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TEACHER PERCEPTIONS OF THE ROLE OF SOCIAL ROBOTS AS TEACHING ASSISTANTS IN THE ONLINE TEACHING OF STUDENTS WITH AUTISM SPECTRUM DISORDER

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By

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DEDICATION

I dedicate this work to my wife, Jen, and my children: Marc, Kris, Luke, and Samantha, for their lifetime of sacrifices listening to my endless lectures about anything and everything I got excited about. Your patience, support, and encouragement are what kept me constantly pursuing new ideas and finding new things to explore. You are as responsible for the outcome of this study as I am. We did this together…

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Finally, I am extremely grateful to the members of the Magister Minister autism school in northern California. This includes the school's executives, teachers, staff, students, and parents. I could not have completed this study with you each and every one of you. Moreover, I could have never learned so much about the field of autism or begun to appreciate the wonderful people that inhabit its amazing world without the kind and generous way you embraced me. I sincerely hope that my work, which is embodied in this report, proves worthy of your investment in me.

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Abstract

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Students with autism spectrum disorder (ASD) are the fastest-growing group of children with special education needs. ASD affects individuals from all walks of life, regardless of race, ethnicity, educational levels of family members, or socio-economic backgrounds. People on the autism spectrum have difficulty communicating and establishing socio-emotional connections with other human beings, making teaching those with ASD challenging for their human teachers.

Most research in the field of autism has focused on the clinical aspects of the condition and on the individuals who are on the spectrum. However, research into the perception of the teachers charged with educating ASD students is more limited. In addition, while a wide range of technologies, including artificial intelligence (AI) and social robots, have been used in various forms to assist with teaching ASD students, research into teacher perceptions with respect to the use of these technologies is also limited.

The purpose of this study was to examine teacher perceptions of the use of a social robot as a teaching assistant to help them educate students on the autism spectrum. Furthermore, due to the COVID-19 pandemic outbreak, this study was conducted under unprecedented circumstances, when all schools throughout the United States were closed, and all teaching was conducted online using video conferencing technologies. Teachers from an autism specialist

school in northern California were asked to use a social robot as a teaching assistant with a selection of ASD students during their online Zoom-based video conference teaching sessions. Data were gathered through observations of these sessions and through teacher interviews and a focus group.

This study was conducted using the persuasive technologies conceptual framework. This framework was enhanced to include the teacher as a new persuasive influencer. The findings from this study revealed that ASD teachers found the social robot to be a useful tool to use as a teaching assistant. In particular, teachers found the use of a social robot teaching assistant offered a new approach to teaching and new ways to communicate with and engage their ASD students. Overall, students responded well to instructions and feedback given by the robot. However, student reactions ranged from neutral to very engaged, based upon the complexity of the task the student was undertaking and their general interest in technologically related topics. Importantly, no student reacted negatively to the inclusion of the robot. This report highlights a variety of operational challenges that the teachers experience in integrating the robot into their teaching practices and identifies a range of future research opportunities.

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CHAPTER 1: INTRODUCTION

Students with autism spectrum disorder (ASD) are the fastest-growing group of children with special education needs (Guldberg et al., 2017). ASD affects individuals from all walks of life, regardless of race, ethnicity, educational levels of family members, or socio-economic backgrounds (Busby et al., 2012). People with ASD have difficulty communicating and establishing socio-emotional connections with other human beings (Boucenna et al., 2014; Kennedy et al., 2016; So et al., 2019), making teaching those with ASD challenging using traditional teaching methods.

Background

Autism refers to a spectrum of neurological conditions where, at one end of the spectrum, individuals may be only mildly impacted and require little support, while at the other end of the spectrum, those impacted may require very substantial support. I will cover the autism severity levels in more detail in chapter 2. Autism can impact an individual's ability to engage in effective social interactions, including difficulties in verbal and non-verbal communication or establishing and maintaining eye contact. More severe levels of ASD may also include repetitive behaviors, mood swings, and learning difficulties. They may also have difficulty recognizing or interpreting facial expressions, recognizing or understanding someone else's tone of voice, recognizing or interpreting gestures and body language, or realizing when certain expressions should not be taken literally (Autism Speaks, 2020). These challenges may make it difficult for those on the autism spectrum to connect emotionally and communicate with other people.

ASD is a significant personal and social issue in the US and around the world. In 2018 the Centers for Disease Control and Prevention determined that approximately 1 in 59 children in the United States were diagnosed with ASD, affecting four times as many boys as girls. By 2019 the Centers for Disease Control and Prevention had increased their estimate to 3% of children in the United States, while the World Health Organization (2019) report estimated one in one-hundred-and-sixty children worldwide are affected. Autism affects individuals from all walks of life, regardless of race, ethnicity, educational levels of family members, or social-economic backgrounds (Busby et al., 2012).

In addition to the personal and emotional cost of autism, this condition also incurs a high financial cost for all concerned. According to the Centers for Disease Control and Prevention (2019), the costs associated with caring for children with ASD are four to six times greater than those not on the spectrum. Overall median expenditures are estimated to be 8.5 to 9.5 times greater for those with ASD than those without autism. Autism is a costly issue for parents, local communities, and the nation alike.

Problem

As its name implies, ASD refers to a range of challenges for those on the autism spectrum. These challenges can include an impaired ability to walk, speak, communicate, or establish a social/emotional connection to others (Boucenna et al., 2014; Kennedy et al., 2016; McBride, 2017; So et al., 2019; World Health Organization, 2018). Because the characteristics of ASD may be different for each student, no one approach is optimal for all students (Pennisi et al., 2016). Through the Individuals with Disabilities Education Improvement Act (IDEA), 2004, the US recognized the unique challenges that those with ASD have in learning, requiring public schools to develop an individualized education plan (IEP) for every student with a disability.

Of particular importance to this study is the difficulty those with ASD have in interacting in normal back-and-forth conversations and in initiating/responding to social interactions

(Boucenna et al., 2014; Centers for Disease Control and Prevention, 2019; Kennedy et al., 2016; So et al., 2019). These challenges impact the ease with which those with ASD learn as they are less able to focus on and intuitively understand their human teachers (Jordan, 2008). These difficulties present specific challenges for teachers of students with ASD, as teaching is fundamentally a human endeavor, relying upon the teacher's ability to communicate effectively with their students (Popenici & Kerr, 2017). The challenge teachers of students with ASD face is further complicated because ASD affects each student differently and to varying degrees (Busby et al., 2012; McBride, 2017). These variations make it difficult for teachers to communicate effectively with their students (Jordan, 2008; Pennisi et al., 2016), making the task of teaching students on the ASD spectrum especially difficult.

As the literature points out, the overarching problem that teachers of students with autism spectrum disorder face can be summarized as a combination of these two factors. First, their students have difficulty connecting to and communicating with them through the typical social interactions most students use. This makes using traditional human-based teaching methods challenging at best or wholly inappropriate and ineffective at worst. Second, as each student on the autism spectrum can experience a unique combination of ASD impairments, teachers have to deal with a highly diverse set of student needs. Teachers must adapt their teaching methods and styles to suit every student individually. This study used technology, specifically a social robot, to assist teachers of students on the autism spectrum by adding a non-human-based entity into the teaching process, thereby aiding communication between them and their students.

Technology Use in Education

While teaching is a predominantly human activity, a wide range of technologies, including artificial intelligence (AI), have been used in various forms to assist teachers, including robots (Gleason & Greenhow, 2017; Gulson et al., 2018; Popenici & Kerr, 2017; Roll & Wylie, 2016; Timms, 2016). When considering the use of technology in education in general, researchers have found that some teachers lack training and experience. This results in some teachers fearing the use of technology. However, the literature also indicates that student attitudes towards the use of technology in the classroom are overwhelmingly positive, believing that teachers' use of technology in the classroom is vital for their overall performance in life (Hoffmann & Ramirez, 2018). In particular, a common theme in the research is the positive role of robots in education (Gleason & Greenhow, 2017; Gulson et al., 2018; Ivanov, 2016; Popenici & Kerr, 2017; Timms, 2016), which showed this as one of the most promising and influential branches of AI (Popenici & Kerr, 2017). Some researchers believe this will continue to improve (Timms, 2016). Of particular relevance to this study, Huijnen et al., (2018) and Pennisi et al., (2016) identified robots as a means of providing teachers with a new means to connect to students with autism.

Artificial Intelligence Trends in Education

In a review of trends in the application of artificial intelligence in education (AIED) over the period, 1991 to 2016, Dillenbourg (2016) identified several trends that he believes would influence the future of AIED (and education in general) going forward. Of particular interest to this study, these trends include new forms of physically connecting with technology, such as the Internet of Things (IoT) devices and robots. The Internet of Things refers to the enormous range of objects (or things) that incorporate sensors of some form and are connected to the Internet. This includes everything from smartphones to home automation devices (e.g., Amazon’s Alexa and Google Home). These technological trends also include the ability to capture a lot of new data, allowing the focus to shift from solely right/wrong answers to interpreting richer data inputs. AI techniques also enable less rigid educational models where students can freely explore different paths, guided by feedback and hints. Similarly, Timms (2016) explored the potential role of AIED over the same 25-year period and predicted two significant opportunities for the future role of AIED: Internet of Things (IoT) and Robotics. Timms projects that in the future, robots would work alongside human teachers as collaborative robots. He further predicts that these robots would need to be human-like in order to be effective and accepted. Timms further proposes that by embedding sensors into the objects students use (including cameras in the classroom and sensors in robots), the AIED system would detect, analyze, and react to student activities.

Being challenged with establishing a socio-emotional connection to others (Kennedy et al., 2016; McBride, 2017; So et al., 2019; World Health Organization, 2018) to engage in normal back-and-forth conversation (Centers for Disease Control and Prevention, 2019), technology has the advantage that it does not require those on the autism spectrum to establish a socio-emotional connection (So et al., 2019). Assistive technologies, such as social robots, can be powerful tools when designed and implemented according to each student's unique requirements (Huijnen et al., 2017; World Health Organization, 2011). Studies show that when presented with a robot "face", the heart rate of individuals on the autism spectrum are unaffected, whereas those not on the autism spectrum experienced elevated heart rates, suggesting that ASD students may be less alarmed by the face of a social robot (Boucenna et al., 2014). This acceptance of robot technology was further demonstrated by Pioggia et al. (2008), who observed that ASD students were attracted to an android, unafraid to walk up and touch its face while ignoring the presence of human attendants involved in their experiment. However, the efficacy of robots in teaching those on the autism spectrum is not without its challenges. While teachers generally have a positive attitude toward the use of robots, some educational professionals are somewhat cautious (Ivanov, 2016; Kennedy et al., 2016), feeling that, while the use of robots may be initially exciting, children with low-functioning ASD may quickly lose focus and interest. It is not certain whether robots can effectively teach students with social and communication skill challenges (So et al., 2019). The literature on the use of robots in the education of ASD students indicates that studies undertaken to test the effectiveness of robots in this area have been limited and inconsistent. The literature indicates that more research is required in this field (Pennisi et al., 2016).

Current Robot Uses in ASD Education

Huijnen et al. (2016) indicate that the use of technology as an efficient support tool for the education of individuals with ASD and those who support them is accepted (Boucenna et al., 2014). They suggest the effectiveness of technology with students on the autism spectrum may be due to the ability to use technology to create an environment that reduces the anxiety these students often associate with traditional human-oriented social situations (Aresti-Bartolome & Garcia-Zapirain, 2014). As this relates to the use of robots, Aresti-Bartolome and Garcia-Zapirain (2014) also point out that robots can be programmed to display simple, repeatable, and predictable behavior. Furthermore, robots can control the social situation, making them less complex and help the ASD individual feel less anxious. Research has found that robot use in students with ASD education can be as efficient as human interventions in encouraging ASD children to ask questions (Goodrich et al., 2012). The literature also indicates that those with ASD communicate more with adults when playing with robots (Kim et al., 2012; Lee et al., 2012).

Potential Roles of Robots in ASD Education

Popenici and Kerr (2017) point out that education is fundamentally a human endeavor where the role of technology/AI should be to augment human teachers and enhance the education process. This point is further emphasized by Timms (2016), who projects the use of robots alongside human teachers as collaborative robots. Therefore, the social robots used in this study were used to assist teachers of students with ASD, not replace them. Jordan (2008) proposes that specialist autism schools should be centers of excellence, pioneering new ways of working with students with ASD and acting as research centers for new ways to educate students with ASD. This study was undertaken in collaboration with the Magister Minister (MM) autism school in an action-oriented mode, where I acted as an outsider collaborating with the MM insider teachers (Herr & Anderson, 2015). Note: Magister Minister (Latin for Teacher Assistant) is a pseudonym used to ensure anonymity and privacy for the teachers, students, and the school.

