, ***classmate-***, and ***homebound-controller-centered*** analytic frames. Although many features of some current robots fit school settings, we discovered a number of cases where there was a mismatch. While our results are described according to the analytic frames, our final recommendations are organized by the classes of features, such as audio, video, power, etc. to suit the developer. However, because solutions that benefit those with special needs often benefit the general population as well, many of these desired features are likely to benefit others in schools, hospitals, and offices, opening up even bigger markets for developers.

Introduction

Advances in pediatric medicine have changed the outcome of many once-fatal childhood illnesses. As a result, millions of children and adolescents in the US now live with chronic illnesses such as cancer, immune deficiency, and the like (Sexson & Madan-Swain, 1993). This has led to a growing population of children who are unable to physically attend school, but still need to learn academically and grow socially. In the US, traditional services for these students consist of 4-5 hours of home instruction per week along with sets of exercises and homework to complete by themselves. While this may, in part, serve the child's academic needs, it completely misses the social, developmental, and emotional needs of the child. Studies show that inclusive educational practices result in better learning (Erwin & Guintini, 2000), yet current practices exclude homebound children from the full school experience.

Recent advances in technology have created ways to include homebound children in school. Some educators and researchers have experimented with video conferencing to make a connection between the home and school (Ellis et al., 2013). One study examined a homebound child's use of video conferencing on an experimental non-mobile robot, called PEBBLES (Yeung & Fels, 2005) shown in Figure 5.1. The "face" of the robot showed the homebound child's face, and the "head" could move to show the student different parts of the classroom. Although this gave the hospital-bound students some agency to look at what they wanted, the students still needed assistance moving the robot from one part of the classroom to another or from one classroom to another, incurring a social debt to their helpers.

More recently, commercially available mobile telepresence robots have been introduced into classrooms. A mobile telepresence robot is a video conferencing unit on mobile robot base that is controlled by the homebound child. This mobility allows the child to move the robot around the classroom (e.g., for small group work or a story circle), go to lunch, music classes, assemblies, and even field trips as long as there is good Wi-Fi. Students claim to feel included in class once again, and parents note significant increases in their children's interest and happiness at being with their friends (Newhart, Warschauer, & Sender, 2016). Two commercial telepresence robots that are reported in newspapers and on company websites as being used by homebound students are the VGo and Double, shown in the middle and right, respectively, in Figure 5.1.

Figure 5.1. Three telepresence robots in school. Left to right are PEBBLES, VGo, and Double.

These telepresence robots, however, were designed for adults to use in offices and medical settings. VGo and Double are smaller, and as shown in Figure 5.1, about the size of an elementary school child. VGo was designed to be at the height of a seated adult; Double can change height from seated adult to standing adult. Their height and light-weight (i.e.,. 15 and 18 lbs. respectively) make them suitable for use in schools. Other telepresence robots like the Beam and RP-7 exist in the worlds of telepresence in offices and hospital settings, but are bigger and heavier, perhaps inappropriate for use in schools, although Beam+ has been used some in middle and high schools (Chang, 2016).

How well do these robots, built for adults in offices and medical settings, fit children going to school? What's missing? What other features would make it more suitable for this kind of use and for this kind of user? In this paper, we examine the experiences of 19 homebound children using VGo or Double telepresence robots to attend school. We examine the details of the situations student's experience in class, traveling to another location, etc. then focusing on the teacher's tasks, the classmates' tasks, and finally the student user experience through the controls at home. We call this a ***learner-centric analytical framework,*** but also extend it to the smaller but important tasks in the ***teacher-, parent-,*** and ***classmate-centric frameworks,*** then revisit the student at home using the controls in a ***homebound-controller analytic framework.*** These frameworks organize our findings around the situations in which we uncovered important features for students using the robots to go to school. This organization is less useful, however, for developers of robots. Accordingly, we then reorganize the findings into sets of features such as video, audio, user interface, power, etc. that better fit the questions that developers have. Because some of these desired features are expensive, but not necessarily essential to the learning experience, we suggest that future work be subject to a cost-benefit analysis. As features that help those with special needs are often helpful to the general population, we discuss how these recommended features may even broaden the market for an enhanced robot.

5.1. Related Work

5.1.1. The size of the problem

In the United States, advances in medicine have reclassified illnesses once considered fatal to chronic illnesses. As a result, the number of children with at least one chronic illness has grown dramatically in recent years. For childhood cancer alone, the overall 5-year relative survival rate for all childhood cancers combined has improved markedly over the past 30 years due to new and improved treatments. It has risen from 58% to 83% comparing cases diagnosed between 1975 and 1979 and those during 2003 through 2009 (DeSantis et al., 2014). Childhood cancer prevents children from attending school due to symptoms before diagnosis, then again during treatment and recovery. The American Cancer Society reports that in the United States, an estimated 15,780 new cases of childhood cancer were diagnosed in 2014 (Ward et al., 2014). If 83% of them survive, there are likely now 12,600 who are likely homebound from cancer alone, and thus experiencing physical segregation from their schools for long periods of time and social isolation during their critical developmental years (Ward et al., 2014).

There are a number of other diseases that keep children from attending school. Chronic immune deficiency, heart disease, sickle cell disease, HIV/AIDS, etc. all make the child especially vulnerable to diseases that are commonly passed among children at school. All told, prior research has estimated that 6.5% of children are at least significantly or permanently homebound, over 5 million out of an estimated 85 million school aged children in the US (McCabe & Shaw, 2010; McCarthy, Lindgren, Mengeling, Tsalikian, & Engvall, 2002). To gauge the size of this population with more recent data, we reviewed figures from the US Census (2016)and National Health Interview Survey (NHIS) (2016). US Census figures estimate the total 2016 US population to be 323,127,513. Of that population, Census figures estimate the child population (i.e., persons under 18) to be 22.8% with 6.2% of that figure under the age of 5 years. To align 2016 Census figures with NHIS (2016) data, (that provide school absence data for children 5-17 years) we removed the number of children under 5 years of age from the total number of children under 18 years of age. This resulted in an estimation for the percent of children in the US who are school-aged to be 16.6% or 53,639,167 children in 2016. The National Health Interview Survey (2016) estimates that 4.2% of children in this age group (i.e., 5-17 years) missed 11 or more days of school and .5% did not attend school at all due to illness. Based on NHIS estimates, the number of school-aged children in 2016 who missed significant amounts of school (i.e., 11+ days of school) due to illness would be 2,252,845 and the number who did not attend school at all due to illness would be 268,196. Through detailed evaluation of both US Census data and NHIS data, we estimate the size of the US child population who are significantly homebound at a more conservative figure of 2,521,041 out of 53,639,167 school-aged children in the US.

5.1.2. Home instruction

Children attending school are generally in an academic and social setting 4-6 hours of every weekday, *20-30 hours per week*. In contrast, the standard of educational services for homebound children typically consists of home instruction services for *4-5 hours per week*. These services include: at-home instruction, at-home tutoring, and worksheets in packets that are sent home with tutors, siblings, or family members to be completed by the homebound students on their own.

The primary error that educators and administrators make is assuming that the effects of being unable to attend school solely impact academic achievement. Weitzman

(1986) found that although the student may be able to achieve academically with homebound instruction, much of his or her social and emotional development is fostered solely within the school setting. Absence from school affects students' social and emotional development, peer relationships, and family interactions, as well as academic performance (Sexson & Madan-Swain, 1993). Sexson and Madan-Swain go on to say that schooling for the child with chronic illness may be as critical for *social-emotional survival* as medical treatment is for their physical survival.

People have tried a number of solutions to supplement homebound academic instruction with social learning or provide more direct connections to the full school experience. Here we examine the use of social media to enhance home instruction and describe what has been tried with online schools. We then follow with an examination of the use of video conferencing into the regular school and, more recently, telepresence robots, both special-built ones from research laboratories and commercially available robots.

5.1.3. Social media

Some students with chronic illness use texting, email, and social networking sites to try to remain connected with their peers (Liu et al., 2015). Liu and colleagues conducted a survey of 10 children with chronic illness who were between the ages of 6-18 years. Medical conditions experienced in this sample group included cancer (4), type 1 diabetes (3), Friedreich's Ataxia (1), and both type 1 diabetes and asthma (1). It is unclear in the literature why conditions for only nine children were reported. However, researchers did not distinguish between types of chronic illnesses and recognized that child participants in this study had a range of chronic illnesses--including illnesses that may not have a significant lifestyle change for patients (Liu et al., 2015). Researchers also interviewed 15 healthcare professionals and 7 parents of chronically ill children to understand communication practices and challenges that these children encountered. The children in this study used various communication technologies to stay in touch with friends. Liu and colleagues (2015) found that texting and social networking sites, like Facebook and Twitter, were the most common forms of social media used by participants. Participants also reported that social media was not enough; they wanted to be able to talk more with their friends, interact more with their friends, and have better ways of communicating with their friends.

5.1.4. Online schools

Because providing the full range of academic instruction one-on-one to homebound children is prohibitively expensive, some suggest that online schools could provide a feasible alternative. Using simple web searches for online K-12 schools reveals a huge number of such services. They vary in cost (with some of them free) and offerings, with some having accreditation and even Advanced Placement (AP) classes. Recognizing the need for social connectivity, some online programs include a variety of student activities such as online clubs and student contests. We did not see any particular support for homebound children to form and maintain friendships with their local peers.

Although the quality of the materials through online programs may be on average better than what the home tutor can provide, there are two problems with online schools for homebound children. First, an important part of school is social learning, for example learning to wait one's turn, to wait in line, to raise one's hand to be called on, etc. These are difficult, if at all possible, from an online school. Second, it is difficult to motivate a child who may be depressed from loneliness to attend school with students they do not know. It is easier to do one's work when one's friends are also doing the same work, a phenomenon called *social facilitation* (Allport, 1924). When physically separated and socially isolated from peers, even in the face of high quality academic material, the homebound student's learning experience is incomplete.

5.1.5. Video conferencing

One would think that videoconferencing could offer a solution, such as that shown in Figure 5.2. Although there are several studies that have explored the effectiveness of teaching and learning via videoconferencing in general (Comber & Lawson, 2013; Hopper, 2014; Hussa, 2012), very few studies have explored the use of this technology for homebound children. A review study in 2010 acknowledged the paucity of studies of this practice and urged studies of all the new technologies for homebound children (Drotar, 2010). One recent study of three temporarily homebound students using videoconferencing for sporadic 1-hour conversations found that even with this low level of inclusion, the students had stronger relationships with their classmates and teachers, the families felt "normal" once again with a connection to the outside world, and the experience made reintroduction back into the classroom easier (Ellis et al., 2013). They noted, however, no change in the student's academic performance, and there were a number of hurdles to overcome. Some of these hurdles were technical (e.g., unreliable connectivity), but most were social. Teachers found setting up the connection stressful and an extra burden to their already busy schedules; students worried about friends seeing them with no hair; and it was a challenge to find appropriate time for the 1-hour sessions.

Figure 5.2. Child using Skype to come to class.

The earliest study of real-time videoconferencing to connect children with chronic illness and their classmates was conducted in Canada via a non-mobile telepresence robot through PEBBLES (Providing Education by Bringing Learning Environments to Students) (Yeung & Fels, 2005). PEBBLES combined videoconferencing with simple robotics to provide high school students with a presence in their classroom from a remote location such as a hospital or home, as shown in Figure 5.3. Case studies were carried out in three different classrooms with use ranging from six weeks to five months. These studies concentrated on evaluating the social, academic, and communication aspects of the system (Fels et al., 2001).