In their study of the roles, strengths, and challenges of robot-mediated interventions with students with ASD, Huijnen et al. (2018) identified six potential roles for social robots: provoker, reinforcer, trainer, mediator, prompter, and diagnostic information provider. These roles indicate a spectrum of opportunities for the use of social robot solutions. The MM teaching community identified the provoker, reinforcer, and prompter roles as those they felt most likely to be beneficial for the MM students and which the ASD teachers were most keen to use.

The robotic system selected for this study was the Misty II robot from Misty Robots Inc. (see Figure 1). This robot was selected because it consists of an open platform that meets most of the criteria described in the research (Dillenbourg, 2016; Timms, 2016), such as mobility, voice recognition, speech, vision, and artificial intelligence.

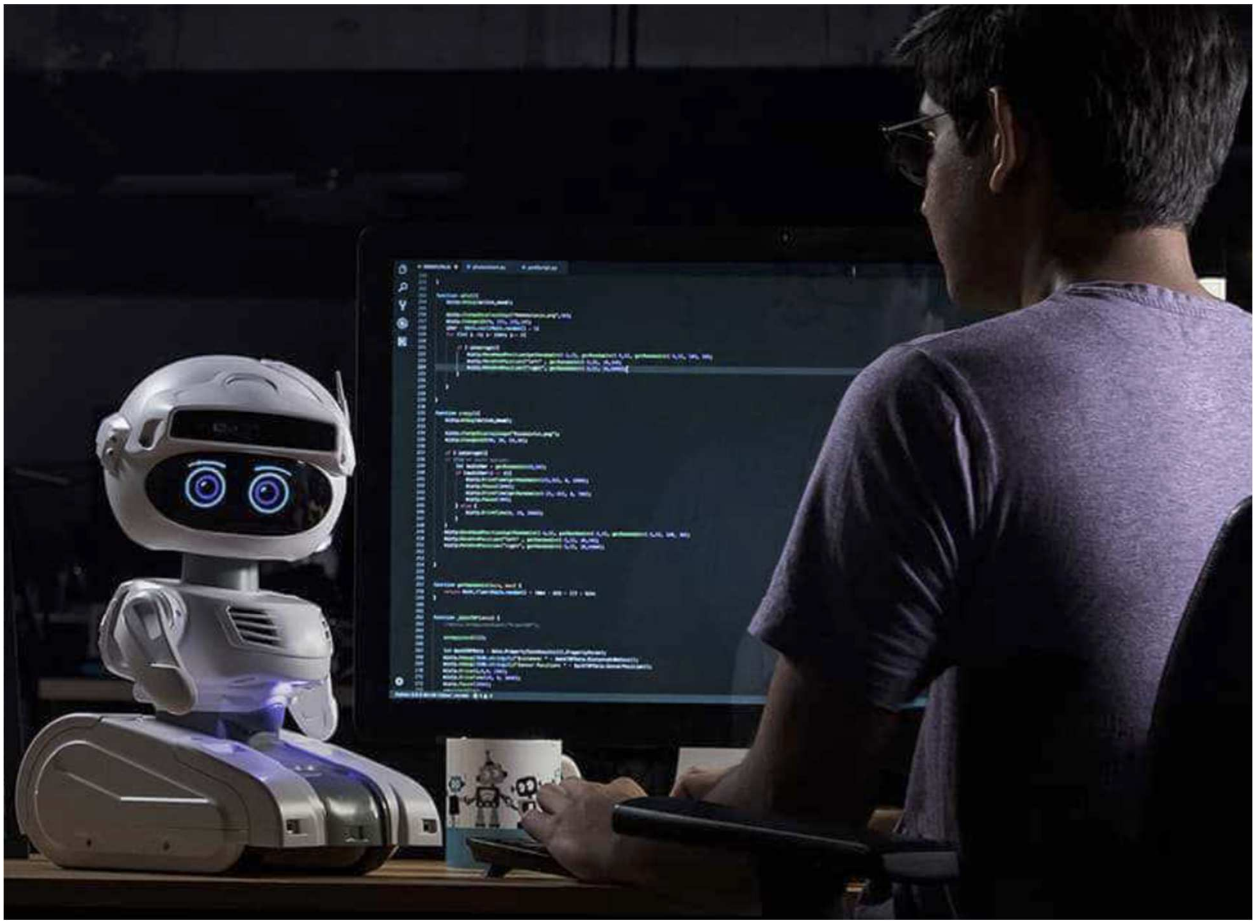

Figure 1. The Misty II robotics platform

Most importantly, the Misty II platform is fully programmable. This enabled me to design and develop, in collaboration with the MM ASD teaching specialists, a customized robot control application that enabled the teachers to engage the robot in the most effective way. The custom web-based robot control solution gave the MM teachers full control over the robot, enabling the teachers to use the robot to provide instructions, reinforcement, and feedback to the students. The application also captured appropriate data for the MM school.

Purpose Statement

The purpose of this action-oriented study was to work collaboratively with ASD teaching specialists at the Magister Minister in northern California to develop new ways of teaching students with ASD. The recent COVID-19 pandemic outbreak, which has led the MM school to close for the foreseeable future, provided me with the unique opportunity to conduct my research in an online mode. During this study, teachers at the MM school conducted all teaching sessions online using video conferencing technology, with a parent or guardian assisting the student during the teaching sessions. The approach I used for this study was to introduce the Misty II robot into the teaching sessions as an additional participant in the video conferencing sessions by developing a web-based robot control application that enabled the MM teaching staff to use the robot to assist them in their educational activities. Teacher perceptions were gathered on the suitability and effectiveness of social robots in online ASD education so that I was able to conduct a qualitative analysis.

Research Questions

The research questions guiding this study were:

- How do ASD teaching specialists perceive the impact of social robots in helping students with ASD to achieve their learning objectives more effectively/faster than traditional teaching methods?
- For which types of students with ASD do ASD teaching specialists perceive social robots to be most helpful?
- For which types of ASD learning activities do ASD teaching specialists perceive social robots to be most/least effective?
- How do ASD teaching specialists perceive the role of social robots as an effective and useful teaching aid?

Significance

The literature indicates that more research into the use of social robots in the field of ASD education should be conducted (Pennisi et al., 2016). Huijnen et al. (2018) specifically propose a focus on the effectiveness of robot interventions depending on the gender, intelligence, or age of the participant. This study used the persuasive technologies conceptual framework to correlate the impact of the robot-assisted teaching activities as perceived by the MM teachers with characteristics of the students. Fogg et al. (2002) suggest that, while most persuasion literature has focused on measuring attitude changes, focusing on behavioral change may provide more compelling results. This study addressed this gap by focusing on teacher perceptions of their ASD students' behavioral changes brought about by introducing a social robot into the teaching process. In addition, many studies have focused on clinical/therapeutic uses of robot technology and less on its application in an educational setting (Huijnen et al., 2016; Odom et al., 2016), a gap that this study specifically addresses. Furthermore, technology has advanced rapidly since the studies undertaken in much of the literature. Advances made in speech synthesis, and machine learning in particular, along with a fully open, programmable interface, have only recently become available in an affordable format through the Misty II robotic platform that I used in this study. These new robot capabilities open up new ways to use social robots in ASD education. This research adds to the existing literature by developing custom robot features targeted at the needs of teachers who are teaching students on the autism spectrum.

This study informs the ASD teaching staff at the Magister Minister autism school in northern California about the role social robots can play in the education of students with ASD. It enabled these teachers to experience using robot technology to assist them in their educational activities. The study's findings identify which types of students with ASD and which types of educational activities social robots can be most beneficial. The study also identifies for which students and educational activities this technology may not be appropriate. This study's results and the ASD teaching staffs' experiences at the MM school serve to inform the broader ASD and ASD education communities on the role that social robots with advanced programmable capabilities can usefully take in the ASD education process. The study also serves to inform the robotics community on ways social robot technology can be developed to assist in the education of individuals on the autism spectrum.

The teaching of students on the autism spectrum remotely using online video conferencing technology was a new and challenging task necessitated by the unprecedented, widespread impact of the COVID-19 pandemic. Therefore, this study also informs the MM autism school and the autism educational community about the role social robots can play and their potential impact in an online educational delivery scenario.

Conceptual Framework

I conducted this study through the lens of the persuasive technologies (PT) conceptual framework (Fogg et al., 2002). Persuasion theory (Reardon, 1981) acts as the foundation for the PT conceptual framework. Persuasion theory identifies three influencers of an individual's attitudes and behavior: personal characteristics of the individual, the characteristics of the information being conveyed, and features of the context of the persuasive event. The intent is to understand how these factors influence behavior and the intended attitude change.

Fogg (2002) defined persuasive technology as any computing system designed to influence an individual's attitudes or behavior in a predetermined way. Using this definition, in 2013, the technology group of the Center on Secondary Education for Students with ASD (Center on secondary education for students with ASD), proposed a conceptual framework showing the variables affecting the use of technology for students with ASD based on persuasive technology principles. This framework identified three major components: the characteristics of the individual on the autism spectrum, the activity they perform, and the technology used during the persuasive event (Odom et al., 2015). However, in this study, I introduce a new, fourth actor into the framework: the role of the influencer, in this case, the teacher. I have, therefore, used an enhanced version of the Center on Secondary Education for Students with ASD framework (see Figure 2).

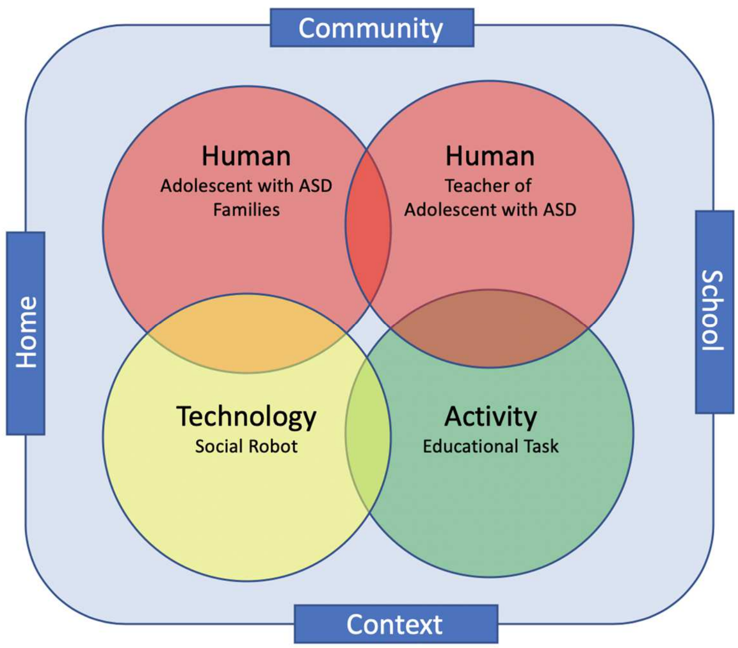

Figure 2. Enhanced conceptual framework

The use of the Misty II social robot used as educational assistive technology in this study was an example of the “Technology” element of the PT framework. The purpose of using the PT framework in this study was to capture the MM ASD teaching staffs’ perceptions about the role of social robot persuasive technology. I captured teacher perceptions about how effectively assistive robot technology can be used to persuade students with ASD to learn and modify their behavior. I also captured teacher perceptions of the four sets of interactions of the enhanced PT framework: teacher-robot, student-robot, student-task, and teacher-student interactions. In addition, the study links teacher perceptions to the three underlying focus areas of persuasion theory.

I will discuss the conceptual framework in more detail in Chapter 2.

Delimitations

This study took place from October 2020 to February 2021. The ASD teaching staff of the Magister Minister autism school in northern California used the Misty II social robot solution with their students. Due to the breakout of the COVID-19 global pandemic, the MM school itself was closed, and all teaching activities were conducted fully online using the Zoom video conferencing technology. The MM teachers introduced the social robot as an additional participant in their online sessions with their students. I arranged for three individual robot assistants to be available, one for each of the three classrooms involved in this study. Two classrooms involved students from 12-22 years of age and represented individuals predominantly towards the severely impacted end of the autism spectrum. The third classroom involved adult students ranging from 22-60 years of age, many of whom had more developed linguistic skills and were capable of more prolonged online focus and concentration than the younger students in the other two classrooms. I captured data through individual, one-on-one video conference interviews with each of the ASD teaching staff, a focus group session with all of the teachers together, and through analysis of the recordings of the online teaching sessions. Furthermore, as indicated by the Autism Society of America (2008), each student with ASD is unique - "If you've seen one person with autism, you've seen one person with autism." Not only are ASD students different from one another, but they can also exhibit different reactions and behaviors from one point in time to the next. The findings of this study reflect the reactions and behaviors of the MM students at the specific points in time in which they were exposed to the robot during the data gathering stage of this study. Therefore, the student reactions and behaviors could be different at other times or evolve over time.

I provide a complete discussion of the research design in Chapter 3.

Essential Definitions

Many terms within this study that need specific definitions. Some of the below terms have already been defined in this introduction; however, they are important to the study and need direct and clear definitions.

Artificial intelligence: (AI) computing systems that can engage in human-like processes such as learning, adapting, synthesizing, self-correction, and use of data for complex processing tasks (Popenici & Kerr, 2017). AI embraces a number of sub-branches, including Machine Learning, Neural Networks, and Robotics.

Artificial intelligence in education: (AIED) the application of AI capabilities to the field of education (Dillenbourg, 2016).

Autism spectrum disorder: (ASD) refers to a range of conditions characterized by some degree of impaired social behavior, communication and language, and a narrow range of interests and activities that are both unique to the individual and carried out repetitively (World Health Organization, 2019).

Center on secondary education for students with ASD (CSESA): the technology group (2013) that proposed a framework for conceptualizing variables affecting the use of technology for adolescents with ASD that is consistent with the principles of persuasive technology.

High-functioning ASD: used to describe those on the autism spectrum who have mild impairments (World Health Organization, 2019).

Individualized education plan: (IEP) the unique educational plan developed to meet the specific needs and an individual student with disabilities (Individuals with Disabilities Education Improvement Act, 2004).

Low-functioning ASD: used to describe those on the autism spectrum who have more severe impairments (World Health Organization, 2019).

Misty II: the social robot platform from Misty Robotics, Inc. used during this study (https://www.mistyrobotics.com).

Magister Minister: (MM) the fictitious name for the specialist autism school in norther California, used for this research. The MM school name was used to ensure the confidentiality and privacy of the students, teachers, and school involved in this study.

Persuasion theory: the theoretical framework used in this study. Persuasion theory is founded in behaviorism and refers to the theory underpinning how an individual's attitudes and behavior are influenced (Reardon, 1981).

Persuasive technology: any computer or device that is used to influence an individual's attitudes or behavior. Social robots are an example of persuasive technology (Fogg, 2002).

Social robots: robotic technology employing multiple sensors, including vision, speech, and voice recognition, along with artificial intelligence software, that is designed to interact with humans. Social robots are used in a social or personal setting as opposed to industrial robots that are used in large scale industrial settings such as manufacturing (Dillenbourg, 2016; Timms, 2016).

Summary

Students with autism spectrum disorder (ASD) are the fastest-growing group of children with special education needs. This condition affects individuals from all walks of life, regardless of race, ethnicity, educational levels of family members, or social-economic backgrounds. People with ASD have difficulty communicating and establishing socio-emotional connections with other human beings, making the teaching of students with ASD difficult as students with ASD have difficulty learning through traditional, human-teacher-based teaching methods.

The purpose of this study was to work collaboratively with ASD teaching specialists at the Magister Minister autism school in northern California to develop new ways of teaching students with ASD using the Misty II social robot platform. Teacher perceptions of the suitability and effectiveness of social robots in ASD education were captured and analyzed.

This study informs the ASD teaching staff at the Magister Minister autism school in northern California about the role social robots can play in the education of students with ASD. It enabled these teachers to experience using robot technology to assist them in their educational activities. The findings of the study identify which types of students with ASD and which types of educational activities social robots can be most beneficial. In addition, the study's findings identify which types of students with ASD and which types of educational activities the use of social robots may be less beneficial. Furthermore, the results of this study and the experiences of the ASD teaching staff at the Magister Minister autism school also serve to inform the broader ASD and ASD education communities on the role that social robots with advanced programmable capabilities can usefully take in the ASD education process. The study also serves to inform the robotics community on ways to develop social robot technology to assist in the education of ASD individuals. Finally, the study provides the Magister Minister autism school and the autism educational community as a whole an understanding of the role social robots can play and the impact they can have in an online educational delivery scenario.

CHAPTER 2: LITERATURE REVIEW

The purpose of this action-oriented study was to work collaboratively with autism spectrum disorder (ASD) teaching specialists at the Magister Minister (MM) autism school in northern California to develop new ways of teaching ASD students. This was achieved by introducing the Misty II social robot platform into the MM teaching process and developing new web-based robot control mechanisms that enabled the MM ASD teaching staff to engage the robot in the way they deemed most effective for their educational activities. The MM students at this school tend to be towards the severely impacted end of the autism spectrum, and many are non-verbal, non-communicative, and highly variable in their responses to instruction. Having worked with their students for many years, the MM teachers were well-placed to provide feedback on the impact the social robot has on their students and themselves as teachers. Consequently, the teacher perceptions of the introduction of assistive robot technology into the teaching process provided direct evidence from those most closely involved. Therefore, I gathered teacher perceptions of social robot suitability and effectiveness in ASD education to conduct a qualitative analysis.

The research questions guiding this study were:

- How do ASD teaching specialists perceive the impact of social robots in helping students with ASD to achieve their learning objectives more effectively/faster than traditional teaching methods?
- For which types of ASD students do ASD teaching specialists perceive social robots to be most helpful?
- For which types of ASD learning activities do ASD teaching specialists perceive social robots to be most/least effective?
- How do ASD teaching specialists perceive the role of social robots as an effective and useful teaching aid?

Autism

This review analyzes the literature regarding the use of social robots as assistive technology to aid teachers of students with autism. The first section provides a background of autism, defines its characteristics, and the educational challenges that autism presents for both those on the autism spectrum and those who teach them. Section two reviews the role of technology in education, focusing on artificial intelligence (AI), including robots, and defines what social robots, as assistive technologies, are and then reviews the roles that social robots have taken as assistive technologies in education. The third and final section presents the conceptual framework of persuasive technologies (PT) and includes a background on the foundational area of persuasion theory.

Autism Background

One of the quintessential abilities that distinguish human beings is our ability to apply our minds to a broad range of feelings and emotions. We are capable of reflecting upon our own beliefs and desires and applying our imagination to infer the feelings and emotions of others. These abilities, which fall under the theory of mind in the literature, are impaired in those on the autism spectrum (Baron-Cohen, 2001). Autism spectrum disorder (ASD) refers to a complex neurological disorder that results in a range of lifelong developmental disabilities, including impaired social interactions, communication and language difficulties, a narrow range of interests and activities, and repetitive actions. Of importance to this study, people with ASD have difficulty communicating and establishing socio-emotional connections with other human beings, cannot comprehend social boundaries, and may be oversensitive to, or in increased need of, sensory stimulation (Boucenna et al., 2014; Kennedy et al., 2016; Kohn, 2020; Øhrstrøm, 2011; So et al., 2019). At the time of this study, it was estimated that up to 90% of those on the autism spectrum experience sensory input differently than those not on the spectrum and that this can involve any of the senses, including sight, sound, touch, taste, and smell (Robertson, & Baron-Cohen, 2017). ASD is not related to an individual's ethnic or racial origin, nor is it impacted by the educational level of family members or their socio-economic background (Busby et al., 2012; Centers for Disease Control and Prevention, 2020). With over 3.5 million individuals affected, autism is the fastest-growing developmental disability in the US, with the rate of diagnosis increasing by 10-17% (Autism Speaks, 2020). The Centers for Disease Control and Prevention (2020) findings support this growth trend, showing in the year 2000, 1 in 150 children were impacted. By 2016 that had increased to 1 in 54 children. However, Wright (2020) points out that this growth in diagnosed individuals does not necessarily indicate an autism epidemic. Contributing factors may also be how behavioral conditions are diagnosed and classified and the growing awareness of the condition.

While some research points towards various biomarkers and hereditary susceptibility to autism (Goldani et al., 2014), the exact cause of autism remains elusive. Researchers suggest there may be many factors that make it more likely that a child may be affected by this condition (Autism Speaks, 2020; World Health Organization, 2019). However, autism is not a "disease" and cannot be "cured." People with autism simply experience the world differently than other people (National Autistic Society, 2020). While one of the major objectives of ASD education is to modify ASD student behaviors in their social and life skills (Mintz, & Aagaard, 2012), not everyone on the autism spectrum wants to be "fixed." Some ASD individuals see attempts to correct their condition to indicate that the way they experience the world is considered wrong by those not on the spectrum. For some on the spectrum, "normal for me is to be abnormal" (Autistic UK, 2018; Think Autism Guide, 2020).

Those on the autism spectrum often share the same difficulties. Still, it is important to recognize that autism is a spectrum of conditions that can affect different people in different ways. Each student with ASD is unique - "If you've seen one person with autism, you've seen one person with autism " (Autism Society of America, 2008). In addition to autism, some on the autism spectrum may also have learning disabilities or other conditions such as mental health issues (Denne et al., 2018; National Autistic Society, 2020). In 2013 the American Psychiatric Association released its latest version of the diagnostic and statistical manual of mental disorders, DSM-5. This version of the manual recognizes the concept of ASD as being a spectrum of disorders, replacing the term “pervasive development disorder” with the current term “autism spectrum disorder.” The DSM-5 further defines three distinct severity levels (see Table 1), based on the level of support an individual’s needs in two specific areas; the ability for social communication; and the degree of restricted, repetitive behaviors (American Psychiatric Association, 2020; Healthline, 2020; Mazurek et al., 2018; Ousley & Cermak, 2013).

Table 1
Severity Levels

Severity Level	**Description**
Level 1: Requires support	While individuals may be able to engage in conversation, they have issues holding an ongoing conversation or socializing with others.
Level 2: Requires substantial support	Individuals at level 2 are more severely challenged and may lack both verbal and nonverbal communication skills. At this level, individuals can be challenged by changes in schedule and a reduced ability to detect and appropriately react to social cues.
Level 3: Requires very substantial support	In addition to a severe lack of communication and social skills, individuals at this level also display repetitive or restrictive behaviors (e.g., rocking back and forth or repetitively speaking the same phrase).

The students at MM school tend towards level 3. Most require very substantial support throughout the day. For example, Kevin (a fictitious name) was a 19-year-old male at the MM school. He was almost completely nonverbal, managing to communicate using only grunts and sounds that are incomprehensible, except to those who have worked with him over an extensive period (i.e., his MM teachers and family members). Kevin was prone to repetitive behavior. When stressed, he would sit on a large rubber ball and rock back and forth. He also liked physical stimulus to relieve his stress, in the form of having his shoulders rubbed. By contrast, other level 3 students at MM are over-sensitive to physical stimuli and prefer not to be touched, especially when stressed). Understanding the severity level and the particular characteristics/needs of each student are essential for the MM teachers to know how to provide the most effective support.

ASD cost implications. ASD can have a significant impact on the lives of those affected by this condition and their families. In addition to the personal and emotional cost of autism, this condition also incurs increased stress on families and caregivers' financial costs. According to the Centers for Disease Control and Prevention (2019), the costs associated with caring for children with ASD are significantly higher than those not on the autism spectrum. In a 2015 study, the overall economic costs associated with autism in the US were estimated at $268 billion (Autism Speaks, 2020), including direct costs, medical costs, and lost parental earnings. For society as a whole, Medicaid costs alone were six times higher for children on the autism spectrum than those who were not. Autism Speaks (2020) goes on to indicate that a 2014 study shows that, across the United States and the United Kingdom, autism was the fourth most expensive medical condition, behind only trauma, cancer, and cardiovascular disease. The average cost of medical bills for the families of dependents on the autism spectrum was estimated to be $10,700 per child per year for those with ASD - four to six times greater than those not on the spectrum. ASD individuals also incur an additional $40,000 to $60,000 per year for intensive behavioral interventions. By analyzing the literature from the US, UK, Australia, Canada, Sweden, the Netherlands, Egypt, and China, Rogge and Janssen (2019) identified the lifetime costs of individuals on the autism spectrum were $2.4 million. Their review also showed that these costs are higher for those with more severe impairments. These costs were broadly incurred as follows in the US (see Table 2).

Table 2
Cost Categories

Cost Category	Cost Allocation	Description
Medical and healthcare-related services	79%	Includes inpatient, outpatient, pharmaceutical expenses, special education services.
ASD individual productivity	12%	Loss of production for adults with ASD
Families/caregiver productivity	9%	Informal care costs and costs associated with lost productivity for families/caregivers

Overall median expenditures are estimated to be 8.5 to 9.5 times greater for those with ASD than those not on the autism spectrum (Centers for Disease Control and Prevention, 2019). Rogge and Janssen (2019) indicate that studies show the medical and healthcare costs for people with ASD increase steadily over the lifetime of the individual with ASD.