Figure 5.3. PEBBLES in class.

Investigators found that in time the students who used PEBBLES were able to take part in many of the same tasks as their peers and participate actively in their classroom without creating any excessive disturbances (Yeung & Fels, 2005). Real-time audio and video communication was valuable in maintaining or establishing connections with peers. However, the PEBBLES robot system was movable but not mobile (i.e., remote-controlled mobility) and needed assistance when moving from one class to another. Students did not have control over their mobility and thus may have incurred implicit social debt to their peers. In recent studies on telepresence robots in the classroom, classmates complained when the mobile telepresence robot lost connectivity and had to be carried or pushed on a cart (Newhart, 2014). It is possible that Yeung et al. did not examine this social debt since mobility was not an option when they implemented PEBBLES.

Other digital devices and interfaces such as tablets, computers, Skype, Smartboards, etc. have been used in educational settings. Local news stories and personal accounts exist but to our knowledge, no studies have been conducted on these technologies for homebound children going to school.

5.1.6. Telepresence robots

Two commercially available robots, VGo and Double, are reported in a number of news articles as being used by children to attend school. The news reports talk about how the students feel engaged and connected using the robot. Clearly, being with their friends and participating in school activities during the day and even after school is extremely important to them. Some of the articles report some negative aspects concerning their fit to school. For example, when Wi-Fi connectivity is spotty, both units stop in their tracks; when connectivity is restored, the VGo announces that the student is present, which is very disruptive to class. We are the first to do a systematic study of real-world users (i.e., homebound students) using telepresence robots in real-world classrooms. Our first paper from this study examined the homebound student's school experiences (Newhart et al., 2016). The second examined the ramifications for parents, teachers and administrators, highlighting, for example, that connectivity opens up issues of privacy, both for the classroom and the student's home (Newhart & Olson, 2016). This paper focuses on designing the robot and user interface devices to better fit classroom activities, better for the homebound student, the teachers and classmates.

Newly developed telepresence robots can be moved and controlled by a remote person. These robots provide real-time audio and video exchange, with the person's face typically shown on the robot's "head." Figure 5.4 shows four commercially available robots.

Figure 5.4. Four examples of commercially available telepresence robots: (left to right) VGo, Double, Beam, and RP-7

These robots differ from each other in significant ways. They have different mobility features; they may or may not allow pan and tilt of the camera; they have different microphone and speaker placements; and they have different network security features, among other things. Desai and colleagues (2011) present a nice comparison of the features of various robots and how they might matter in workplace settings. For my dissertation, I created a table that compares basic features of the Double and VGo robots (Table 5.1).

Table 5.1.
Comparison of Double and VGo features

	Double	**VGo**
Battery life	8-10 hours	6 or 12 hour option
Camera pan (left and right)	no	no
Camera tilt (up and down)	no (fixed)	180 degrees
Cliff sensors	No	Yes
Drive	1 large wheel	2 wheels and 2 casters
Facescreen, display static image	Yes	Yes
Facescreen, life-size	9.7" LED, Yes	6" LCD, No
Microphones	1 forward facing below screen	4 around video screen (2 front, 2 back)
Navigation control	Mouse, arrows keys, joystick	Mouse, arrows keys, no joystick option
Number of cameras	1 front facing and 1 "always-on floor view"	1 front facing
Resolution of cameras	5 megapixel	3 mega pixel
Speakers	1 below face	2 (woofer in base, tweeter in head)
Top speed	1.6 mph	2.75 mph
Two-way audio & video	yes	yes
Unit cost	$3K + cost of iPad	$5K
Video encryption	128-bit AES, HMAC-SHA1	SSL
Weight	15 lbs.	18 lbs.
Wheels are American Disabilities Act (ADA) Compliant	Yes	Yes
Wi-Fi Access Point switching	yes	Yes

A number of papers report on the use of robots in the workplace, healthcare, and aging in place (Kristoffersson et al., 2013; M. K. Lee & Takayama, 2011; Tsui, Desai, Yanco, & Uhlik, 2011). For example, people reacted to the person on the robot as if they were physically present, successfully collaborating on projects with informal (hallway conversations) as well as formal interactions (participation in meetings). Those using the robots found it difficult to "walk and talk" because of their having to concentrate on navigating the space. They called also for a way to identify physically who was on the robot, more than just looking at the face on the screen. Control over volume was difficult, often projecting a louder voice than intended for the setting. They also wished to know from where a sound was coming so they could orient to a particular person. As we will report, a number of these features are also important for homebound children in school.

In healthcare settings, the focus of the research was more on quality of care delivered rather than recommendations for enhanced features. For example, in an emergency room, care was much better because specialists could "hop on the robot" quickly no matter their physical location. But they did comment on desired features as well. For example, because remote physicians were often involved in doing rounds, they asked for better aids in navigating.

Schools differ from workplace and healthcare situations in a number of important ways. In these environments, the users are adults; in schools the users are children who are engaging in critical intellectual as well as social-emotional development experiences. These experiences are occurring while the student is moving around the classroom and in some cases from room to room. For adults in health care settings, there is a formal provider-recipient interaction where the physician is viewed as the disseminator of knowledge, and often the remote physician is brought in for a particular issue, such as diagnosing a medical condition. In schools there are similar provider-recipient interactions between teacher and student but the model is flipped—the provider is a human and the recipient is on a robot. In addition to the role of recipient of knowledge, the homebound students also plays a role similar to that in a corporate setting where s/he is a colleague and engages in peer-to-peer interactions with classmates.

In corporate settings, there is a social structure that more closely resembles a school setting in that the robots may be used for both formal and informal interactions. In an office, the robots are used not only for top-level executives who are viewed as disseminators of knowledge but also as corporate workers who may play dual roles as both disseminators and recipients of knowledge. Top-level executives may use the robots to attend conferences/meetings where their presence is critical for decision-making and thus follow a pattern of formal interactions much like physicians. Corporate workers, however, may use the robots to attend important events but may also use the robots for daily interactions with colleagues, superiors, and subordinates. It is in this transitioning between interactions and roles via robot that the adult experiences of telepresence may assist in better understanding of student experiences.

5.2. Method

5.2.1. Participants

We interviewed participants in nineteen cases of children with chronic illness who were currently using or had previously used telepresence robots for virtual inclusion (Table 5.2). The children in this study had a range of chronic illnesses including cancer (12), spinal muscular atrophy (3), immunodeficiency disorder (2), heart failure (1), and unintentional injury (1). The age range of the children was 5 to 18 years old with 10 male students and 9 female students. Of the 19 students covered in our study, in-person interviews were conducted of 11 students. Not all students were available for interviews due to medical issues and data for 8 of these students was collected from parent or educator interview.

Table 5.2.
Homebound students (i.e., cases) in this study

Name	**Grade**	**Condition**	**Robot Used**
Bailey	11th	Autoimmune	Double
Ben	1st	Cancer	VGo
Beth*	7th	Cancer	Double
Dana	8th	Cancer	VGo
Daniel	6th	Cancer	VGo
Daphne*	K	Spinal Muscular Atrophy	Double
David	3rd	Immunodeficiency	VGo
Eileen	9th	Cancer	VGo
Hannah*	1st	Spinal muscular atrophy	VGo
Ian	1st	Cancer	VGo
Marco	12th	Spinal muscular atrophy	VGo
Nancy	2nd	Cancer	VGo
Nathan	2nd	Cancer	VGo
Nick*	9th	Unintentional Injury	Double
Robert*	1st	Cancer	VGo
Samuel	5th	Heart	VGo
Tara*	6th	Cancer	Double
Tina*	5th	Cancer	Double
Victor	6th	Cancer	VGo

*students were not available for interview, data was collected from parent or teacher. No real names or locations of participants are used in this paper.

In addition to collecting data from the homebound children, whenever possible, we interviewed and observed their parents/guardians (n=16), teachers (n=20), and school administrators (n=16) and conducted focus groups with the classmates (n=44). All interviewed participants produced a sample size of N=107 with an additional 45 classmates in two separate classes where observations and field notes on classmate interactions with the robot were recorded. We did not conduct focus groups after the observations due to issues with district parental consent forms. Notes from these observations were consistent with data from the interviews and focus group sessions and support our recommendations.

5.2.2. Interviews

Over 45 hours of interviews were conducted with homebound children and their parents, teachers, and school and district officials All interviews were semi-structured and lasted 30 to 60 minutes. Interview topics included the motivation for using the robot, technical aspects of robot use, and academic experiences while using the robot, social experiences while using the robot, child's well-being, and general experiences with homebound educational services when applicable (e.g., not all children received home instruction services). Interviews took place in multiple sites with child/parent interviews taking place in homes, a restaurant (child was traveling to the hospital), and a hospital. Interviews with teachers and administrators took place on school or district campuses.

5.2.3. Observations and focus groups

Observations took place in four classrooms where the robot was deployed. These observations lasted 45-60 minutes. Focus groups were conducted immediately after the observations in two of these classrooms. Focus groups of two full classrooms with an average size of 22 students, lasted 5 to 10 minutes. Discussions were limited to questions on the classmates' attitudes and perceptions of attending school with a robot. Open responses were allowed for each question with an average of two to three minutes allowed per response to each question.

5.3. The Robots In The Study

The robots used in these classrooms were the VGo, shown in Figure 5.5 and the Double, shown in Figure 5.4.

Figure 5.5. The VGo robot deployed in this study.

In all of the cases, the robot moved around the classrooms and could move between rooms (e.g. to the computer lab, gymnasium, lunchroom), and in some cases even went on field trips.

5.4. Results

In what follows, we present what was said and what we observed focusing on the expected ***tasks*** of the remote student while embodied in the robot, teachers, fellow students, parents, and administrators where appropriate. We begin with what is required from the school infrastructure to bring the robot "live" for participation and progress to a description of the tasks required from the remote student, teachers and classmates in the school environment. We end with a description of the home environment and the technology used to accomplish tasks from the home environment.

5.4.1. Participation essentials

The recent availability of affordable telepresence robots allows remote students to attend school from home. Once the robot is purchased, however, there are several technical features that are critical for use of the robot. It is important for users to understand the significance of these features and how they contribute to a remote student's ability to control the robot and actively participate in school. The robot alone is not able to provide the provide the full virtual inclusion experience for a student--schools must ensure that there is a technical infrastructure on campus that allows for strong connectivity, that remote students understand how their use of the robot affects battery life, and that there must a be a backup method for communication between the home and school.

Wi-Fi connectivity

The most cited frustration with the mobility of the telepresence robot used in this study was not physical obstacles but the Wi-Fi connectivity. All 19 cases, their parents, teachers, administrators, and their classmates cited frustration with the connectivity of the robot and the remote student (embodied in the robot) "turning off."

Connectivity issues varied from spotty connections where a student would suddenly be disconnected for a brief time—"it loses connection a lot and like gets back on five seconds later and I miss like the middle of a sentence that the teacher would be saying"-- to long-term disconnection. Eileen's mother reported that, "There were times when she couldn't go to class at all because we couldn't get it to connect" and, at the time of the study Nathan reported that "Sometimes it logs off and then it stays gray...takes like 30 minutes to log back on…" Victor had not been able to attend school for three months due to connectivity issues at the school. The principal of his school had provided the funds for Victor to have adequate Wi-Fi at his home but the school's technology team had not been able to work out the connectivity issues at the school in order for the robot to operate within the school. The robot sat unused and Victor remained limited to home tutoring until the school's technology team was able to provide the necessary hardware and connectivity.