ASD student learning challenges. The socio-emotional impairments impacting students with autism include difficulty establishing connections to other people, sensory processing, verbal and non-verbal communication, creative play, and interpreting the social cues that communication depends upon (Boucenna et al., 2014; Kennedy et al., 2016; Lindsay et al., 2015;

So et al., 2019; Yun et al., 2015). These impairments impact all individuals on the autism spectrum to a greater or lesser extent, as indicated above (see Table 1). In their seminal work in the 1970s, Wing and Gould defined what they termed as autism's "triad of impairments." This has become one of the most commonly used impairment categorization models in the autism field and defines the challenges faced by those on the autism spectrum along three broad dimensions. The triad of impairment categories includes social communication, social interactions, and imagination (see Figure 3). In addition, those on the autism spectrum may face additional challenges, such as learning difficulties or struggle with sensory overload. As has already been mentioned, the characteristics of each person on the autism spectrum are unique and may be affected by some or all of the elements identified in these categories. Each individual can also be affected to a greater or lesser extent, as defined in the DSM-5 severity levels. As a result of the unique ASD characteristics, it is not possible to use one single approach that would be optimal for all students (Pennisi et al., 2016). With this in mind, customizing the technology to each student's specific needs, in part, determines how credible and persuasive it is (Huijnen et al., 2017).

Regarding the triad of autism impairments (see Figure 3), Cabibihan et al. (2013) explain that social interaction challenges can range from complete indifference or an unwillingness to communicate with others to strong feelings of frustration due to an inability to connect and communicate, and to make friends. Those on the autism spectrum often lack the ability to empathize and appreciate what others may be thinking or feeling and have difficulty engaging with others in gameplay. Social communications can include both verbal and non-verbal challenges. Some ASD students are entirely non-verbal, while others may have difficulty in initiating or contributing to conversations. Impairments in imagination can also result in an inability to generalize concepts or to apply abstract thinking, leading ASD students to tend toward rigid and repetitive patterns of behavior. These three categories of impairment make it difficult for those on the autism spectrum to interact in a normal back-and-forth conversation or initiate/respond to social interactions (Centers for Disease Control and Prevention, 2019). Overall, these impairments result in ASD students finding it difficult to intuitively communicate with and understand their human teachers, making it difficult for them to learn through traditional teaching methods (Jordan, 2008; Pennisi et al., 2016).

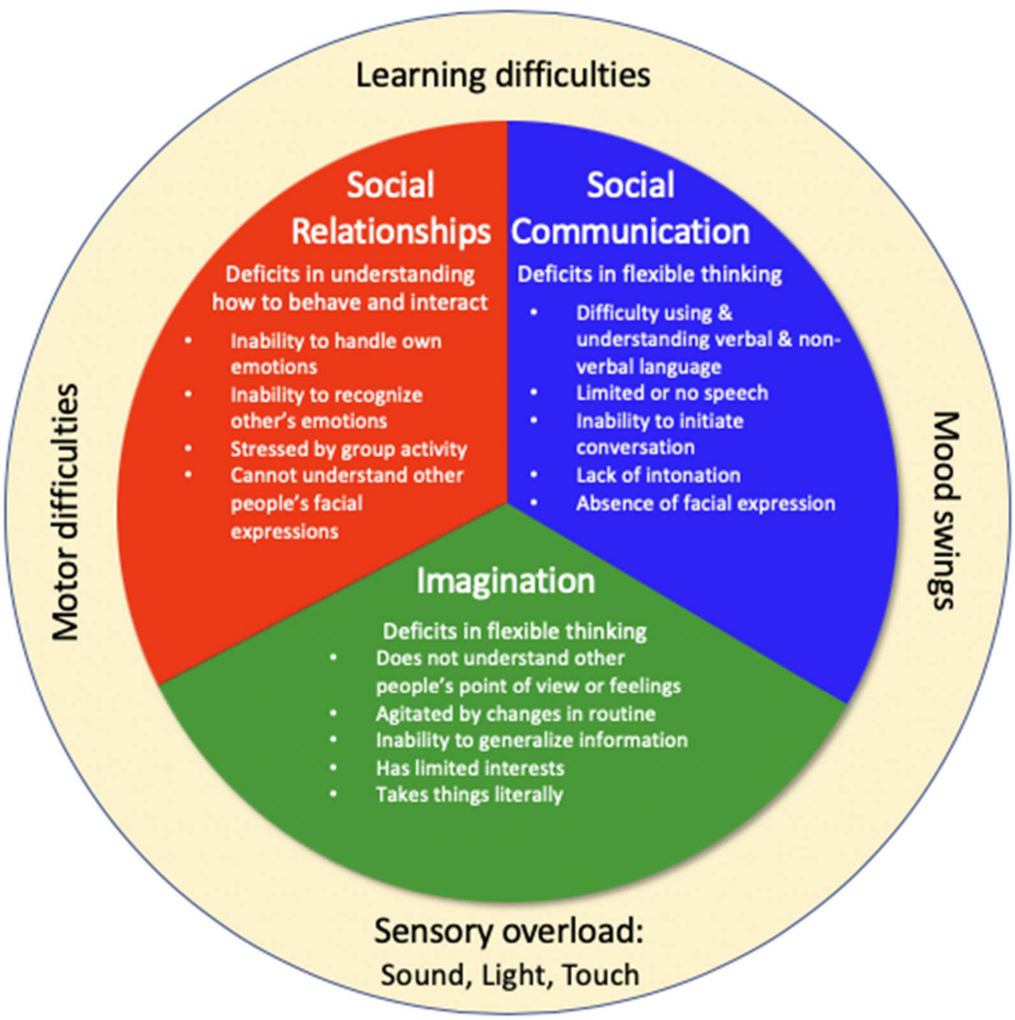

Figure 3. Triad of autism impairments

In addition to the triad of impairment categories themselves, autism often involves various forms of sensory overload. A broad range of sensory inputs such as noise, touch, too much light, flashing lights, or light of a specific color can stress individuals. Impairments can also include mood swings, motor challenges (e.g., difficulty walking), and learning difficulties.

ASD Teaching Challenges

Typically, traditional teaching methods rely on students using various human senses and cognitive functions to achieve learning. Students learn through a combination of these vectors, for example, by looking at a picture book and hearing their parents/teacher read the accompanying text. Or by experiencing the effect of the physical action of pressing a button (Autism Research Institute, 2020). In addition to the teaching methods, studies have also shown that teachers of students on the autism scale place different priorities on educational outcomes than their counterparts who are teaching non-ASD students. Teachers of ASD students rank friendship, social skills, and emotional development as more important, possibly reflecting their ASD students' specific learning needs (Petrina et al., 2017).

As teaching is fundamentally a human endeavor, relying upon the teacher's ability to communicate effectively with their students (Popenici & Kerr, 2017), ASD student challenges in this area result in significant problems for their teachers (Jordan, 2008). These challenges include difficulty in effectively communicating the informational characteristics they are trying to impart, or helping their students to understand instructions, or communicating their feedback, such as encouragement. In addition, due to their students' difficulties in expressing how they are feeling or what they need, teachers are challenged to understand how best to meet their needs. To further complicate these teacher challenges, autism often involves various forms of sensory overload. Characteristics of the communication, the circumstances of when the communication is taking place, and the characteristics of the individual student can strongly influence a student's reaction to sensory input. For example, some students may be over-stimulated by sound, while others may be sensitive to light. Some students do not like to be touched, while others prefer to be hugged – especially when stressed. Failure to understand the characteristics of each student can result in extreme and sometimes violent reactions (Lindsay et al., 2014; Boyer & Lee, 2001). Therefore, teachers must understand the physical and emotional challenges/needs of each student at any point in time, matching the task and their teaching style to the student. The need to understand these needs is equally true for the use of persuasive technologies, which must be used at the right time and place (Kairos) and in a manner that the student is willing to accept and respond to (the credibility of the technology).

Persuasive Technology Use in Education

As time progresses, technology becomes increasingly more powerful and more sophisticated. Of particular importance to this study are the emergence of artificial intelligence (AI) and machines capable of human-like characteristics, including robots (Gleason & Greenhow, 2017; Gulson et al., 2018). These characteristics include voice recognition, speech, computer vision, locomotion, and the ability to simulate human intelligence processes. The fundamental tenet of AI is that by studying human intelligence, we can develop machines to perform the same kinds of cognitive activities that human minds are capable of and which are capable of adjusting their behavior by learning from their environment (Panagiota, 2020). These technologies are embedded increasingly in many of the devices we use in every aspect of our lives, such as home automation, smartphones, and tablet computers. AI is now commonplace in educational settings where students and teachers alike use devices with intelligent (or smart) capabilities, such as internet searching, voice recognition, face recognition, text-to-speech, and speech-to-text.

In their research into the trends of artificial intelligence application in education (AIED) over the period 1991 to 2016, both Dillenbourg (2016) and Timms (2016) found that AI offered opportunities to engage students in new ways, allowing students to explore topics in their way, and engage in richer forms of exploration than traditional right/wrong answers to prescribed questions. Two of the trends they identified are specifically relevant to this study: sensor technologies (Internet of Things (IoT) devices), and robots. Robots often embrace many of the characteristics stated above, using sensor technologies to perform tasks such as voice recognition, speech, computer vision, and locomotion with collision avoidance. The Misty II social robot platform selected for this study includes all of these features. In addition, Misty II is fully programmable, has built-in three-dimensional vision, and onboard artificial intelligence neural network engine that enables the robot to conduct human-like cognitive functions (Misty Robotics, Inc., 2020). Timms projected that in the future, robots would work alongside human teachers in a collaborative mode. This study focused on the collaborative role of robots and their ability to assist teachers of students on the autism spectrum.

Persuasive Technologies

Persuasive technologies are those technological systems used to try and change human behavior (Fogg, 2002). These technologies typically involve computer systems used to influence individuals to change their behavior as they interact with it. Through advancements in computing power, a broad spectrum of sensor technologies, and sophisticated AI algorithms, the ability for technology to persuade has continuously increased over time. Devincenzi (2017) and

Fogg (2002) propose six specific advantages technology has in influencing human behavior (see Table 3).

Table 3
Technology Advantages

Advantage	Description
Persistence	Technology does not get tired or require vacations. Nor does it get frustrated by its human operative's inability/refusal to respond correctly
Anonymity	People are more inclined to volunteer information and be more honest when interacting with an anonymous computer than another human being.
Capacity	Computers are capable of storing and processing vastly more data than humans. Access to more data, and the ability to process that information more quickly than humans, enables computer-based technologies (such as social robots) to interact in potentially more persuasive ways than people.
Flexibility	Technology is capable of using more forms of communication than humans, often at the same time - for example, video, voice overlays, and visuals cues such as colored lights. Matching technology to the personal, informational, and situational characteristics of the individual can better enable Behavioral change.
Scalability	Technology can be scaled more rapidly and to a far greater extent than is possible by humans.
Ubiquity	It is possible to use technology in more locations and situations than humans. For example, in inhospitable/dangerous environments or hard/impossible locations that would be unsuitable or impossible for humans. Technology can also be used at the right time and in the right place/way (Kairos).

Robots, when used as a way of influencing human behavior, are an example of persuasive technology. For robots to influence human behavior, they must socially interact with their human operatives and, in this role, are referred to as social robots.

Social robots. The field of robotics is broad, encompassing large-scale robots costing thousands or even millions of dollars to small technologies embedded within other machines and technologies for a few cents. Different types of robots address different situations and needs. For example, industrial robots undertake physical tasks that are often too difficult, dangerous, or labor-intensive for humans to undertake. Similarly, medical robots can perform complex physical tasks, such as surgical operations, with very high precision (Institute of Electrical and Electronics Engineers). Social robots are a relatively new branch of robotics designed to anthropomorphize technology, enabling humans to interact with it in a more natural and engaging manner (Breazeal, 2002). As Breazeal points out, humans are a profoundly social species. Imbuing robot technology with social qualities, such as hearing, speech, and vision makes them more acceptable and easier to interact with and understand, which adds to their credibility. These human-like characteristics of social robots extend robotic platform capabilities to interact with people both physically and socially in social settings such as homes, hospitals, workplaces, and schools (Weir, 2018). Social robots, such as the Misty II robot that I used in the study, extend the traditional physical characteristics of robots (e.g., mobility) by combining multiple forms of advanced technology, including speech recognition, computer vision, and machine learning algorithms (Misty Robotics, Inc., 2020).

How social robots can help in ASD education. Given the challenges those on the autism spectrum have with establishing a socio-emotional connection to others and engaging in normal back-and-forth conversation (Centers for Disease Control and Prevention, 2019; Kennedy et al., 2016; McBride, 2017; So et al., 2019; World Health Organization, 2018), robot technology has the advantage that it does not require these forms of communication. Social robots do not require people with ASD to establish a socio-emotional connection with them (So et al.) The literature indicates that ASD students are not alarmed by the "face" of the robot (Boucenna et al., 2014). Breazeal (2002) also suggests that robot interfaces designed to be less complex are less stressful for SD students. Furthermore, while students on the autism spectrum find verbal and audible communication challenging, by contrast, Shane et al. (2012) point out that presenting content through a visual medium can bypass those challenges and enable the presentation of complex concepts and ideas. Therefore, appropriately designing technological solutions can increase their credibility and acceptance.

Some researchers remain unconvinced of the effectiveness of robots in ASD educational situations (So et al., 2019). However, a common theme observed in much of the literature is that robots positively impact education (Gleason & Greenhow, 2017; Gulson et al., 2018; Ivanov, 2016; Popenici & Kerr, 2017; Timms, 2016). Some researchers see robotics as one of the most promising and influential branches of AI, which many believe will undoubtedly continue to improve (Popenici & Kerr, 2017; Timms, 2016). Of particular relevance to this study, Huijnen et al., (2019) and Pennisi et al., (2016) identified robots as providing teachers with a new means to connect with students with autism. Due to its flexibility, human characteristics can be mimic by assistive technologies such as social robots, or not, depending on the intended use. When designed and implemented according to each student's unique requirements, robot technology can be a potent tool in ASD education (Huijnen et al., 2017; World Health Organization, 2011).

As previously mentioned, autism is a spectrum disorder, impacting ASD students to varying degrees and various ways. Therefore, it is clear that the use of technology, including social robots, to assist in the education of ASD students must be matched to each student's communication needs as different students will be more or less receptive to different features of technology (Breazeal, 2002). It is also important to match technological features to the student in conjunction with the appropriate instructional approach (Shane et al., 2012). The Misty II robot that I used for this study is semi-humanistic, with a face, eyes, arms, and voice. However, it is equally clear that it is not human, having tractor tires for mobility, and is only one foot tall. The Misty II platform is fully programmable (Misty Robotics, Inc., 2020), so the humanoid characteristics it displays can be selectively exposed depending on each ASD student's personality. Indeed, the Misty II capabilities were used in a custom manner, matched to the specific needs and the specific tasks of each student. For some students, arm movements coupled with an enthusiastic verbal message and wide, amused eyes were effective. For others, simple, repetitive messages pf encouragement were more effective. Controlling the characteristics displayed by the robot was important to ensure student attention was maintained at an appropriate level and to ensure the effectiveness of robot inclusion in the educational process (Ivanov, 2016; Kennedy et al., 2016).

Robot uses in ASD education. Huijnen et al. (2016) indicate that the use of technology as an efficient support tool for the education of individuals with ASD and those who support them is accepted (Boucenna et al., 2014). They suggest the effectiveness of technology with students on the autism spectrum may be due to the ability to use technology to create an environment that reduces the anxiety these students often associate with traditional human-oriented social situations (Aresti-Bartolome & Garcia-Zapirain, 2014). As this relates to the use of robots, Aresti-Bartolome and Garcia-Zapirain (2014) also point out that robots can be programmed to display simple, repeatable, and predictable behavior. Furthermore, robots can control the social situation, making them less complex and help the ASD individual feel less anxious. Research has found that robot use in the education of students with ASD can be as efficient as human interventions in encouraging ASD children to ask questions (Goodrich et al., 2012). Those with ASD also tend to communicate more with adults when playing with robots (Kim et al., 2012; Lee et al., 2012).

Potential roles for social robots in ASD education. When used as assistive technologies to aid teachers, social robots demonstrate both positive and negative implications. On the positive side, social robot technology can produce enthusiasm, motivation, greater confidence, and self-esteem within students, helping them undertake educational tasks they traditionally find difficult. Robots can also help teachers gain greater insight into how students approach tasks and learn. These attributes add to the credibility of social robots as useful and trustworthy technology. By contrast, robots can also be frightening to some students. They can also present challenges for teachers who have to learn how to use them and incorporate them into their teaching practices (Catlin & Blamires, 2019).

As education is fundamentally a human activity (Popenici & Kerr, 2017), the role of technology/AI should be to augment human teachers and enhance the education process. This point is further emphasized by Timms (2016), who foresees robots working alongside human teachers as collaborative robots. Therefore, the social robot used in this study was used to assist the MM teachers, not replace them. Shane et al. (2011) indicate that research suggests that people with autism may be particularly attracted to content delivered visually using technology. They indicate that there is growing evidence that those on the autism spectrum can effectively imitate behaviors they see on a screen and generalize them to other settings.

The use of social robot technology in the education of ASD students is not without its challenges, however. Catlin and Blamires (2019) explain that teachers must learn these new technologies, understand how to operate the robotic platforms, and deal with the associated technological environment such as software loading and configuration, data storage, and integrating the robot into their teaching practices. They go on to describe suggestions received from teachers in the Special Education Robotics Project (SERP) conducted by Blamiers (1993), on how to incorporate design features for using social robots effectively in educational settings (see Table 4).

Table 4
Design Features for Social Robots in Education

Feature	Description
Flexibility	Utilizing the flexibility of social robot platforms to address the different learning challenges of each student.
Variety	Include different mechanisms for student-robot interaction, such as switches, joysticks, and voice control.
Extensibility	The ability to add and store new software features.
Audio	Improved audio capabilities, including auditory feedback, and the availability of pre-recorded voices and music.

In addition to the above design considerations, in their experiments using the KASPAR robots, which stands for “kinesics and synchronization in personal assistant robotics”, Huijnen et al. (2018) identified six potential roles for social robots (see Table 5).

Table 5
Social Robot Roles in Education

Role	Description
Provoker	The robot acts as a stimulus to students, triggering/encouraging them to engage in interaction.
Reinforcer	The robot provides positive reinforcement to students when they achieve a goal, make the correct selection, or take the right action. Positive reinforcement is more effective than negative feedback.
Trainer	Here, the robot can repeat an activity multiple times to train the student in the required skill. Repetition of activities could occur across several minutes, days, or weeks. The robot can faithfully repeat the activity on each occasion, ensuring consistency and comparability.
Mediator	Using the robot to act as a mechanism to establish a connection with and interact with others (could be the teacher or another student). The robot may be a more socially acceptable mediator for some students than their human teacher.
Prompter	Similar to the "trainer" role, but for non-repetitive purposes. The robot prompts the student to take some action/achieve a goal. The robot may be a more socially acceptable prompter for some students than their human teacher.
Diagnostic information provider	In this role, the robot acts as an assistant to the teacher by providing detailed information about the student's interaction with the robot and task achievement. This data may provide teachers with a new perspective and new insights into how each student learns.

These roles indicate a spectrum of opportunities for using social robot solutions in this study. Research into the use of robots with ASD students suggests that we are still at relatively early stages. The literature indicates that more research is needed to understand the actual effects and added value in therapy and education (Diehl et al., 2012).

The Misty II social robot system I chose for this study was selected because it consists of an open platform that meets most of the criteria described in the literature (Dillenbourg, 2016; Timms, 2016). These features include mobility, voice recognition, speech, pre-recorded voice responses and music, vision, and artificial intelligence. Importantly, the Misty II platform is fully programmable, which gave me the ability to design and develop capabilities that enabled the MM teachers to custom the robot's interactions and responses to the needs of each student and each teaching activity.

Persuasive Technologies Conceptual Framework

Behaviorism (Bandura, 1977; Skinner, 1938) is one of the most common theoretical frameworks used in the field of autism research, with applied behavioral analysis (ABA) as the most common and best researched educational approaches to modifying the behavior of students on the autism spectrum (Denne et al., 2018). However, while this study may involve behavioral changes in the ASD students, the primary focus of this study was to capture teacher perceptions of their use of social robot assistive technology in their teaching practices. Therefore, I conducted this study through the lens of the persuasive technologies (PT) conceptual framework (Fogg et al., 2002).

While the concept of persuasion dates back to Aristotle, in her seminal work on persuasion theory (Reardon, 1981) identified three influencers of an individual's attitudes and behavior (See Table 6).

Table 6
Persuasion Influencers

Influencer	Description
Personal characteristics	An individual's characteristics influence how they will react to a given stimulus. These characteristics, therefore, influence how persuadable an individual is for any given situation.
Informational characteristics	The characteristics of the information (message/content/activity, etc.) and how attractive/interesting/important the message is to the recipient have a major influence on how persuaded they will be to modify their behavior.
Contextual characteristics	Features of the context of the persuasive event can impact how influential the event will be in persuading an individual to modify their behavior. Some situations are more conducive to the recipient being persuadable than others. For example, a noisy environment, or one where the recipient is distracted, is less conducive to encouraging the recipient to focus on the persuasive message and modify their behavior.

Persuasion theory intends to understand how these three factors influence behavior and the intended behavioral change (Mintz, & Aagaard, 2012). Persuasion theory forms the foundation for the PT conceptual framework.

In 2013 the Center on Secondary Education for Students with ASD technology group proposed a conceptual framework (see Figure 4) showing the variables affecting the use of technology for students with ASD based on the principles of persuasive technology (Odom et al., 2015). Fogg (2002) defined persuasive technology as any computing system (device or application) designed to influence an individual's attitudes or behavior in a predetermined way. While Mintz and Aagaard (2012) mention that some have criticized Fogg's early work, there can be little doubt today of the myriad ways technology is used to persuade in every aspect of society. Good examples of current persuasive technologies can be seen in commercial recommender systems such as Netflix's listing of movies that are "trending now", Amazon's use of “frequently bought together” listings, or eBay’s use of a seller rating system designed to persuade sellers to provide quality service.

The PT framework identifies three major components (see Figure 4): the characteristics of the individual on the autism spectrum, the activity they perform, and the technology used during the persuasive event (Odom et al., 2015). However, in this study, I introduce a new, fourth actor into the framework: the role of the influencer, in this case, the teacher. I have, therefore, used an enhanced version of the Center on Secondary Education for Students with ASD framework for this study (see Figure 5). While this framework also identifies three contexts within which these elements interact, this study focused specifically on the school environment. I recognized that, in addition to teachers, parental involvement in their student's education is also extremely important. Therefore, extending the findings of this study by exploring the home and community environments is recommended for future research.

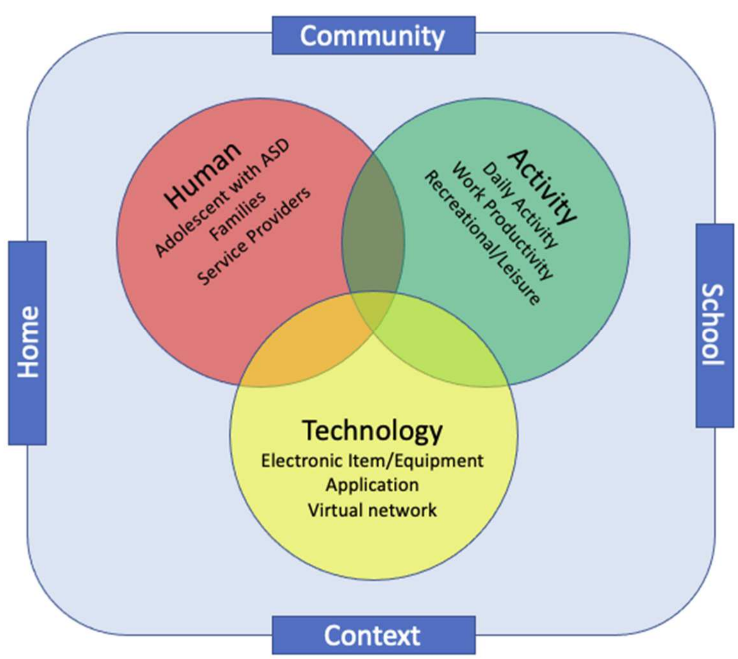

Figure 4. Conceptual framework

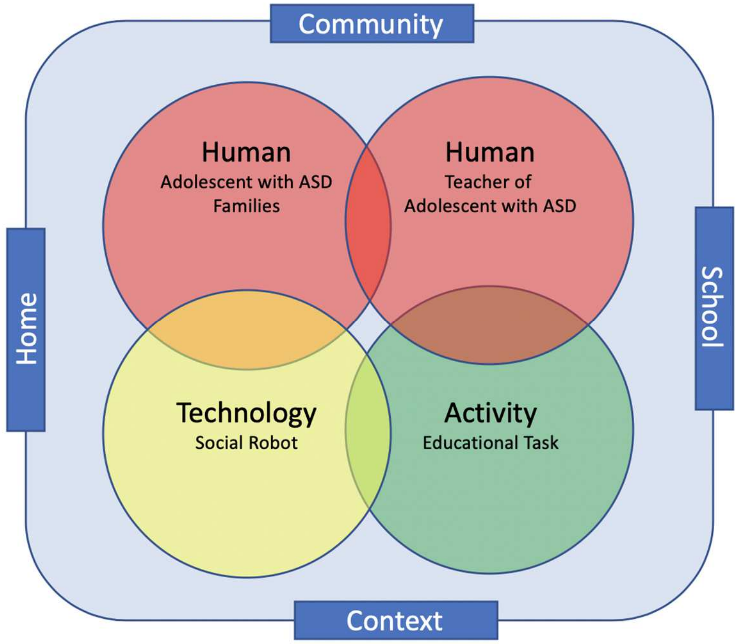

Figure 5. Enhanced conceptual framework

The use of the Misty II social robot used as educational assistive technology in this study is an example of the "Technology" element of the PT framework. The purpose of using the PT framework in this study was to capture the perceptions of the MM ASD teaching staff about the role of social robot persuasive technology. I captured teacher perceptions about how effectively assistive robot technology can persuade students with ASD to learn and modify their behavior. I captured teacher perceptions of the four sets of interactions of the enhanced PT framework: teacher-robot, student-robot, student-task, and teacher-student interactions were captured. In addition, the study links teacher perceptions to the three underlying focus areas of PT.