More commonly, the connectivity issues were spotty and related to the strength of the school's Wi-Fi. Dan's principal reported that "The big problem [was that]….we tested with no kids in the building and it ran…but once the students came…they got all those cell phones and tablets going and...suddenly there were dead spots that we didn't find...and he would be driving...and it would just quit." Even when additional routers were installed, administrators still failed to understand why the robot would disconnect while traveling through the school. He blamed it on the robot's sending system, saying, "It needs a stronger receiver system...cuz my phone and my tablet don't lose connectivity where that robot's going dead." Understanding that connectivity might be an issue created opportunities for classmates to help in school areas where connectivity issues were identified. Nick's teacher pointed out that," My understanding is that he drove himself with an escort, and the only time people needed to carry him was when the Wi-Fi knocked out or the Bluetooth knocked out in a dead zone in our school, which ironically is the hallway that you have to take to come out to where I am in the trailers…"

Accordingly, we recommend consistent connectivity in both school and home environments. The fact that the robot stops altogether in a dead spot requires intervention.

Router transitions

When the robot switched access points or lost connection, the robot would stop moving. We observed that, as a 2nd grade class was traveling to the gymnasium for a Book Fair, connection was lost. There was no Wi-Fi in the outdoor space between the buildings. The teacher then picked up the robot and hauled it to the gym on a wheeled dolly. Once the robot arrived in the gymnasium, Wi-Fi connectivity was restored and the student was able to autonomously wander around in the Book Fair. The teacher at this school stated that this was a common practice as, "The robot is hooked up to Wi-Fi so when we go in between buildings, it loses the feed." A teacher from another school also mentioned that "in between the hallways there were dead spots so that we would have to like push the robot a little to get it going again." A student reported that, "when it leaves one point and goes to the next one for like maybe three seconds, it'll pause and then it'll reconnect and then it'll keep going." An administrator from a middle school that did not have outdoor spaces between the classrooms and buildings described their solution to this problem. "We put in more contact points and got it where we got smooth transmission throughout the building. But infrastructure's a big deal with this robot."

We recommend that that an adequate number of routers be installed along the paths the robot must travel to get to classes and regular activities. We also recommend that these routers be tested during high traffic hours when other students are also using Wi-Fi connections.

Hotspots

Mobile hotspots are devices that tap into a cellular provider's 3G or 4G wireless data service to deliver internet data at broadband speeds via a built-in Wi-Fi router. They work anywhere that the data service receives a signal and vary in size and shape but are typically the size of cell phone or wallet. In this study, hotspots were used by the remote students as a way to maintain connectivity to their laptops during long drives to the hospital or when traveling outside of the school or home where strong Wi-Fi was not readily available. However, some hotspots did not have strong enough signal for this practice and one parent reported having to upgrade her phone and data plan in order for her child to attend school during the long drives to the hospital "we're actually on our way...to pick up my new phone so the hotspot works and then he can go back to school."

Hotspots were also used at the schools to provide consistent connectivity for the robot between transition points. However, the robots do not have designated ports or places to attach hotspots and there were some issues reported with the placement of the hotspots. "We had to use a hot spot and that was spotty and it was on there with Velcro and so when they moved the robot, we were concerned it would fall off...and it still had some issues traveling…"

We recommend that hotspots be provided for the robot and homebound student as needed (e.g. travel, outdoor hallways, field trips, playground, etc.).

Consistent transmission

Delay can be very disruptive to human conversation. At the end of every utterance, the normal pause to signal that you will not continue speaking, to signal someone else may take a turn is 200 ms. (Walker & Trimboli, 1982). When the pause is longer than this, people may assume the person is finished speaking and they are free to take the floor. People assume that the robot will behave similarly to humans since it has a "live" audio/video feed of the homebound student. Classmates may assume silence beyond this length (i.e., 200 ms.) are the remote student's signal that s/he has completed their communication or, conversely, the remote student may assume that a pause in the remote classroom is an opportunity to speak next. This happened with the robots in the classroom. If the remote child hears a question that has been significantly delayed from a slow transmission, they will be delayed in responding and sound even more delayed back in the classroom. One teacher reported that she had to alter her teaching style and increase the wait time for responses because "there's a delay… he'll say something and then like two, seconds later, you'll actually hear him say it." "They would ask her a question...she would answer it...but they would think she wasn't answering it so they'd just move on…" Eileen also commented, "and like every single time I would talk, it would get delayed. Like it would take a few seconds for my words to actually come out of the robot."

We recommend that the connectivity have enough bandwidth to reduce artificial delays in conversations.

Battery life

In addition to losing connectivity due to issues with Wi-Fi service, users of the robots also struggled with loss of connectivity from battery life. The VGo comes with two battery options, a 6 or 12-hour battery life. At the time of this study, the cost of the extended battery (i.e., the 12 hour battery) was an additional $185. Three out of the 19 homebound students expressed frustration at the battery life. One set of classmates said they were frustrated at having to carry the robot when the battery went out. A student who attends a full day of school must be able to rely on enough power to run at least 6 hours. There was one reported incident where the robot battery went out completely while the robot was going up a ramp. A parent reported that the robot "shut off on one of the ramps...nobody was in the school and we're calling…'my son is stuck...by the lunchroom...Could somebody take him and charge him?'' An administrator commented, "The battery is lasting but he certainly can't go all day" and a student put it simply when she said, "It didn't last all day."

Many held the view that the battery ran out faster if the robot moved more. One student mentioned that she was told, "The more you roll, the more battery it wastes." This was a problem for her because she was in high school and had to travel between classrooms spread out on two different floor levels. A teacher of another student commented that, "When he comes back from the gym, he's almost out of battery 'cause he's been moving so much." Another teacher suggested a design change, that the head move separately from the body so that it would make fewer gross movements to turn to see something. Another teacher came up with a solution to compensate for the short battery life. "We just leave him on the charger so that the battery charges...battery, that's a frustration...but we've been able to work around it...we keep the docking station at his desk…" While this work-around is good for a child who is in one classroom all day, this solution may not work for students who travel to different classes throughout the day. Four of the 19 cases reported issues with battery life. All four cases were using VGos but were not aware if their robots were equipped with VGo's optional extended life battery or not.

We recommend that the battery be able to last for at least six hours including allowing for student movement throughout the school.

Ensuring student privacy

When people are collocated, they have a general idea about who can see them and who cannot. When the actions are communicated long distance via digital feed, there is always worry of unauthorized interception of the feed (Guizzo, 2010). Teachers and administrators are the people responsible for ensuring student privacy and monitoring student-only access to the classroom via the robot. The VGo and Double robot address this risk and assist school staff by providing a strict username and password login system, encrypted feed, and not allowing video recording of the live stream. Administrators knew of and appreciated these features before permitting use of the robot in their schools. One administrator stated that he would not have supported use of the robot in the classroom if it could record, as this would violate student privacy. A second aspect of privacy, the fact that the parents can see into the classroom and the teacher and classmates can see into the home are discussed in later sections (4.3.6 and 4.5.7.)

We recommend the robot transmission feed be encrypted, a strict password system be used at both ends, and that video recording be disallowed.

Secondary communication channels

Twelve of the nineteen participants and their parents reported using a cell phone to communicate with school faculty, staff, or peers when they encountered connectivity or battery issues with the robot. Teachers also reported using cell phones to communicate with the remote students when there were connectivity issues. One teacher even reported asking a classmate (who was a close friend of the remote student) to text the remote student on his cell phone to see if he wanted to continue to attend class. Four of the students who used a cell phone for backup communication also used Google Classroom. One student did not use a cell phone but used Google classroom exclusively to communicate when she experienced connectivity issues. A teacher explained, "have a backup plan …If something is going on where one of you can't hear each other or there's connectivity issue, have a chat opened separately…it can be through your Google Classroom…" A backup form of communication was necessary due to the inconsistent connectivity of Wi-Fi and battery issues.

We recommend that the school and the homebound student mutually agree on a secondary mode of communication to help them recover from various outages.

5.4.2. Homebound Student Tasks On The Robot

After the robot is purchased, the Wi-Fi infrastructure is established, and connectivity is consistent, the remote student can begin actively participating in school activities. We outline expected tasks for these activities according to location. The first section describes expected tasks that take place in the classroom; the second section describes tasks outside the classroom, and the third section describes tasks in the home environment. The tasks inside the classroom are broken into three participant groupings: 1) remote student via robot, 2) teacher interacting with the robot, and 3) classmates interacting with the robot. Due to inconsistency of teacher and classmate presence, the second and third sections describe tasks solely expected of the remote student.

Attending class

Students used the robots to attend traditional classes such as math, language arts, science, foreign languages, art, history, tutoring, physical education, social studies, etc. The opportunity to attend classes was appreciated by all participants; however, hours of class attendance varied by participant due to medical or physical restrictions. Since students needed some degree of flexibility in their class attendance, teachers appreciated knowing when the student was arriving to or exiting from class. Three students shared that their VGos verbally announced when they had logged in to the robot and when they logged off. Although fitting the original purpose, this self-announcement turned out to be very disruptive when the robot was going repeatedly on and off due to spotty connectivity. When it announced "Samuel is in the room" and Samuel had been in the room throughout class, it was at first comical. But on its third or fourth time, it was annoying to the point of having to turn Samuel's robot off entirely. This announcement feature was reported during year one of our data collection but during years two and three, this feature of the VGo was not reported as a nuisance. It is possible that the announcement feature became optional or awareness of how to turn it off became more widespread. Participants using the Double robot did not experience disruption due to this form of occupancy awareness.

Given these issues, we recommend that for occupancy awareness, the robot softly announce entrance and exit or a light go on and remain on when the student is connected to the robot.

Personalization

The social environment of a school is as complex as the physical environment, with various personalities and age groups interacting for different purposes. However, with the physical, moving robot, homebound students are able to rely on traditional social norms and relationships that remain fairly stable in the school experience. One social norm that most students follow is getting ready for school (like getting up at the right time and eating breakfast) but it also includes getting dressed for school.

Importantly, the robot's physical being was the representation of the homebound student. It was what the fellow students and teachers saw. Homebound children often expressed their identity by dressing the robots, being sensitive in particular in how they came across to their friends. Ten of the nineteen cases in our study dressed and personalized their robots at least once for the school day or a school event. In a related local news story (Brown, 2013), a 2nd grader (known for wearing pink) dressed her robot in a pink tutu and necklace, shown in Figure 5.6. Because neither the VGo nor the Double were built to be dressed, eight students using the VGo taped a hangar to the back and put a t-shirt on it to personalize their robots. Double has a convenient opening on the back of the robot where a certain model of hangar can be placed. Two students using Double robots used this feature to personalize their robots.

Dressing the robot did have some drawbacks. An administrator recalled that a VGo robot was not operating properly because the hem of a jersey was blocking the cliff sensor. Even the color of the robot evoked a connection with the person. A classmate commented, "I like the robot is white, because white is one of my favorite colors."