In addition to the three foundational concepts of persuasion proposed by Reardon (1981), I added the two additional concepts of the persuasive technologies conceptual framework to guide this study: credibility and Kairos. Fogg (2003) described credibility as having two dimensions: trustworthiness or perceived goodness or morality of the source, and expertise, representing the knowledge or skill of the source. He also explains that Kairos refers to the theory that the persuasiveness of a message depends upon it being delivered at the right time and in the right place. As indicated in figure 3 above, there are three broad places where the persuasive influence of social robot technology could, theoretically, take place: the home, in the community, or at school. This study focused on social robot impact on the educational activities of the school environment. However, the second element of Kairos is to deliver the persuasive message at the right time. This study brings together all five of these framework concepts, plus my addition of the personal characteristics of the teacher, to frame the execution of the study and data capture (see Table 7).

Table 7

Study Focal Concepts

Concept	Description
Personal characteristics of the student	Consideration of each student's characteristics, how they related to the selected task, and how the student was engaged in that task.
Personal characteristics of the teacher	Consideration of each teacher's characteristics, how they related to the student and the use of the robot in their teaching sessions.
Informational characteristics	How the characteristics of each task and the informational content being conveyed was designed to match each student's interests and known preferences.
Contextual characteristics	Consideration of the educational context a student usually experiences when conducting tasks, compared to that of the robot-assisted educational activities. This included the same human teacher who would normally work with that student, the same online mechanism for the educational task that has been used since the outbreak of the pandemic in March 2020, and the same duration.
Credibility	Mintz and Aagaard (2012) explain that the teacher's introduction of and personal interaction with the robot during the student activities will reinforce the robot's credibility. Having the robot engaged in familiar tasks that the teacher has worked with the student on in the past added to the student's acceptance of the robot as a trustworthy addition to the process.
Kairos	Robot interaction with the student as they conducted their assigned tasks was coordinated by the teachers to provide instruction and feedback at the appropriate point in the educational process. Furthermore, teachers had the ability to operate the robot from their laptop/tablet devices and instruct the robot to provide specific instructions or feedback to the student in real-time. For example, to provide additional encouragement if a student was struggling or additional praise for a task well done.

Summary

This literature review provides an overview of the communication and social interaction challenges experienced by those on the autism spectrum. These challenges make it hard for ASD students to interact with their human teachers and learn through traditional teaching methods. Similarly, the communication challenges of ASD students, coupled with the highly varied nature of autism and the myriad ways it impacts those on the spectrum, make teaching ASD students particularly challenging.

Technology has been used, throughout history, to assist teachers in communicating with and educate their students. These technologies have become increasingly sophisticated and artificially intelligent, with robots representing current leading-edge technology that integrate multiple AI aspects. Social robots are a particular branch of robotics that incorporate human characteristics, such as voice recognition, vision, speech synthesis, and mobility, enabling them to interact with humans in a social context. As robots do not require ASD students to connect with them at a socio-emotional level, social robots are an ideal candidate as a useful tool to assist teachers in communicating with their ASD students. As the social robot used in this study was highly programmable, it was possible to customize the robot's assistive capabilities and enable the teachers to select and use the available features in a custom manner to meet the specific needs of each individual student and each individual teaching interaction.

I conducted this literature review using the persuasive technologies conceptual framework. This framework provides the context for applying the persuasive nature of social robot technology to an autism school's educational environment and the needs of teachers with ASD students.

The literature indicates that research into the area of social robot application to autism education has been limited and inconsistent and that more research is required. No literature currently exists on the role of social robots to assist teachers of ASD students using remote online video technology during a global pandemic.

CHAPTER 3: METHODOLOGY

Introduction

The purpose of this action-oriented study was to work collaboratively with ASD teaching specialists at the Magister Minister (MM) autism school in northern California to develop new ways of teaching ASD students. This was achieved by introducing the Misty II social robot platform (Misty Robotics Inc., 2020) into the MM online teaching process and developing new web-based robot capabilities that assisted the MM ASD teaching staff in their educational activities. This qualitative study gathered the ASD teacher insights and perceptions of the suitability and effectiveness of using a social robot in ASD education.

Research Questions

The research questions guiding this study were:

- Do ASD teaching specialists perceive social robots as helping students with ASD to achieve their learning objectives more effectively/faster than traditional teaching methods?
- Which types of ASD students do ASD teaching specialists perceive social robots to be most helpful?
- Which types of ASD learning activities do ASD teaching specialists perceive social robots are most/least effective?
- Do ASD teaching specialists perceive social robots as a useful teaching aid?

This chapter explains the methodology and research design that I used for this study. It begins with a description of the proposed methodology I used, followed by an in-depth description of the research design. The chapter also describes the participants of the study and why/how they were selected. I also explain how data were collected and analyzed and how the trustworthiness of the data was ensured. Finally, this chapter includes an explanation of the limitations of the study.

Approach

As the name implies, autism encompasses a broad spectrum, from those who are only mildly impacted to those severely affected. As stated in chapter 2 above, the American Psychiatric Association has defined three autism severity levels in their DSM-5 (see Table 5). The MM students are mostly at the severely impacted end of the spectrum (level 3 – requiring very substantial support), displaying significant challenges in communicating and undertaking cognitive activities (World Health Organization, 2018; Kennedy et al., 2016; So et al., 2019; McBride, 2017; Boucenna et al., 2014). However, autism is not a one-size-fits-all condition. Each student with ASD is unique – "If you've seen one person with autism, you've seen one person with autism" (Autism Society of America, 2008). Indeed, as pointed out by the MM teachers, not only do students differ one from another, but the same student may react differently to the same stimuli/situation from one day to the next.

Given the unique and variable nature of the MM ASD students, a qualitative approach was considered appropriate for this study. This study focused on the MM teachers and their experiences using the robot solution to aid them in their online teaching activities. The MM teachers know their ASD students very well, having worked with each of them one-on-one for several years. This experience with their students enabled the MM teachers to provide insights into the impact of using a social robot assistant in their online educational activities. This study captured teacher perceptions of how the robot assistant affected each student and their personal experiences as teachers.

Methodology

This study introduced the Misty II social robot platform into the MM online teaching processes to gather the MM ASD teachers' perceptions of how the use of a social robot assists them in educating their students. I gathered teacher perceptions of social robot assistant suitability and effectiveness in online ASD education to conduct a qualitative analysis. Given the experimental nature of this study, I used an action research approach. Teaching is fundamentally a human endeavor, relying upon the teacher's ability to communicate effectively with their students (Popenici, & Kerr, 2017). Therefore, the focus of this study needed to be the teachers' experiences in their use of social robot technology rather than the technology itself.

I conducted this study at the Magister Minister (MM) autism school in northern California. The MM school specializes in the education of ASD students with over 50 years of experience. The site consists of several classrooms, each dealing with students of different age ranges.

For the purposes of this study, I was granted permission to work with teachers and students from three classrooms: the adult classroom and two of the younger student classrooms. I was introduced to all of the teachers in each of these classrooms. In addition, I explained the nature and purpose of the study to them. The adult classroom was dedicated to ASD students aged between 22-60 years of age. The adult classes, which were run as a group, usually included 25-30 ASD adults, with typically three teachers administering each session. The younger student classrooms typically consisted of 9-12 students, with teachers conducting educational sessions with each student individually. In the younger non-adult classrooms, students rotate between each teacher in their classroom to undertake specific tasks. Six teachers from the two younger student classrooms were selected to participate, and a further seven teachers from the adult program. Each educational session was, on average, 20-30 minutes. However, given the online nature of MM's current teaching practices and the challenges this poses in terms of maintaining student attention, these teaching sessions ranged from 10 to 40 minutes.

The school's executive director, who fully endorsed this study, also explained the benefits of the study to the MM teaching staff (see Table 8).

Table 8
Teacher Benefits

Benefit	**Description**
Evaluation of new techniques	MM has a long-standing history of pioneering new approaches and techniques in the education of ASD students and sharing their findings with others in the autism community. The MM school saw this study as an ideal opportunity to investigate the potential benefits of new, modern technologies such as social robot teaching assistants.
Enhanced student experience	MM's students experienced social robot assistance during their online educational sessions. The potential benefits include: • More engaging tasks and activities. • New ways to interact with their teacher/teaching activities.
Enhanced teacher experience	MM's teaching staff were able to experiment with and experience the flexibility and educational impacts of social robot teaching assistance in an online educational setting and a safe environment that they control. They were also able to experiment with new ways of interacting with their students by leveraging robot-based actions directly under their control.

I conducted this study through the lens of persuasive technologies (Fogg et al., 2002). Persuasive technologies (PT) is based upon the foundational work of Reardon (1981) on persuasion theory in which she proposes the way an individuals attitudes and behavior are influenced through three persuasive influencers (see Chapter 2, Table 6), personal characteristics of the individual, the characteristics of the information being conveyed, and features of the context of the persuasive event. Fogg et al. (2003) built upon Reardon's persuasion theory by linking it to the role of technology in influencing behavior. PT defines persuasive technology as any system (computer, device, or application) designed to influence an individual's attitudes or behavior in a predetermined way. The use of the Misty II social robot used as educational assistive technology in this study was an example of persuasive technology. As described in chapter 2, this study used the three foundational concepts of persuasion proposed by Reardon (1981), along with the PT conceptual framework elements of credibility and Kairos, plus the personal characteristics of the teacher that I have added to the conceptual framework. I used these six framework concepts to guide the execution of the study and the data captured (see Table 9).

Table 9
Study Focal Concepts

Concept	Description
Personal characteristics of the student	Consideration of each student's characteristics, how they related to the selected task, and how the student was engaged in that task.
Personal characteristics of the teacher	Consideration of each teacher's characteristics, how they related to the student, and the use of the robot in their teaching sessions.
Informational characteristics	How the characteristics of each task, and the informational content being conveyed, are designed to match each student's interests and known preferences.
Contextual characteristics	Consideration of the educational context a student usually experiences when conducting tasks, compared to that of the robot-assisted educational activities. This included the same human teacher who would normally work with that student, the same online mechanism for the educational task that has been used since the outbreak of the pandemic in March 2020, and the same duration.
Credibility	Mintz and Aagaard (2012) explain that the teacher's introduction of and personal interaction with the robot during the student activities will reinforce the robot's credibility. Having the robot engaged in familiar tasks that the teacher had worked with the student on in the past added to the student's acceptance of the robot as a trustworthy addition to the process.
Kairos	Robot interaction with the student as they conducted their assigned tasks was coordinated by the teachers to provide instruction and feedback at the appropriate point in the educational process. Furthermore, teachers had the ability to operate the robot from their laptop/tablet devices and instruct the robot to provide specific instructions or feedback to the student as the student was conducting the task. For example, to provide additional encouragement if a student was struggling or additional praise for a task well done.

I conducted this study in collaboration with the Magister Minister (MM) school in northern California in an action-oriented mode, where I worked as an outsider collaborating with the MM insider teachers (Herr & Anderson, 2015). I am not an insider as I do not have experience in ASD and do not bring pre-conceived biases into the research regarding ASD. However, I do have significant experience with technology and recognize that my familiarity with technology could introduce researcher bias. To reduce the potential of my technology experience biasing the research, I did not take an active role in the teacher-student-robot interactions. Indeed, as the educational activities were conducted online using Zoom video conferencing, I was not a participant in these online sessions and did not, therefore, have any influence over the interactions that occurred. I captured teacher perceptions regarding the efficacy of the robot-assisted activities through one-on-one Zoom-based interviews, using a consistent interview protocol (see Appendix D). I used a semi-structured, open questioning approach (Merriam & Tisdell, 2016) that allowed teachers to express their perceptions without undue influence from myself. Individual teacher video conference interviews were conducted once all teaching sessions using the robot had been concluded. After the final robot-assisted teaching session had been completed, I conducted a focus group session with all involved teachers to gain final, collective perceptions (see Appendix E). I also conduct member-checking of the data captured from the interviews, the focus group session, and my observations of the teaching session video recordings with the MM teaching staff to verify the accuracy of my notes, interpretations, and conclusions. Member checking aided in the trustworthiness of the data by ensuring that my opinions and biases had not unduly influenced the research findings.