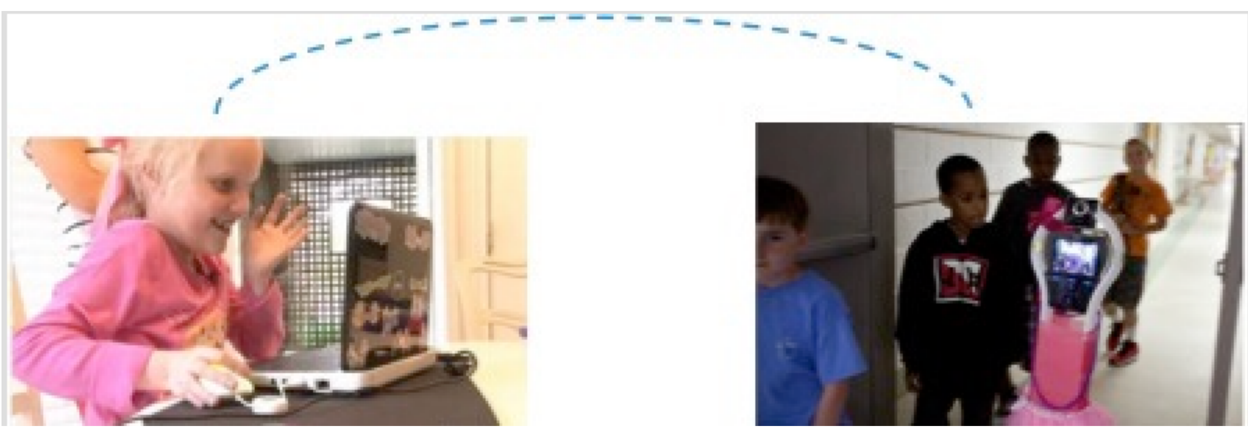

Figure 5.6. The VGo personalized to fit the tastes of the homebound girl (Brown, 2013).

Personalization of the robot also occurred through the screen or "face" of the robot. For example, Nathan, the one student who did not report personalizing his robot for school, still engaged in the social norm of getting ready for school. He dressed himself in his school uniform every day, even though he was attending school from home. His adherence to the school-required uniform was self-initiated and was visible to anyone who interacted with him via the robot.

One teacher, however, noted the downside of having a live video feed of the homebound student into the classroom. The student "... would be on his robot trying to take part in class and get physically ill, where he may start vomiting….and we would see that." She suggested that the camera of the homebound student be turned off, though the sound would be live. We recommend that in situations like this, it would be better to have a still picture of the child showing while the audio is live.

Because the robot is an embodiment of the child, we recommend that the screen be big enough to show the homebound student's face and shoulders near life size. The VGo's 6" (diagonal) screen in our study "shrinks the head" of the student, whereas the image on the Double is nearly life size 9.7" (diagonal). We also recommend the robot be able to switch the live video feed to a still picture of the student's head and shoulders so that either some acts of the illness or resulting physical changes (e.g., loss of hair from chemotherapy) may be hidden from those in school per homebound student preference.

In all, we recommend that the body of the robot should also allow for personalization without affecting the sensors or cameras. The screen should be big enough to project the child's head and shoulders nearly life size. Additionally, the robot should be equipped to be able to project a still picture of the child per child's preference.

Getting attention

The remote student using the VGo has three ways to get attention via the robot: speaking up, moving toward the target person, and turning on a blinking light. The remote student on the Double may raise their "head", move towards the target person, and sway back and forth. For informal conversations, merely speaking up seemed to be sufficient. The audio was loud enough to be heard by, for example, fellow students walking with the robot down the hall, but not always in the lunchroom. One student reported, "sometimes...I just keep calling them...if they keep not answering me. Sometimes it's too loud at lunch."

The ability of the homebound student to move provided a second way to get attention in the classroom. Several teachers reported the robot "rolling right up" when the homebound student wanted to ask a question or join a group. The blinking light was used in more formal efforts to communicate. During our two focus group discussions, both remote students actively blinked their lights to signal they were waiting for a turn to speak. Overall, when asked how they gained attention from the teacher, nine students reported blinking their lights, two students reported simply calling out, two students raised their "heads", two students used text messages to the teacher or a friend, and four did not comment on how they got attention from the teacher.

We recommend that the robot have a light at the top that the homebound student can blink to call attention, providing a consistent visual signal to the teacher that the student is raising a hand. Volume controls should allow the homebound student to adjust the speaker level appropriate for the environment they are in, including the lunchroom.

Viewing objects in the classroom

Because the VGo camera could tilt up and down, students could look down to read papers that were on the desk and also look up at a projected screen. Unfortunately, the camera did not pan left or right. Consequently, if the student wanted to look at something to the right or left of the robot, the entire robot had to turn. This was a challenge to one student who wanted to watch the teacher as she spoke while walking around the room. Sam's mother commented on his vision via the robot, "you have...no peripheral vision...it's more straight focus...if they're like get this sheet out...he has to turn the whole robot around...and it makes everyone look up."

A teacher made a positive comment about the movement of the camera, "The robot can move its head [actually only the camera] up and down...so if he was working with another teacher...he would be able to face down and see what she was writing." However, the cues as to what the student was looking at were minimal; it would be better if the whole "head" could move so people could see what the student is looking at as naturally as is done when they are physically in the classroom.

Teachers also expressed appreciation of the child's ability to see what is going on in the classroom. One teacher remarked on the usefulness of this feature, "[especially in] science experiments in class and he's witnessing the science experiment." The ability to see the experiment performed and how it turned out allowed the remote students to participate in the problem solving and learn with their group in real time.

Ten students reported having problems reading the interactive white boards. During class time, students must be able to read information off bulletin boards, chalkboards, and SmartBoards. In all four classrooms that were observed, the robot was positioned near the front of the room in order to maximize visibility of the whiteboard or Smartboard at the front of the room. The robot's camera was best suited for the homebound student to read high-contrast information (i.e., black writing on a white background). Homebound students had complaints about the ability to see classroom material: "I couldn't see everything that was written on the board." "[She had trouble with] the document projector...cuz the white paper...the glare... she couldn't see the writing on there" "Depending on if the light is shining on it...We figured out..he can get in front and see like head on. It's more difficult if it's at an angle…'cause the light just reflects funny."

The camera could also zoom in and out, something that proved valuable on a number of occasions, but it too was not perfect. "[She had trouble with] the SmartBoard. So when she would zoom in, the words would get blurry."

The camera can also take snapshots of the environment, a feature that turned out to be helpful in augmenting note taking. One teacher, when asked what changes she'd like said, "[I'd like] a slate, a tablet-like device where if I'm teaching in my classroom and I've got the SmartBoard on...instead of having the kid go up to the board and write...they could write on this [tablet] and then it appears on the Smartboard."

Accordingly, we recommend that the camera for viewing classroom material be high quality, able to reduce glare and handle various lighting situations. The camera additionally should be able to move left and right as well as up and down, ideally moving with the screen as if a head. The camera's abilities to zoom and to take snapshots were helpful. Adding tablets that allow the homebound student to "write on the board" would add capabilities that are more inclusive.

Participating in class discussions

Participating in class discussions is an essential aspect of being present in the classroom. The ability to hear what the teacher is saying, respond, and gain feedback is central to both formal and informal interactions.

Some students reported that they are not able to distinguish from where the voice is coming if the person is not within visual range of the robot. Microphones are located in the front and back of the VGo robot, allowing them to hear anything around them. The remote student has the ability to control the volume of either one, including muting them. One student reported muting the back microphones because he was confused about the physical location of activities and people. His mother stated that he did that, "so he can kinda track better because…when they're both on, and somebody talks, he doesn't know if they're behind or beside him."

The student also reported that he turned off the back speakers because "it'll echo like in the front and back." Several students commented on the echoing of voices through the robot. One student using the VGo reported continually keeping his microphones muted because "if it's unmuted and the people on the other end say something, it'll kind of echo through the robot" During a focus group discussion, a classmate asked, "Why does sometimes your voice echo back? In the robot?" Nathan, the remote student in this case, attributed it to bad internet, but it is more likely due to a rebound from his speakers into his microphone.

Because the VGo speakers are on the front both in the base and near the screen, the voice appropriately appears to be coming from the homebound student's mouth. Because the school environment has periods of quiet in the classroom ("indoor voices") and noisy periods in class and in the hall, it is important for the fellow students or teachers to be able to control the volume on the speakers. Students reported, "We could turn the volume...just like the kids whispering, only the group could hear." It is hard for the homebound student to know how loud he or she is in these different environments. They are not able to hear themselves the way traditional students are able to when they are physically collocated.

A school counselor who was responsible for troubleshooting technology issues on the Double shared that, "there were some issues on days about either echoing or volume…I don't know what device it was coming from or if it was just a joint thing through the program, that I don't know." In this case, the echoing issue occurred on the classroom end. If the issue was not resolved quickly, the teacher would mute the robot as it was disruptive to the class. When there was some down time, the teacher would unmute the robot and try to troubleshoot the problem with the home student.

Classrooms contain a diverse body of learners. The same instructional style may not fit everyone. Barr and Dreeben (2014) found that teachers create subgroups of similar students to manage activities not easily handled the classroom as a whole. Because the robot is mobile, the homebound student can move to their group to work together. A teacher notes, "He could roll right up to their desk." During certain group activities, if the remote student has to speak with only one person, s/he can use the VGo headphone or ear bud jack. Since the robot has a volume control on it, the students in the group can control the volume to suit the situation. The Double robot uses the iPad headphone port for a forward-facing microphone. In order to use headphones with the Double, peers would need to be knowledgeable about unplugging the microphone to plug in the headphones.

We recommend two echo-canceling microphones on the robot so the source of sound can be located. At home, the remote student should either wear headphones or have an echo-canceling microphone. All should be able to be controlled both at home and on the robot. The speakers should be near the screen of the robot, projecting sound as if coming from the mouth. The robot should have a audio jack so that earbuds or headphones can be attached. We recommend that the homebound student receive training beforehand on what volume setting is suitable for "indoor voices" and to be heard in the classroom and/or hallway or lunchroom. A numeric scale on the user interface would also help students know which volume number is appropriate for which school situations (e.g., classroom volume could be at a "4" and lunch room volume could be a "9").

Sitting versus standing

Relative height influences ease of communication and conveys relative power (Burgoon & Johnson, 1998; Fullwood & Doherty-Sneddon, 2006; Rae, Takayama, & Mutlu, 2013). The VGo's height is 4 feet, which is about the height of younger elementary school children. Conversation with the VGo among high school students is less natural, as shown in Figure 5.7. The height is not adjustable; therefore, the robot cannot "stand" or "sit" to maintain eye contact with peers who choose to stand or sit while talking. None of our participants, however, noted this as a challenge. The Double telepresence robot has adjustable height, suitable for sitting and standing. Even when "sitting," the height might be helpful in adjusting the sight line around something blocking the view to the teacher, as mentioned by one of our teachers.

We recommend that the robot have adjustable height under the control of the remote student.

Figure 5.7. VGo with High School Student.

Completing assignments and taking tests

Having the remote student take tests is difficult to manage. The test needs to be sent to the student, the student needs time and a mechanism to mark on it, and then the marked test needs to be returned. All of these could be supported with a printer and scanner or a tablet and software that allows for stylus markings on an image, but not all the children are equipped with those. One teacher had a clever work-around; she designated a local student to be the homebound student's agent: "Like an oral quiz. I'd have one student put on ear buds so only they can hear him, and they would read into his speaker...and he could give the oral...answer...and only she heard." If teachers prepared tests online, this situation would be simpler (but with similar issues as in the next point about using the home computer for something other than running the robot). But online test taking has not yet penetrated to all schools; preparation for this is an extra burden on the teacher. Similar issues arise with handouts and worksheets, as well as turning in assignments.

We recommend this issue be discussed between the teachers who will be having a robot in their classes and the homebound student's family to come up with a solution that is age-appropriate for their student and fits their style of teaching and testing.

Participating in computer labs

A class in the computer lab presented another challenge to a student. While students in school worked on their computers, the remote student had to change his computer screen from displaying what the camera viewed in the room to displaying the technical material on the screen. When he did this, he could no longer "see." Daniel's teacher commented, "If we say 'let's go to this website and look at this' then he no longer sees us... He's like out of the classroom. He can hear but he can't see 'cause he's changed screens on his computer."

Samuel's mother reported that they worked around this problem by having two laptops open for computer class because, "You can't see what they're doing. That's the only downside…'cause the video still works and they're seeing him but he can't see what they're doing. So that's why we bring the other [laptop] so he can see what they're doing."

A second computer would also be necessary if the student were going to take tests or do worksheets electronically or "go to the board" when a SmartBoard is in use, as mentioned above in section 4.2.4. This solution may solve the problem of using the computer that drives the robot for something else but it may not be financially feasible for school districts to issue two laptops to each remote student.

We recommend that there be a way for the homebound student to control the robot in the classroom via a dedicated computer and use another device for various exercises and classes. Some students have attempted picture in picture (less preferred because the picture would be very tiny on a laptop). In order for the virtual inclusion experience to be as immersive as possible, we recommend a second device or computer monitor for additional activities beyond controlling the robot.

Moving throughout the school

In this study, robots were observed not only in four classrooms, but also in three hallways and a gymnasium during a book fair. Students reported attending libraries, assemblies, church, gymnasiums, auditoriums, stadiums, robot clubs, and museums. They had to navigate hallways, elevators and ramps via the robot. Within these different environments, there are several different types of flooring that students must traverse: linoleum, carpet, tile, concrete, blacktop, wood, etc. They must traverse door thresholds and ramps. Within each local environment there are combinations of desks, shelves, plants, etc. for the homebound student to navigate. Controls for navigating both models of robot are arrow keys, track pads and computer mice. Driving the robot takes a certain amount of cognitive load and one student commented that he would put the robot on mute when he was driving. He couldn't speak with others when he was driving the robot, "I'll have to unmute it, say 'hi' and mute it and then keep on driving. But I can't drive while I unmute it…" When questioned about this, he explained that it took too much concentration to "walk and talk" at the same time.

In this study, six students used the arrow keys, two used trackpads (iPads), and one used a joystick as exclusive ways to drive their robots. Two students reported using a combination of the arrow keys and a mouse. Eight cases did not did not share how students controlled their robots. One homebound student complained of having to keep pressing the arrow key to continue to go down a long hall and one student complained that his finger hurt after driving the robot all day. He then mused, "I wish we could hook up a joystick to the computer and then I could just use that to move the robot." When we suggested using the mouse, he replied, "That one's harder to do."

Challenges included stairs, elevators, ramps, doorjambs, and walls. The VGo, weighing 18 lbs., is light enough to be picked up and carried, as shown in Figure 5.8 at the stairway (Desai et al., 2011). An administrator reported that the robot was "a little wobbly" going over the door threshold. "It went over...but we had to make sure it didn't fall…" One administrator reported feeling that the robot was "underpowered" when going up ramps. While successfully going up ramps requires a strong motor and sufficient tread on the wheels, successfully navigating door thresholds was dependent on the robot's balance. Remote students also needed help opening doors and pushing the elevator buttons. A student reported being late to class and finding the door closed. Unable to open it or even knock, he moved the robot to face the door a few feet from it. He then moved forward as quickly as he could and rammed the door to "knock" on it. Another challenge came when a student was left inside a classroom, "Sometimes I'll get locked in a room and I can't unlock the door or open it...so lots of times I just wait there…I have the lights on though...so I don't sit in the dark."

One administrator reported originally being concerned for the safety of other children if the robot crashed into them or fell over. However, he reported that his fears had been unfounded due to the light weight of the VGo. There were no reports of the robot falling or crashing into another *student* but weight is a design consideration if the robot would be interacting with small children. While the robot is very stable, small children may not be. When Nathan was at a book fair we witnessed a classmate rush to get to a book and inadvertently bump into the robot. The robot teetered for a few seconds but regained its balance and then continued on its way. The robot did not fall over in this case, but it is easy to see how a stronger bump would have caused the robot to fall over. With the light weight of 18 lbs., running into the robot does not seem to pose any greater risk for small children than running into a real classmate.

Figure 5.8. Picking up the VGo at the Stairs.

Five students experienced crashing into things when learning to drive the robot, causing embarrassment for some students. Eileen reported, “In my first period class...every single person would stare at me and like crack up laughing if I ran into something.” For other students the crashing was reported as happening only “at first” when they were learning to “drive” the robot. In the two focus groups with classmates, they reported continued crashing and even falling. Nathan’s classmates commented, “Sometimes he bumps into a lot of desks” or, “He usually bumps into a lot of stuff.” Nathan himself said simply, “I crashed a lot.”

Samuel found that his robot behaved erratically and caused some frustration. His mother reported, “He gets really, really, frustrated when, it will start spinning or run into the walls or things like that.” Samuel followed with, “The wheels get a little crazy… it hit the door jamb...and then shut off...we couldn't get it back on for a while." When asked if that happened often, Samuel replied, "It ran into the wall yesterday after Math, and then it shut off..." Samuel's classmates also reported, "When he's driving around, he crashes and everything." They tried to troubleshoot the problem, saying "The robot's back tires, like, it gets messed up and he bumps into walls and stuff."

The Double robot has also displayed some erratic behavior. It reportedly "lurched forward and back uncontrollably." This behavior influenced a school district decision to not use the Double in their classrooms.

Samuel also struggled with his robot falling over. During the focus group, Samuel commented, "I hug the ground" and went on to explain that this meant the robot fell over. When questioned as to how many times he had actually "hugged the ground," he reported the robot falling four times and needing to be picked up by a buddy. His classmates confirmed that he "fell a lot." He reported this when it was only November of the school year; more falls were expected.

Samuel's range of vision affected his navigation, resulting in his bumping into things. He said, "I wish it had a wider screen so he wouldn't crash all the time...well a wider camera" and "I wish he had a backing camera so he knows where he's backing up." Samuel's mother also explained how she tried to help the classmates understand Samuel's vision via the camera, "I was trying to give a demonstration because they're like 'why do you keep running into the wall?' and he's not meaning to--sometimes it just does it on its own." She went on to describe what she told them, "If you close one eye and do this [make a circle with one eye and cover the other one] that's how the robot sees."

Accordingly, we recommend the robot be lightweight to be safe, have sufficient stability, to keep it from falling over, and have the power to ascend Americans with Disabilities Act (ADA)-compliant ramps. The camera should provide a wide angle of view and perhaps be augmented with a downward facing view when moving. Ideally, the control of motion should be less of a cognitive load, perhaps controlled with a joystick or a video game controller like an Xbox or PlayStation.

Extracurricular activities

Students attended several extracurricular activities via the robot. Seven students reported eating lunch with friends via the robot-- four in classrooms and three in the cafeteria. Many of the features and recommendations we outlined above applied to these environments with one exception. Of the students who ate lunch in the cafeteria, one commented that, " They had trouble hearing me because the lunch room's so loud and my robot is loud but not compared to the lunchroom…" Students also used the robot to attend field trips (e.g. visit to the Capitol, a professional baseball game) and extracurricular activities (e.g. choir auditions and rehearsals, Boy Scouts, book fair, freshman orientation, homecoming, and a costume party) and religious functions such as mass: "He goes up for his blessing just like the rest of the kids do." Attendees at some of these functions are expected to wear special outfits: choir, scouts, dances and costume parties, making the recommendation that it be easy to dress the robot even stronger.

In these activities, it is likely that the robot will be moving outside the school's Wi-Fi. We therefore recommend the use of a mobile Hotspot, perhaps even attaching it directly to the robot. Again, the robot's ability to traverse various floor surfaces and the power to move along with peers are important. The wheels and power need to be able to run over grass and carpet, including up a small incline. The importance of cliff sensors is reinforced as well.

We recommend that the wheels of the robot be able to be put in "neutral," disconnected from the motor but able to freely roll, so that if it needs to be moved manually, it can be pushed rather than having to be lifted or placed on a dolly.

The quality of sound from the speaker should be good enough to support activities like choir auditions or choir performances. Since the robot will be traversing unfamiliar territory with different social expectations about how loud someone speaks (e.g., church services), it is important for the homebound student to have indicators for different levels of his voice coming from the robot as well as the ability to mute.

We recommend audio adjustments with indicators on how loud one is at the other end, with possibly an indicator of the *relative* volume given the surround. Sound quality needs to be good enough for a choir audition.

5.4.3. Teacher Tasks

The previous section uncovered a number of desired features taking the point of view of the robot-student learning in school. In this section we take the point of view of the teacher.

Finding a "seat" for the robot

Teachers reported that they did not need to make any more modifications to the classroom than they would normally make for a student in a wheelchair. Aisles were to be kept clear, objects were to be picked up off the floor, and doors were held open for the robot, as they would have been for a student in a wheelchair. One administrator stated that they, "took the desk out and that's where the robot was placed." The goal is to have the robot at seated height with height adjustable so that it neither blocks nor is blocked by a classmate. As for placement in the room, five students expressed a preference for sitting in the front of the room. This placement may also be helpful if the teacher needs to see what the student is doing at home when there is a classroom activity such as science experiments or anything involving manipulatives. When the activity is manual, such as using counting blocks, the teacher needs to make sure the student is doing things correctly and be in a position to advise or give counsel.

Consequently, we recommend that the robot have adjustable height and a wide-angle view. Teachers would be advised to place the robot where the homebound student has a good view of important activities and information in the classroom, and where their activity can be seen by the teacher.

Handing out and receiving assignments

All remote students received packets of paper, manipulatives, and reading materials via parents, siblings, or home instruction teachers. Teachers and administrators expressed interest in features that would reduce the time spent on assembling take-home materials, allowing for increased teaching flexibility, and making the remote student "closer to being just another kid in the classroom." Both the VGo and the Double have a camera that can zoom and take snapshots. One administrator reported that the snapshot feature works but not as well if it is something that has to be handed in right away, like a quiz. He expressed, "so if there was a way to...scan and print out…and hand it right back...that would be really cool." Teachers often collect work from students at the same time and this would allow for the remote student's assignments to be included along with other classmate's work. This would also ease the burden on the teacher when grading assignments.

As noted above when focusing on the student, we recommend that this process be discussed and designed locally to find a workable solution. Three workable solutions include having a buddy have the answers whispered to him/her and written down in class, having a print/scan solution (e.g. a fax machine), and using a device (e.g., tablet) with the test taking done electronically, and with a stylus the student can even “show her work.”

Maintaining student engagement

Teacher-to-student and student-to-student interactions require that the homebound student be able to focus on the teacher or classmate, to read facial and gestural cues such as pointing at an object or giving a demonstration. The literature supports the effect of eye contact on learning (Fullwood & Doherty-Sneddon, 2006). One teacher reported that she made every attempt to keep the remote student engaged by “looking at his eyes and make sure he saw my eyes.” When questioned about this practice she said it was what she did for all of her 2nd graders. She felt it was important for maintaining the student’s interest and engagement.

We recommend a screen that portrays a life-size image of the homebound student’s face, with the camera placed as close to the student’s eyes as possible to emulate eye-contact.