Method

I recognized that this research involved participants who lacked the ability to give informed consent, namely, the students on the autism spectrum. Therefore, I took great care in selecting only those students that the MM teachers and the executive directors of the MM school believed would be appropriate for inclusion in this study. Furthermore, as the parents of each student involved in the study would need to be present during each teaching session using the robot (in case the student had a negative reaction to the robot), care was taken to only invite students whose parents were considered to have sufficient time to dedicate to these activities. Second, I held an online Zoom video conference to demonstrate the robot and explain how it would be used during the teaching sessions. Both teachers and parents/caregivers were invited to this event. The robot was also on the video conference to allow participants to see the technology and to enable them to express their opinions and ask questions. This event took place in December 2020, giving teachers and parents ample time to digest what they have heard and consider whether they wished to participate in or have their students included in the study. The robot's introduction into the MM educational sessions, and the gathering of data, began in January 2021. Parents were asked to read the informed consent form (see Appendices A) and respond with their consent for their students to be included. In addition to parental consent, students who were deemed by the MM school's executive director as capable of giving an informed response were asked to sign a student assent form (see Appendix F). I also asked those teachers who agreed to be involved in the study to sign an informed consent form (see Appendix B). I only included teachers and students in the study for whom prior consent had been received.

The recent COVID-19 pandemic has necessitated the academic community to adopt remote learning methods to teach their students. During this study, the MM school conducted all teaching sessions online using Zoom video conferencing technology, with a parent or guardian assisting those students who require assistance during the teaching sessions. While the pandemic has caused significant disruption, many schools now realize that remote learning offers some benefits over traditional in-classroom teaching. Schools are now considering whether to retain some of their distance learning capabilities for the long term, even after the pandemic has subsided. This study provided me with a unique opportunity to understand teacher perceptions of using a social robot as a teaching assistant in a distance learning modality. These insights will be informative to the ASD and education communities long after the COVID-19 crisis has passed.

I introduced the Misty II robot into the teaching sessions as an additional participant in the video conferencing sessions (see Figure 6). I did not take part in these sessions as my participation would have been visible to the student and teacher and could have influenced the study results. However, I recorded the Zoom video conference sessions, allowing me to observe each teaching session unobtrusively after the event. Both parent and teacher consent was obtained prior to any recordings taking place (see Appendices A and B). To establish the credibility of the robot (Fogg, 2003), the teacher introduced the robot at the start of the first session that it was included for each student, and a reminder at all subsequent sessions that "our friend Misty is joining us today." The robot's credibility and trustworthiness were, therefore, established by having the students trusted teacher introduce it.

Figure 6. Video conference teaching session

To enable the robot to be included in the video conferencing teaching sessions, I set up each of the three robots in a permanent location. It was important to ensure acoustic isolation between each of these locations so that the sounds from one robot-assisted teaching session did not interfere with any other. I used a computer with an attached video camera to enable the robot to join the video session (see Figure 7). The video camera provided both video and audio transmission to the teacher and student. I established a Google email account for each of the three robots, providing each robot with its own email and calendar. I also established a Zoom video conference account for each robot. This enabled each robot to log into the teaching sessions for the classroom the robot had been assigned to. The robot's email enabled teachers to invite the robot to the video conferencing sessions. I maintained a master calendar of robot bookings so that I could ensure each robot was added to the appropriate Zoom session at the right time.

Figure 7. Robot video conferencing setup

To ensure the robot-assisted sessions were conducted in a timely, quality manner, I adopted the following execution protocol (see Table 10).

Table 10
Execution Protocol

Process Step	Action
1	Each morning, each of the three was powered on and tested. These tests were designed to ensure that the robot was fully charged, was accessible from the internet, and was able to perform each of the key functions (change the color of the light on its front, could move its head and arms, and responded to requests to speak).
2	Five minutes before the scheduled teaching session, I logged the robot into the Zoom video call. In those instances where the Zoom call was already in session with another student, the robot's video and audio were disabled.
3	When the scheduled teaching session time was reached for the appropriate student (for whom consent had been given), the robot's visibility and audio were enabled. For the adult classes, where the classes involve many students, not all of whom had been invited/given consent to be included, the robot was entered into a separate Zoom breakout room. At the appropriate time, those students for whom consent had been given were moved into the breakout room by their teacher.
4	At the start of each session, I used the Camtasia video capture application to record the lesson being conducted. This enabled me to conduct post-session observations.
5	At the end of the session, the robot was withdrawn from the Zoom call, and the Camtasia recording was stopped.
6	The resulting Camtasia recording was exported and then copied to the main storage location on the Synology Network Attached Storage device.

I will describe the technical design of the study in Chapter 6.

Data capture. The main method of capturing data was through individual teacher interviews and a focus group interview session. However, I also video recorded the teaching sessions as described above, enabling me to conduct post-session observations to capture both teacher and student interactions with the robot. Observing via video recordings was the only practical way I was able to conduct observations given the teaching sessions were online, conducted through video conferencing. Joining these teaching sessions myself would have been visible to both the teacher and student and would have unduly affected the interactions of the participants. Without video recordings of the teaching sessions, I would have been reliant upon the teacher interview responses and the focus group discussion alone. Both parent and teacher consent was obtained prior to any recordings (see Appendices A and B). I used a consistent video recording observation protocol across all teaching sessions (see Appendix C). These observations allowed me to obtain first-hand observational data of the teacher and student interactions with the robot technology. Using these multiple sources of data collection increased the data's internal validity by triangulating the teacher responses with my own observations (Merriam & Tisdell 2016).

The MM executive directors requested that I minimize the time impact of my study on the teachers involved. Therefore, I limited the duration of my data capture period to three weeks, as agreed with the executive director. During that time, the teachers conducted 25 separate robot-assisted teaching sessions, 14 with the younger student classrooms and nine with the adult students. These sessions involved 14 teachers, seven from the younger student classrooms and seven from the adult class. I used short one-on-one teacher video conference interviews, each lasting between 20-30 minutes, to capture individual teacher insights and perceptions. I also used an hour-long focus group session with all teachers to gather final perceptions across all participants. Similarly, I describe how data from the teacher focus group session was captured in the data collection section.

For this study, I adopted an action-reflection cyclical approach (McNiff, 2017), as shown in figure 8.

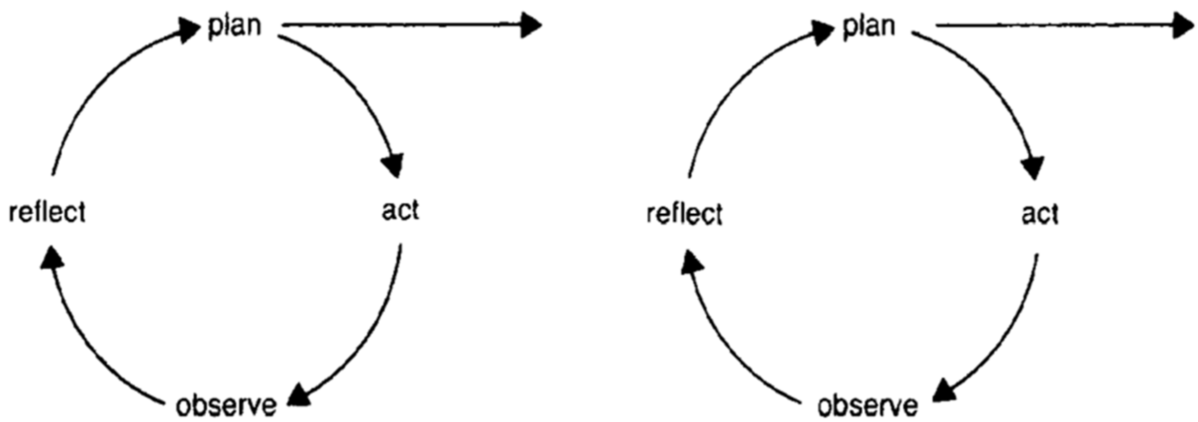

Figure 8. Action-reflection cycle

The study consisted of four stages: an initial design stage, an execution stage consisting of multiple execution cycles, the final review stage, and a write-up stage.

Design and development stage. The engagement commenced with a video conferenced education workshop with the MM teachers and executive directors. The workshop focused on achieving two specific outcomes. First, to educate the MM teachers on the Misty II robot and the web-based control application that I had developed. Second, using the MM teachers' new-found understanding of the robot capabilities, I engaged the MM teachers in a collaborative co-creation design exercise where I worked as an outsider collaborating with the MM insider teachers (Herr & Anderson, 2015) to refine the web-based robot control application design. This resulted in the identification of new robot control capabilities and other ways the teachers wished to engage the robot in student interactions.

Based on their request, the MM executive directors sent the notification about the study to each student's parents (see Appendix A) and, where appropriate, the assent form to the students (see Appendix F), as they have a long-term trusted relationship with them. This notification also invited the parents to attend the video conference session.

The final step in the design and development stage was the software development of the web-based robot control features the teachers had identified.

Execution stage. My original intent was to develop new, robot-based activities for the MM teachers to use with their students. However, through discussion with the MM school executive director, I decided that this approach would have had two detrimental effects. First, it would have required the teachers to learn these new activities. This would have been counter to the executive director's requirement to minimize the time and effort impact on the MM teachers. Second, the students would also have been presented with a new suite of activities to perform. These new robot-based activities, therefore, would have introduced new variables into the teaching activities, in addition to the introduction of the robot teaching assistant. The new robot-based activities would, therefore, have masked the sole effect of introducing the robot. I decided, therefore, to conduct the study by asking the MM teachers to introduce the robot into their normal teaching sessions, using the typical teaching activities that they would normally conduct with their students.

Similarly, my original intent was to include two action-reflection cycles. However, the Magister Minister teachers proved to be far more enthusiastic and actively involved than I had anticipated. The MM teachers provided almost daily feedback on their experiences of using the robot, along with suggestions and requests for additional capabilities. The result was that I conducted six action-reflection cycles, with more frequent cycles occurring at the beginning of the data-gathering period than at the end (see Figure 9). To allow time for the teachers in all three classrooms to conduct sufficient teaching sessions and gain sufficient experience to form meaningful perceptions of using the robot in their teaching sessions, I secured the use of three Misty II robots, one for each classroom. Approved teachers in the two younger age classrooms scheduled time with their assigned robot to meet their teaching schedules. Scheduling of the robot for the adult sessions was conducted in a similar manner. However, as the adult classes are conducted as one large group, and as not all students were included in the study (and had not been asked for parental consent), the robot was joined into a Zoom breakout room where only those students for whom parental consent had been obtained, were also joined.

I conducted a teacher/parent workshop meeting in December 2020. This allowed me to demonstrate the robot/web-based application and to gain immediate feedback. Further development of the web-based robot control applications was then conducted over the December to January holiday period. Each action-reflection cycle then provided further teacher feedback based on their use of the robot in their teaching sessions. Enhancements to the web-based robot control application were conducted within a few hours, immediately after each action-reflection cycle. Once all robot-assisted teaching sessions were concluded I conducted an individual video conference interview with each teacher to gather their perceptions. As the robot-assisted teaching sessions progressed over the three-week data-gathering period, the number of requests for changes and additions reduced. Prior to the end of the data-gathering period, no new requests were being received, and I concluded that I had identified and incorporated all necessary changes.