Minimizing distractions from the robot

A number of people worry that the robot will be a distraction to the classmates in the classroom because of its novelty and its behaviors. One administrator noted that the initial distraction is short-lived. He remarked, “I’ve found that students are more comfortable with technology than adults, you know? They get used to it faster than we would.”

Some of the classmates noted distractions from the lights at the bottom of the VGo, hearing the overloud robot in an adjacent room, and being annoyed with the technical difficulties. One teacher, noting that sometimes the teacher had to call the homebound student's name repeatedly to get his attention (because of sound issues), said in response to asking if it was a distraction, "Not any more than a regular student, 'cause there are students we have to call on all the time."

Accordingly, if the technical difficulties listed in this paper were addressed, the distraction to the classmates would be greatly reduced.

Disconnecting the robot

While the remote students were largely in control of their connectivity, teachers could also disconnect the robot. There were no reports of the teachers disconnecting the remote students due to disruptive behavior by the homebound students. There were, however, reports of a teacher turning off the robot due to technical difficulties such as an audio squeal from a technical malfunction. In one case where the audio feedback was loud and disruptive to the whole classroom, the teacher reported that she first informed the homebound student that "it's not working right now" and she then turned off the robot. All reported instances of teachers turning off the robot were followed with an effort to reconnect the student when the technical issues or disruptive sounds were resolved.

A teacher reported that when fire drill took place while the robot was in class, she picked up the robot and carried it out with the rest of the class because the students were saying, "We can't leave [name] behind!" The teacher said that she was compelled to take the robot outside with them because she "could just see the school burning down and there's [name]-- his little face on the robot, burning away...wondering 'what's going on?'"

We recommend that the robot have a control on it to turn it off in the case of malfunctions or emergencies, and a setting to disconnect the wheels from the motor so it can be easily rolled out of the classroom manually.

Maintaining privacy from others in the homebound student's home

Just as the teachers and classmates can see into the homebound child's home (Section 4.5.7), people in the child's home can see into the classroom. Several teachers commented about some of the children's mothers being unhappy about what they had seen and posting comments on FaceBook. Teachers and school administrators were very unhappy about this. One school countered by requiring parents of homebound children to take training to be a school aide. One of the rules about being a school aide is to maintain the school's privacy by not revealing to anyone what goes on in school. This allowed the parent then to "enter" the classroom via their child's robot (being with the child, not the main head on the robot) and follow the rules of a classroom aide.

We recommend that the parents of the homebound child either:

1) contractually agree to maintain the school's, staff, and student privacy by not revealing anything they witness via their child's robot, or
2) receive appropriate training as a classroom aide—which again extracts a promise of maintaining privacy.

5.4.4. Classmate Tasks

Acting as helpers

Another frustration with the robot centered on the need for helpers and the implicit social debt that the helping act incurred. Twelve students and their teachers reported a need for helpers for at least one of the following: opening doors, accessing elevators, filling out papers, carrying the robot when it could not move, and guiding the robot. Students and teachers expressed the need for helpers to guide the robot "because there's no peripheral…" or "like, it's hard to see where you're going sometimes…" One teacher expressed the ineffectiveness of students trying the guide the robot with commands like "Go to your left! No, I mean your right!... and then he's looking this way and they're looking at him so their left and rights are opposites."

None of the contemporary, commercially available telepresence robots have arms to allow students to open doors or push buttons. Faced with an ADA-compliant door button, robots may "crash" into it to push it. A fifth-grade homebound student reported feeling frustrated when he came to school and found his classroom dark and empty. He turned on his lights and rolled around in the classroom but could not open the classroom door to find his class.

Another student, in high school, expressed frustration with using elevators to access classrooms on the second floor. She was frustrated at needing a friend to help every day. When her friend was sick, the homebound student reported sitting in the office and waiting for a buddy who never came. During a focus group interview of 2nd graders, one student reported "Sometimes he doesn't have enough charge and we have to carry him around to the classroom and he's kinda heavy." When asked if there were something they wish the robot could do, one student replied "two things—I wish we wouldn't have to carry him back and forth when he had connection issues and I wish he didn't have connection issues." The need for helpers is an obstacle to the remote student's autonomy.

To reduce the need for helpers, we recommend a wide field of view and the ability to move the camera and screen (connected, as if a head) left and right as well as up and down. Complete connectivity would reduce the need to carry the robot. And, when disconnected, again, we recommend the ability of a helper to put the wheels in "neutral," so they can easily roll the robot instead of having to carry it. In addition, if homebound students are going to find clever ways to "crash" into doors or buttons, the body of the robot should be robust.

Assisting when robot is bullied

Sadly, one normal behavior in a school setting is bullying. One piece of evidence that the homebound students were accepted as normal is that they, too, were bullied. One robot had his "face" smeared with ketchup, something he couldn't "see" nor feel; the only way he could have sensed it was if he saw the action and/or the ketchup was applied to the lens of the camera.

Another homebound high-school girl heard the remark from an oncoming boy in the hall, "What is that? A vacuum cleaner." Being very sensitive to her social presence, she refused to come to school on the robot again.

In a third incident, a classmate sitting nearby the robot in class subtly reached over and turned him off. Only later did the teacher see that he was no longer visible on the screen and turned him back on again. The homebound student was helpless to this action. The only recourse to this action is to use a secondary channel like a cell phone to reach the teacher. Being disconnected by others is very disheartening to the remote student. A parent reported that her child "does not like it when they end the call...he likes to end the call himself."

We recommend that controls for turning off or muting the robot include a pass code given only to trusted parties, such as a teacher and a buddy. Additionally, if the camera and screen could pan left and right as well as up and down, the homebound student could see who was around them and identify the bully. The potential bully would see the homebound student looking around and this action may defer their attack.

5.4.5. Homebound Student Tasks

Many of the things that are important in the design of the robot and the accompanying best practices have been covered above. However, some of the behaviors, including control of user interface, are best described from the point of view of the homebound student. We focus here on the practice of getting dressed for school, connectivity at home, some issues about seeing and hearing and being seen and heard, the user interface, and particulars about the fact that the remote student is in a house with other people and occasional pets.

Getting dressed for school

Older students who have been to school may realize the importance of getting ready for school because they will be visible on the screen of the robot. For younger children and children who may have not attended school before being on the robot, the process of getting ready for school, appropriately dressed because they will be visible via the robot may take some coaching. David, who attended school for the first time in his life via the robot, commented that the biggest change for him was that he had to get up earlier in the morning to get ready for school. He went on to describe that he had to "comb my hair a little bit earlier in the morning...brush my teeth and eat and be ready for school, like normal kids." When asked how he felt about these changes, he replied, "I don't like them, but they're good." Nathan, 2nd grade, also described getting ready for school by putting on his uniform. This is what he had done in 1st grade and he continued this practice when attending school via the robot.

We recommend that the practice of getting up and getting ready for school be established and regularized. There is the issue of self-presentation, but also being as normal as circumstances permit.

User interface and connectivity at home

Once students are ready to attend school, they log in to use the robot via their home device. Thirteen students in this study were given a district-issued laptop, four used a home computer, and two used a family iPad. All reported having adequate Wi-Fi connectivity in their home. As mentioned above, students used a combination of arrow keys, mice, and track pads (iPads) to control the robot. These devices all had a camera at the top center of the screen through which the homebound students could be seen by the students in the classroom. These devices also had standard microphones to capture the remote student's voice.

We recommend the addition of a joystick or XBox or Playstation controllers for the student to control their movement. The arrow keys could be reserved for moving the head (camera and screen jointly). We recommend that the user interface facilitate the ability to "walk and talk" at the same time for a more immersive experience.

Speaking to people at school

The microphone through which the homebound student is heard is located on a laptop or a tablet and is designed to pick up sounds from a wide physical range. Sibling tantrums, ice makers, television, conversations, and pets were all given as reasons for muting the home microphone. Ten students reported at least one instance of classmates hearing one of these sounds. The VGo robot also has the ability for text-to-voice transmission from the remote student. The student can be muted at home and type in what s/he wants to say and the robot will speak for the student. A student who was having feedback issues when he spoke used this feature. Samuel's mother commented that, "depending on where it's at, they can't hear if he has an extra feedback, they can't hear him 'cause it's like "err err' noise...so you can type into the robot...then it will say what you type." There were no reports of students using a dedicated microphone and it is not clear if that may be a solution for the student's need for self-muting or use of the voice-to-text feature.

We recommend a high quality microphone with volume control that is marked with various levels that the robot is projecting depending on its environment (e.g., mass vs. lunchroom vs. classroom). These settings will have to be determined and marked in a pretest setting in the school.

Hearing what people at school are saying

Students relied on the speakers on the laptop to hear their teachers and classmates. The robot has the ability to mute incoming sounds. Eileen reported that, "it was just hard to hear so that's the only reason I couldn't pay attention that well." It was evident that hearing ability affected her ability to pay attention to what was going on in the class.

We recommend stereo output for the homebound student, meaning the robot would have several microphones set to translate to stereo. This would help the student locate where a particular sound is coming from so they can move their head or body to that location to continue the interaction. The student should have the ability to mute the incoming sound, for example, while traversing to another classroom. Headphones would also help cut out background noise and improve the homebound student's ability to hear.

Being seen

The camera on the home device serves to display the student's face but it is also important for students wanting to show their work to their teacher or classmates. Just as the camera on the robot is critical for students viewing what the teacher is displaying on the board or on her desk, the home device camera is just as critical for students to share their work. One parent described, "He was able to demonstrate doing the ten-block squares and then moving the camera down so she [the teacher] could see" and another reported, "He loves his teacher...shows her things like...his drawings...and things he builds with his Legos."

We have recommended that the student arrange their camera so that most of the time, their face projected on the robot screen life-size. The student needs to have feedback about whether they have drifted off over time. Therefore, we recommend a small picture-in-picture to allow the students to position themselves correctly, whose visibility would be under the control of the student.

Being able to control what they see

All students need control over what they are seeing. It is also well known that conversations are more successful if the person you are conversing with knows what you are looking at as well (Vertegaal, Van der Veer, & Vons, 2000). The VGo "head" is immobile; the camera can pan up and down, not left and right. In order to look left and right, the homebound student needs to move the entire robot left or right. Furthermore, when the homebound student looks down at their desk, it is only the camera that points down, not the "head." Consequently, the teacher does not know where the student is looking. The Double does not have pan or tilt capabilities and some teachers recommended that their students back away from the desk to get a better view of the materials on the desk. As humans, we naturally move towards things we want to see better and the practice of moving away from something for a better view was difficult for students to grasp. As noted above, it is important for the teacher to assess the homebound student's attention or activity, something that could be better done by reading the body position of the student.

We recommend that the screen function as a head, with the camera on top and control of where the camera points involve head movement as well. We also recommend that the robot have a "neck" so that only the head turns when a student wants to look at something but not move their body. Taking the analogy of the head one step further, we recommended above that there be two microphones so that the homebound student could have stereo audio, to sense where a sound is coming from. These microphones could go on the sides of the "head" functioning as ears.

Avoiding home distractions

Remote students use a home device to attend school but the home environment can be disruptive to a fully immersive experience. Reports of sibling tantrums, noisy icemakers, ringing phones, pets, and parents doing chores were given when students were asked about home distractions. One student stated that he did not have any home distractions because, "I stay cooped up in my room." Others learned to mute their microphones until they wanted to explicitly say something.

The second issue has to do with preserving privacy (Newhart & Olson, 2016). With the live connection to the home, it is possible for the teacher and classmates to see into the home and make judgments as to cleanliness, the behavior of the parents and others in the household, etc.

We have already recommended above that the student have a mute button on the home microphone and consider the use of headphones if comfortable. In addition, we recommend that the student set up a "school corner" in the home that does not reveal general household activities to those in school.

Navigating (knowing where you are going)

Some students felt that they could find their way around the school quite easily. Others had difficulty, often requiring assistance from a teacher or student helper to guide them. However, seven students requested being allowed to practice driving the robot after school or on the weekend in order to better navigate their robot during the school day.

We recommend that the school allow a navigation training session before the robot attends school and give them a map to help the homebound student in finding their way around various parts of school. We also recommend that the training session include practice for navigating from the docking station to class and docking the robot after use.

5.5. Conclusions and Recommendations

Clearly, the robots are successful in allowing the homebound student to attend school, both its academic and important social functions. Indeed, at the date of this writing, there are hundreds of these robots purchased for use by homebound student to go to school. But the robots are not a perfect fit for this population. We have uncovered a number of aspects of the robot, its home interface, and auxiliary equipment that could improve the experience.

Above, we organized our recommendations around the experiences that generated them, which themselves were organized by the tasks of the student-on-the-robot in school, the classmate tasks, the teacher tasks, and finally the student-on-the-computer at home. To be more immediately useful for the makers of telepresence robots and for educators interested in using the telepresence robots, we grouped the recommendations by areas of robot or user interface in the six tables below. First, we note the technical features, then close with recommended social practices.

5.5.1. Participation essentials

Connectivity is key. Table 5.3 lists the essentials.

Table 5.3.
*Features to keep the robot **connected**, powered, and backed up if connectivity fails*

Wi-Fi connectivity with no breaks, both at school, at home, and on the road, implying hotspots. This implies having routers in school and hotspots on the road.
Transmission bandwidth to avoid delays
Battery life of at least 6 hours, including power to move a long time
A docking station in a location known to the homebound student (and not moved), preferably under the desk so it can be powered up while the student is stationary in class.
Secure network to ensure privacy of student behavior and information
Second communication channel to cover when failures occur.
Controls on the robot to turn it off, under password control, to disconnect in case of an emergency (like a fire).

5.5.2. Audio and video

When the student is interacting in school, the audio and video on both ends are critical. The features that we recommend are listed in Tables 5.4 and 5.5.

Table 5.4.
*Features concerning **audio** on the telepresence robot*

Microphones on the robot to convey stereo audio to the homebound student. We recommend they be mounted on the side of the screen representing the head as if ears.
Echo-cancelling mics so there is no feedback loop from the speakers.
An announcement when the homebound student is connected and leaves, but its operation should be under both the teacher and homebound student's control. The control needs to be under password control.

Speakers with high enough quality to represent the homebound student's voice accurately, good enough for a choir audition.
Transmission of the voice of the homebound student to be loud enough to be heard in the classroom, hall and lunchroom, with controls both on the robot and the homebound student's interface.
Speaker that are positioned on the robot as close to the screen as possible so the sound appears to be coming from the mouth.
A headphone jack so that a classmate can plug in earphones to talk more privately to the homebound student.

Table 5.5.
*Features concerning **video** on the telepresence robot*

A camera that is high quality with a wide field of view.
A camera that is placed as near as possible to the eyes of the student on the screen so the teacher can make eye contact to maintain engagement.
A camera that can be zoomed in and out, and one that allows snapshots to be taken by the homebound student.
The camera, attached to the screen as if a "head," able to move left and right as well as up and down, so the teacher and classmates know where the homebound student is looking.
A second camera, pointing down, to show the floor area near the robot to help in moving the robot without bumping into obstacles.
A screen big enough to show the homebound student's head and shoulders almost life-sized.
The ability to project a still picture of the student if the student chooses to not have a live video feed (because of disfigurement from the illness or treatment).
A light on top of the telepresence robot that can be seen from all directions, and on when the robot is connected.
A light on the top that can blink when the homebound student wants to "raise their hand."

5.5.3. Mobility and the robot's body

One of the key features of the telepresence robots is the ability to move about. This gives the homebound child autonomy and competence, two basic psychological needs (Richard M. Ryan & Deci, 2002). The features we recommend appear in Table 5.6.

Table 5.6.
*Features we recommend concerning the **mobility** and the robot's **body***

The ability to move at a variety of speeds, from navigating carefully around objects to walking fast when late.
The ability to turn left and right as well as go forward and backward all while showing both the head's camera and the floor-facing camera.
Sufficient power to move up ramps and self-braking to go down ramps.
Wheels that can be put in "neutral" so helpers can push the robot without resorting to a dolly.
A cliff sensor to avoid falls down stairs or off stages.
Stability to withstand humans accidentally bumping into it and to avoid falls.
A weight that would neither injure a child that it ran into nor prevent an adult from lifting it and carrying it.
A height of the robot that is adjustable so that it fits both sitting and standing positions appropriate for the classmate's age and activity. It should be continuously adjustable in case the homebound child has an obstruction it has to see around or over.
A body that can be personalized with a t-shirt or costume without blocking either the downward-facing camera or the cliff sensor.
A body that is sufficiently strong to withstand it crashing into doors (e.g., to summon help when the door is closed).

5.5.4. The homebound student's interface

The homebound student has a large cognitive task in attending school on a robot. Many features can be set and forgotten, but others, like continuous control of mobility, require attention. In the list above, we are adding features here for the homebound student to control. Consequently, we recommend concerted effort in making the robot controls as easy to use as possible, with some things set, and others under variable control. Table 5.7 lists the recommendations.

Table 5.7.
Recommendations for the ***user interface*** *for the homebound student*

The home speakers or headphones to convey the sounds from school in stereo.
The home speaker or headphone volume under the homebound student's control.
A microphone that is high quality and has echo cancellation.
Control over how loud they sound in the classroom, having been trained about what levels are appropriate for the variety of situations they will find themselves in, from church mass to the lunchroom or book fair. Volume controls include a mute button.
Arrow keys to determine what they are seeing via the remote camera, both up and down and left and right. These arrow keys control the head of the robot, both the camera and screen position.
Picture-in-picture of what the homebound student's camera is projecting so they align their face and shoulders correctly.
The ability to zoom in and out, and take a still photo for later reference.
Two screens if the teacher is using the web for lessons or the student is in a computer class.
The ability to "raise their hand" by blinking the light on the top of the robot, then make it steady again when they "put their hand down." The light is on when the student is connected to the robot.
The ability to raise and lower the height of the robot, with presets for walking and sitting heights.

The ability to print out the snapshot at home.
Mobility that is controlled through a joystick or game controller.
Navigation that is semi-automatic, such that pointing at a map or designated room name (e.g., lunchroom, gym) would take the student there, but the student could override it or interrupt if necessary.
The ability to follow an accompanying person, again with appropriate overrides as necessary.
In addition to a well-designed interface that controls the robot, the student will benefit from having age-appropriate options with which to receive and send assignments, worksheets, and tests. Some students would benefit from a tablet for taking tests and to connect with a classroom SmartBoard.

5.5.5. Recommended social practices

Not all the incidents listed in the first part of this paper have to do with features of the robot itself. Some have to do with how the robot is used by people and the setting in which it resides. For example, the fact that there is a connection between school and home or hospital opens issues of privacy (Newhart & Olson, 2016). In Table 5.8. we list these recommended social practices.

Table 5.8.
Recommended Best Practices for use of the Robot

Provide training for the homebound student to help them navigate the room and the school. Provide a map for later references when there's a new place to go.
Train classmates to be helpers for guiding, pushing elevator buttons, opening doors, and protecting the student-on-the-robot from bullies.
Place the robot in a position in the classroom so the homebound student can see all they need to see, including the widest view of the whiteboard or front material without being blocked by another student.
Pretest sound levels for different environments, so the homebound student can later know how to set their projected sound appropriately.

Collectively design a solution for exchanging both handouts and tests. The solution might involve printers, scanners, devices, or tablets with stylus capabilities.
Have parents of the homebound child agree to maintain the privacy of the school community, by not revealing to anyone the behavior of anyone seen or heard in the classroom via the robot.
Set up the placement of the computer and worktable for the homebound student so the family's privacy is not violated.

5.5.6. Better for everyone?

In the past, a number of redesigns of technologies for the less-abled benefitted those who were fully-able as well—for example, curb-cuts, ramps instead of stairs, closed captioning, and others (Lazar, Demiris, & Thompson, 2015). We believe that a number of the features listed in the tables above will benefit people using telepresence robots in offices and hospitals, etc. as well.

Many of these recommendations are specific to school environments. The secure network is necessary because of Family Educational Rights and Privacy (FERPA) regulations on student activity. Schools have much wider sets of environments in general than offices or even hospitals, requiring the variety of projected sound levels. The telepresence robots in offices and hospitals likely do not require an announcement saying when they are embodied or not. Making eye contact (having the camera as close to the projected eyes as possible) for engagement is less important, though if it is off by quite a bit, the viewer may misunderstand the attention level of the remote person.

Offices and hospitals are less likely to require a headphone jack for more private conversations, although that might be useful for confidential conversations with a patient's family member, for example. The robot's weight is less of an issue, confirmed by the popularity of the very heavy Beam (e.g., 39-90 lbs depending on model) in offices and conferences. Although personalizing the robot is less necessary in office settings, we are aware of instances of Double robots in offices being dressed (e.g., with a t-shirt noting the remote person's favorite sports team, and a silly Halloween costume).

Allowing the remote person to post a still-photo instead of a live feed is more important for an ill homebound student than it would be for a remote office worker. And, the light that allows the student to raise their hand is perhaps less necessary in offices and hospitals where people are more likely to just speak out. There may be situations in the office or hospital where mobility is unimportant; if not, then standard videoconferencing or even a Kubi, shown in Figure 5.9., would be sufficient. The Kubi is a videoconferencing unit that has a "neck" that has full pan and tilt capabilities. Full pan and tilt of the camera and "head" allow the remote person to direct their camera view along with the associated face view while also indicating to remote people where they are looking.

Figure 5.9. The Kubi

However, many of the other features we recommend would make the robot better for everyone. Stereo audio, cameras attached to the screen with separate controls for moving the camera and moving the whole robot, etc. are all features that would benefit those in other environments.

Admittedly, doing all of these improvements would have significant costs both in development time and costs rolled over to the customers. If we handed these tables to developers, their first reaction would be, "Yeah, but which ones *really* matter?" In return, we might say, "Which ones are *really* feasible to build?" Future research will address this issue.

CHAPTER 6

DISCUSSION AND CONCLUSION

This dissertation was motivated by the growing population of children with chronic illnesses who receive minimal homebound educational services. In the U.S., the use of tele-technologies by health care teams is now of such quality that the Centers for Medicare and Medicaid Services (CMS) has released reimbursement rates for some medical services that are delivered via these technologies (CMS, 2018). In my dissertation, I aimed to explore if similar tele-technologies may be as effective for patient personal use as they are for physician professional use. These technologies are considered effective enough for physicians to diagnose conditions and recommend treatments. I wanted to explore if they would be as effective in a different setting by a different population. A key difference between these two populations (i.e., physicians and students) is the motivation for using this technology. Physicians use the technology to perform a professional service for patients who lack access to medical care. But why do students use the robots? For my dissertation research, I sought to explore this question.

Summary of Findings

In Publication #1, I explored not only "why" students were using the robots but also "how" they were using them. Were the robots being used for all day attendance? To attend certain classes? To remain connected to friends? In the five cases in this study, I found the motivation to use the robots for school attendance was strong. I discovered that many homebound students and their families strongly advocated for use of the robots in their schools. One family went so far as to move back to their former school district because their new school district did not allow use of the robot. From these participants I learned that the robots were used to overcome social isolation. These students wanted more than traditional homebound services could provide. By attending school via the robots, and in all cases, there was consistent talk of the homebound child's future. This topic of conversation was particularly salient to this study as one of the parents shared that her son had slowly stopped talking while on homebound services (before he received a robot)—he felt there was nothing to talk about. After receiving a robot and attending school six hours a day, he returned to talking about activities at school, completing his schoolwork, and doing his homework so he would not fall behind academically. Talk of the homebound child's future seemed to communicate to all participants that the child would be returning to school. This belief that the child would be returning to school was facilitated by classmate acceptance of the robot. I found that after an initial introductory period, the classmates seemed to accept the homebound child's presence via the robot. They called the robot by the child's name and recalled what the homebound child had done or said via the robot.

These children's experiences via the robot were possible due to the openness and efforts of willing educators. However, not all schools allowed the robots. I did not believe that schools, administrators, or teachers who refused to use the robots were necessarily against providing improved educational services to homebound students. As homebound children have not had many options for returning to their local schools, I wondered why some schools were willing to use the robots and why other schools were not. What challenges were they facing to this use of technology? For Publication #2, I explored this practice from the perspective of the educators. My questions were similar to those for the students. “Why” were some educators willing to try this new technology and others not? “How” were they using the technology? Publication #2 revealed many issues that educators encountered when deploying a robot program. I felt it was important to communicate the complexity of educational structures and the challenges many educators faced to make this form of inclusion possible for homebound students. I found that there were issues of privacy from both parents and teachers. What makes the robot so valuable for virtual inclusion (i.e., real-time two-way audio and visual communication) also caused the most worry. By having a robot in the classroom, there was a live feed of the classroom going to someone’s home, hospital, etc. Once this challenge was addressed, schools had to decide which model of robot to purchase and which students should receive them. Schools had to develop new policies on student selection for this type of technology. All educators interviewed for this publication had successfully navigated complicated processes to bring these robots into their schools. They provided first-hand knowledge and valuable recommendations for other schools and teachers wanting to deploy robots in their schools.

Exploring the natural setting of school environments, social contexts of learning, child experiences, and educator experiences with the robots allowed me to gain a better understanding of this phenomenon. From this understanding, I produced relevant robot and user interface design recommendations. Design ethnography principles state that understanding the utilization of technology is inextricably linked to the conditions of the user’s environment (Blomberg, Giacomi, Mosher, & Swenton-Wall, 1993). Blomberg and colleagues (1993) go on to recommend that gaining insight on the user’s environment assists in understanding the context of technology use. This understanding provides a fuller, more comprehensive picture of the technology for the user.

Recommendations in Paper #3 are based on the experiences of real-world learners (i.e., homebound students, teachers, and classmates) using robots in real-world settings (i.e., traditional schools). To provide these recommendations, I developed learner-, teacher-, classmate-, and homebound-user centered analytic frameworks that served to analyze the telepresence robot design features by expected tasks in school and home settings. Expected tasks for each user and setting surfaced from the data and served to shape these frameworks. As learning in traditional schools is a socially complex undertaking with many interactions between participants, there was some overlap of the expected tasks and relevant features. The analytic frameworks and resultant recommendations were organized by population groups (i.e., users). To provide a more technical visual of what the features would look like on a robot or user interface, these recommendations were then reorganized into tables. These tables contained relevant groupings by technical functions such as audio, video, mobility, and user interface. After these tables (i.e., tables by technical features), I returned the focus to the users and provided a table with recommended social practices. The social practices table provided guidelines for mutual understanding of expectations for the robot user and classmates. These guidelines were based on user experiences and provided recommendations for an improved immersive and inclusive experience.

Limitations

As qualitative exploratory work, my study examined the academic and social contexts of virtual inclusion as well as gained insight into the practice of virtual inclusion via telepresence robots in the classroom. For the purposes of this study, two assumptions were made. First, it was assumed that responses gathered from the interviews with homebound students, their parents, teachers, administrators, and classmates, were truthful as their responses were self-reported. Second, it was assumed that behaviors and dialogue observed during classroom observations were typical on any given day outside of the days I observed.

There are five limitations identified with this study. First, there is a limitation in the generalizability of this study as there is great variation in the school profiles. As a result, it is difficult to determine whether the results obtained from this study can be generalized to other children or schools. Second, data collection captured a snapshot in time on the day when I was at the school. This may not have allowed for enough data to be collected to gain deep enough insight into the long-term daily experience with this use of technology. Third, the qualitative nature of the study and the number of participants interviewed only provided individual portraits that are, perhaps, unique to the school and the individual student and may not be representative of the entire population of students using robots to attend school. Fourth, answers obtained from participants cannot be anticipated to coincide with the questions asked within my own instrumentation. Finally, my own researcher bias acts as a limitation as the inferences I make from the observations—interview notes are made from my own point of view and may not have accurately aligned with what the participants were thinking when they provided their responses.

There are two delimitations, or the characteristics that limit the scope of the study's inquiry as indicated by the researcher, within this study. The first involves school site selection as I am purposefully sampling the school sites for my case study. My preference is to study this phenomenon in public schools whenever possible as I prefer to study this phenomenon in settings where robots are distributed regardless of income, social support, etc. Second, my instrumentation and measures for data collection and analysis, such as interview protocols, were established by me and implemented by me.

Future Research

This dissertation points to several future avenues for research that will help to further deepen our understanding of virtual inclusion's effects on K-12 students. Future research on virtual inclusion may explore improved educational practices and technologies for homebound students. I would like to explore additional questions that I was unable to answer with regards to the effectiveness of currently available interactive technologies. Of particular interest are state and federally funded K-12 online learning programs. Should these programs be considered a form of virtual inclusion? A first step to answering this question would be to identify the data that is collected on participants in these state and federally funded online programs. If, in fact, these programs do identify homebound students who are using the program, accessibility to de-identified administrative data would be a first step to evaluating the effectiveness of these programs for this population. If these students are not identified in the existing data sets, future work could explore if administrators of these programs would be willing to collect this piece of data when they collect information on student demographics. This simple identifier could provide rich data for future studies on the effectiveness of online programs for homebound students.

This dissertation also raises questions about the lasting social impact of virtual inclusion via telepresence robots. Future research on teacher and student attitudes towards chronic illnesses may explore if the inclusion of homebound children in traditional schools has an effect on existing attitudes. As, traditionally, children who are homebound due to medical conditions are excluded from their local school community, it would be interesting to gauge classmate and teacher attitudes before a homebound student comes to school on a robot. After the child comes to school on a robot, a longitudinal, qualitative study could explore any shifts in attitudes and evaluate if these shifts are long-lasting. Researchers could also examine whether having homebound children in the classroom impacts academic outcomes for classmates. Some student academic outcomes that may result from this practice might be increased interest in science, technology, engineering, math or health career fields.

The inconsistency in state and federal policies that address the inequity of educational services also serves as a promising avenue of future research. Researchers may explore school and district policies and guidelines that are behind a school's decision to accept or refuse use of robots for virtual inclusion. Use of the robot's relative success in the studied schools was a result of multiple willing partnerships and collaborations. How can schools facilitate this practice? How can families provide support to students who are using this technology? What policy guidelines could be modified to meet the needs of this child population? Findings from this research may contribute to publications that evaluate existing state and federal policies for this population and effective educational practices that contribute to improved services. Research in this area may bring awareness to existing policies, services, and partnerships for establishing the use of interactive technologies as an effective means of school attendance.

Additional studies on this practice will also contribute to a growing national database that I have started on this practice. As I continue to collect data on homebound children using robots to attend school, I will evaluate coded data for effects on academic and social learning. I expect that there may be differentiated effects based on age, gender, condition, school features, and family support. As the sample size increases, there may be significant findings that contribute to improved recommendations for selection of students for whom this practice is most promising, design of classroom environments to accommodate the robots, production of school and district guidelines for consistency of services, and creation of teacher professional development for use of telepresence robots in the classroom.

I am optimistic that learning via interactive technologies in schools is a promising practice that will serve to increase the social connectedness of homebound children. I feel strongly that conducting holistic studies that collect data from all relevant participants in natural, every day settings can produce meaningful findings on technology use for the social good. Through increased understanding of the social isolation that homebound students have experienced and the promising practice of using robots, future research will contribute to growing innovative practices and technologies to better serve this underserved population. Additionally, future studies will serve to increase our understanding of this phenomenon and contribute to improved educational policies at local, state, and federal levels.

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Appendix A

Child Interview Topics

Semi-structured interviews covered the following topics:

Technology

1. Introduction to the robot
2. Home user device
3. Benefits/challenges of robot at school
4. Benefits/challenges of technology at home
5. School environment (areas where robot is navigated)
6. Home environment (where home device is located)
7. Training

Learning

1. Daily assignments
2. Tests
3. Classroom participation
4. School activities via robot
5. Extracurricular activities

School policies

1. School rules for student
2. Accessibility to areas
3. Where robot is housed
4. Procedures for arriving at and leaving school

Wrap up

1. Robot improvements
2. Home device improvements
3. Student perceptions
4. Questions for research team

Appendix B

Parent Interview Topics

Semi-structured interviews covered the following topics:

Technology

1. Introduction to the robot
2. Home user device
3. Benefits/challenges of robot at school
4. Benefits/challenges of technology at home
5. School environment (areas where robot is navigated)
6. Home environment (where home device is located)
7. Training

Learning

1. Tests
2. Classroom participation
3. School activities via robot
4. Extracurricular activities
5. Level of parent assistance with academic material

School policies

1. School rules/guidelines for parent
2. Procedures for accepting/returning the robot

Wrap up

1. Robot improvements
2. Home device improvements
3. Parent perceptions
4. Questions for research team

Appendix C

Teacher Interview Topics

Semi-structured interviews covered the following topics:

Technology

1. Introduction to the robot
2. Benefits/challenges of robot at school
3. School environment (areas where robot is navigated)
4. Home environment
5. Training

Learning

1. Daily assignments
2. Tests
3. Classroom participation
4. School activities via robot
5. Extracurricular activities
6. Level of teacher assistance with academic material

School policies

1. School rules for student
2. School rules for parents
3. Accessibility to all areas
4. Where robot is housed
5. Procedures for arriving at and leaving school
6. IT support

Wrap up

1. Robot improvements
2. Home device improvements
3. Teacher perceptions
4. Questions for research team

Appendix D

Administrator Interview Topics

Semi-structured interviews covered the following topics:

Technology

1. Introduction to the robot
2. Benefits/challenges of robot in schools
3. School environments (areas where robot is navigated)
4. Training

Learning

1. Testing
2. School participation
3. School activities via robot
4. Extracurricular activities
5. Level of administrator assistance with robot

School policies

1. District policies for student
2. District policies for parents
3. Accessibility
4. Where robot is housed
5. IT support

Wrap up

1. Robot improvements
2. School improvements
3. Administrator perceptions
4. Questions for research team

Appendix E

Classmate Focus Group Questions

Focus group interviews included the following questions:

1. How do you like having a robot in your classroom?
2. What are the best things about it?
3. Are there things you don't like about it?
4. Are there some things that you would like it to do that it's not able to do right now?