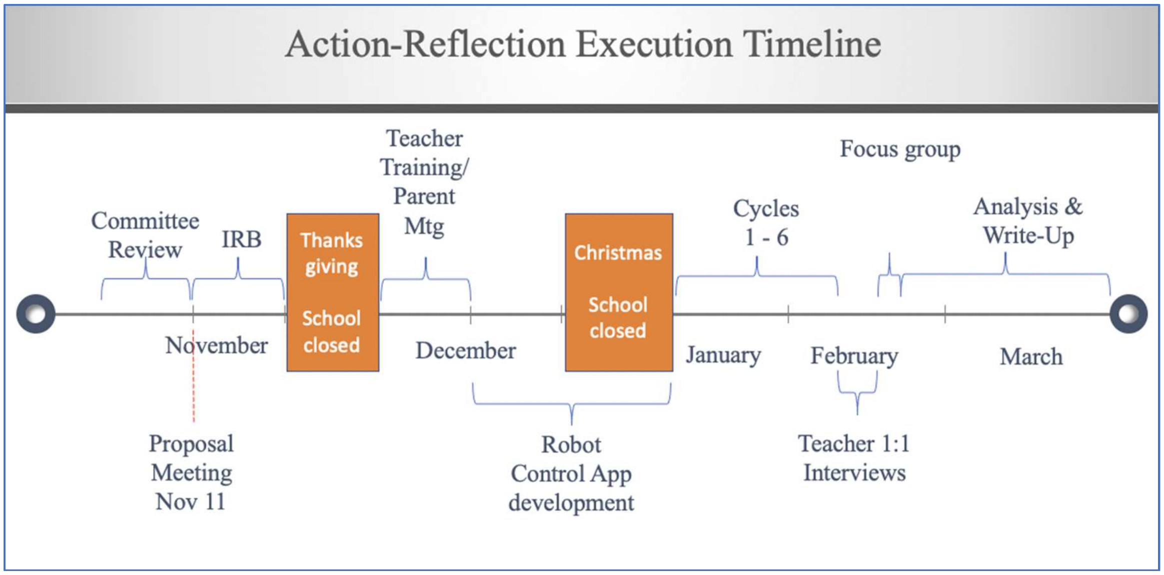

Figure 9. Action-reflection timeline

Final review stage. I used a constant comparative approach for the video conference recordings' analysis (Merriam and Tisdell, 2016). Once all robot-assisted teaching sessions had been completed, I conducted individual interviews with each teacher to gather their perceptions. I then incorporated the teacher perceptions into my existing analysis along with my own observations. I gathered the teachers' final perceptions on the specific research questions posed by the research, along with their perspectives on future research opportunities, during the focus group video conferencing. Subject to prior consent, I recorded the individual teacher interviews and the focus group meeting for post-analysis and coding. Upon completing all action-reflection cycles, I observed no new information or themes in the data as I achieved saturation. I also conducted member-checking with all teachers to verify my notes, interpretations, and conclusions.

Write-up stage. In the fourth and final stage of the dissertation, I documented the results of the research. I described the details of the methodology followed and the data gathered at each stage. I included the MM teaching staffs' perceptions at each stage, and the modifications requested to the web-based robot control application. In the write-up, I included a description of the teachers' experiences and perceptions and how they apply to the research questions. The write-up culminates with my conclusions, recommendations, and recommendations for future research.

Participants

This study took place at the Magister Minister (MM) autism school in northern California. Note: Magister Minister (Latin for "teacher assistant") is a pseudonym used to ensure the anonymity and privacy of the school, its teachers, and students. I selected the MM school due to its ASD specialism and extensive experience in ASD student education, their willingness and interest in trying new methods, their proximity and ease of access for myself, and their willingness to fully support this study.

The MM students are mostly at the severely impacted end of the spectrum, displaying significant challenges in communicating and undertaking cognitive activities. Based on his knowledge of the teaching staff and each classroom's student composition, the MM executive director assigned specific classrooms for this study. I conducted this study with teachers and students from three specific MM classrooms. At the time of this study, students ranged between 14 and 54 years of age. I found this was sufficient to provide enough data to reach saturation. In the typical in-person classroom setting for the two younger age classrooms, teachers normally conducted student activities in 15-minute timeslots. Students would meet individually with one of the teachers for 15 minutes to perform a specific activity. Once the 15-minute timeslot was complete, the student would move on to the next teacher and a new activity. However, due to the COVID-19 pandemic, for the duration of this study, the MM school was required to conduct all educational activities online using video conference-based instruction, and a more flexible teaching strategy was employed. The target was still a 15-minute teaching session, but due to the students' different attention spans, especially when interacting in an online video conference, teaching sessions ranged from five to 30 minutes. Based on the agreed schedule the teachers had agreed upon, the teachers invited the robot to join their teaching sessions as an additional video conference attendee. The adult program was run differently. The adult program was conducted as a group activity, with teachers joining a day-long video conference at different points throughout the day to conduct their specific activity. The robot was added as an additional attendee to a Zoom breakout room at the appropriate time, and only students for whom prior parental consent had been received were added to that breakout room.

The primary focus of this study was the perception of the MM teachers and whether they found the use of social robot technology useful and effective in helping them teach their ASD students. I conducted this study through consultation and agreement with the executive director, program directors, and head teaching staff.

Ethical Considerations

I recognized that the students who participated in this study were incapable of consenting to their inclusion. Therefore, I exercised particular care to ensure that I preserved all participants' rights and conducted the study ethically. The principles of ethical research were adhered to as follows:

Teacher selection. The MM executive director and program directors identified the three classrooms they wished me to include in this research. Along with the classroom leads, these executives identified which teachers were considered suitable to participate in the research. The teachers selected for this study represented all three classrooms and consisted of seven teachers from the younger age group classrooms and a further seven teachers from the adult program. I asked teachers to sign a consent form prior to inclusion in the study (see Appendix B).

Student selection. I asked the MM executive director and program directors, along with the classroom-lead for each classroom, to identify which students they consider most suitable for this study. This selection included considering any students who might be impacted adversely by the robot's inclusion in their educational tasks, whether frightened of the robot or overly excited by the robot. Furthermore, as the parents of each student involved in the study would need to be present during each teaching session using the robot (in case the student had a negative reaction to the robot), care was taken to only invite students whose parents had sufficient time to dedicate to these activities. I gained parental/guardian approval before any student was included in the study (see Appendix A).

Task selection. I asked the MM executive director and program directors, along with the classroom-lead for each classroom, to identify appropriate student tasks.

Informed consent. As described above, the selection of students for inclusion in this study involved agreement amongst three specific knowledgeable parties: the student's classroom lead teacher, the MM executive directors, and the student's parent. I obtained consent from the student's parent or guardian before including a student in the study (see Appendix A). Those students who were deemed capable of providing an informed assent by the MM school's executive director were asked to sign a student assent form (see Appendix F).

Minimizing the risk of harm. Teachers had direct control over every aspect of the robot's actions at all times, including what the robot said, its "facial" expressions, and arm movements. As the teaching sessions were all conducted using the Zoom video conferencing system, teachers had full control over whether the robots were visible or audible and were able to disconnect the robot from their teaching sessions in the event of a student's adverse reaction to the inclusion. However, no student reacted adversely to the robot during the study.

Protecting anonymity and confidentiality. To protect participant confidentiality, I have anonymized all teacher and student data and the results of their interactions with the robot. I generated a unique random number for each student and teacher to enable myself to relate both student and teacher data to specific individuals and activities. The random number relationships were retained for my use only. This study uses the fictitious school's name, Magister Minister (Latin for Teacher Assistant), throughout this dissertation to ensure anonymity and privacy for the school, its teachers, and students. Similarly, I generated a random number to represent each classroom so that the findings of this study could not be related to the MM organization and its teachers or students.

The right to withdraw. All participants retained the right to withdraw from the study at any time for any reason or without providing any reason or explanation. This included the right of MM teachers to withdraw, students to withdraw, and the right of parents or guardians to withdraw their students from further inclusion in the study.

Avoiding deceptive practices. I conducted the study in an open manner with full disclosure of the purpose of the study, the methods used in conducting the study, and the use of the resulting findings. Copies of the study findings/report are available in their anonymized form to all study participants upon request.

Data Collection

I captured data through three methods. First, I observed all video conference teaching sessions involving the Misty II robot technology through video recordings of those sessions. I analyzed these video recordings using a consistent observation protocol (see Appendix C). I used the MAXQDA Analytics Pro 2020, release 20.30.0 (MAXQDA 2020) qualitative data analysis program to store and manage all recordings. I used MAXQDA to store, analyze, and code all documents, including those used for literature research and data collection and analysis during the execution phase of the study. Second, after the conclusion of all robot-assisted teaching sessions, I recorded video conference interviews with each teacher individually to gather their perceptions. Third, I recorded a video conferenced focus group meeting after the conclusion of all robot-assisted teaching sessions and all individual teacher interviews, using a semi-structured protocol (see Appendix E). The focus group session enabled activities and insights experienced by each teacher to be shared and discussed by the group as a whole. Subject to prior consent, I recorded the online video conferenced individual and focus group sessions to aid in post-focus group analysis. I used a consistent interview protocol across all action-reflection cycles (see Appendix D).

Data Analysis

In addition to data storage and management, I used MAXQDA to code all notes and recordings. MAXQDA is one of the most comprehensive software programs for document management and analysis in qualitative and mixed methods research. The software enables researchers to conduct document analysis for any type of qualitative research – including but not limited to grounded theory, literature reviews, exploratory market research, qualitative text analyses, and mixed methods approaches. MAXQDA is capable of managing all types of documents enabling them to be analyzed, including text documents, PDFs, interview responses, images, video recordings, and audio files. I used the software to code the video recordings to identify key elements and themes within each session and common elements across multiple sessions. I also coded the video recordings to identify links to the five elements of the persuasive technology framework, plus the personal characteristics of the teacher that I have added to the conceptual framework.

I coded data at the end of each teaching session as the video recordings become available using a constant comparative approach. Individual teacher interview data were then incorporated into the existing analysis after each interview, as was the final focus group data. I aligned these categories with the research questions addressed by this study. I transcribed each video myself rather than use an external transcription service. By conducting the transcription myself, as soon as possible after capturing the recording, while the discussion was still fresh in my mind, I was able to focus on the salient elements of the conversations and ignored all extraneous "small talk." An external transcription service would have provided a word-for-word transcription of the video recordings, potentially obscuring key elements and making it harder to extract and understand the critical elements of the discussions. Furthermore, by conducting the transcription myself, I was able to establish a personal understanding of both what was said, the tone and inflection of what was said, and the body-language of the participants, thereby increasing the trustworthiness of the data analysis. Using MAXQDA, I was able to link my transcription elements to the appropriate segment of the videos. This enabled me to quickly access the appropriate video segment during the analysis phase.

Trustworthiness of the Data

I used multiple methods to establish the trustworthiness of the data. First, I gathered data from multiple sources, including teachers and students from three different classrooms. I captured data from multiple teachers interacting with an individual student, multiple students interacting with an individual teacher, and the use of multiple tasks. I used triangulation to compare teacher perception data from multiple sources, including individual teacher interviews, focus group feedback, and observations obtained through the video conference recordings. Third, I used member checking to obtain teacher validation of the recorded data and the applied coding.

Delimitations

This study was conducted between October 2020 and February 2020 involving teachers and students from the Magister Minister (MM) autism school in northern California. The MM school was a specialist teaching establishment focused exclusively on the education of students with ASD. Due to the COVID-19 global pandemic, the MM school was closed for the foreseeable future, and so the inclusion of the social robot in the teaching process was done through online video conference sessions. The robot was not introduced physically into the MM classrooms. I included the robot in a limited number of educational sessions involving teachers and students from three different MM school classrooms. Students ranged between 14 and 54 years of age and represent a specific set of individuals at various points along the autism spectrum. I gathered data by observing video recordings of the online teacher-student-robot interactions, individual video conference-based teacher interviews, and through an online video conferenced focus group meeting.

Furthermore, as indicated by the Autism Society of America (2008), each student with ASD is unique - "If you've seen one person with autism, you've seen one person with autism." Not only are ASD students different from one another, but they can also exhibit different reactions and behaviors from one point in time to the next. The findings of this study reflect the reactions and behaviors of the MM students at the specific points in time in which they were exposed to the robot. Therefore, the student reactions and behaviors could be different at other times or evolve over time. These factors may limit the external validity or transferability of the study findings.

Summary

This was a qualitative action-oriented study of teachers of students with ASD perceptions and experiences of using social robot assistive technology in their online teaching sessions. Due to the COVID-19 global pandemic's impact, the MMS school was closed, and they conducted all teaching sessions online using Zoom-based video conferencing. I integrated the social robot in the teaching process through inclusion in the MM school's existing online video conference sessions. I selected the MM school due to its focus and experience in teaching ASD students. Teachers from three classrooms participated in the study. Students were selected for inclusion in the study based on teacher expectations of their suitability to working with robot technologies and as agreed with the selected students' teachers and parents. Tasks involved with the robot were similarly selected based on teacher experience and guidance. I collected Data by observing video recordings of the online teacher-student-robot interactions, individual video conference-based teacher interviews, and through an online video conferenced focus group meeting. I used consistent interview, and observation protocols o gather data. To analyze the data, I used a two-phase coding approach utilizing descriptive and pattern coding. I validated the findings by utilizing multiple data sources, triangulation, and member checking.

CHAPTER 4: TECHNICAL DESIGN

This chapter provides a description of the technical aspects and design I used to aid future researchers who may wish to replicate this study. This includes the robotics hardware, the software application architecture, the software development architecture, and the database architecture.

Robot Platform

The robotic platform used for this study was the Misty II robot from Misty Robots Inc. (2020). This robot was selected because it consists of an open platform that meets most of the criteria described in the research (Dillenbourg, 2016; Timms, 2016), such as mobility, voice recognition, speech, vision, and artificial intelligence (see Figure 10).

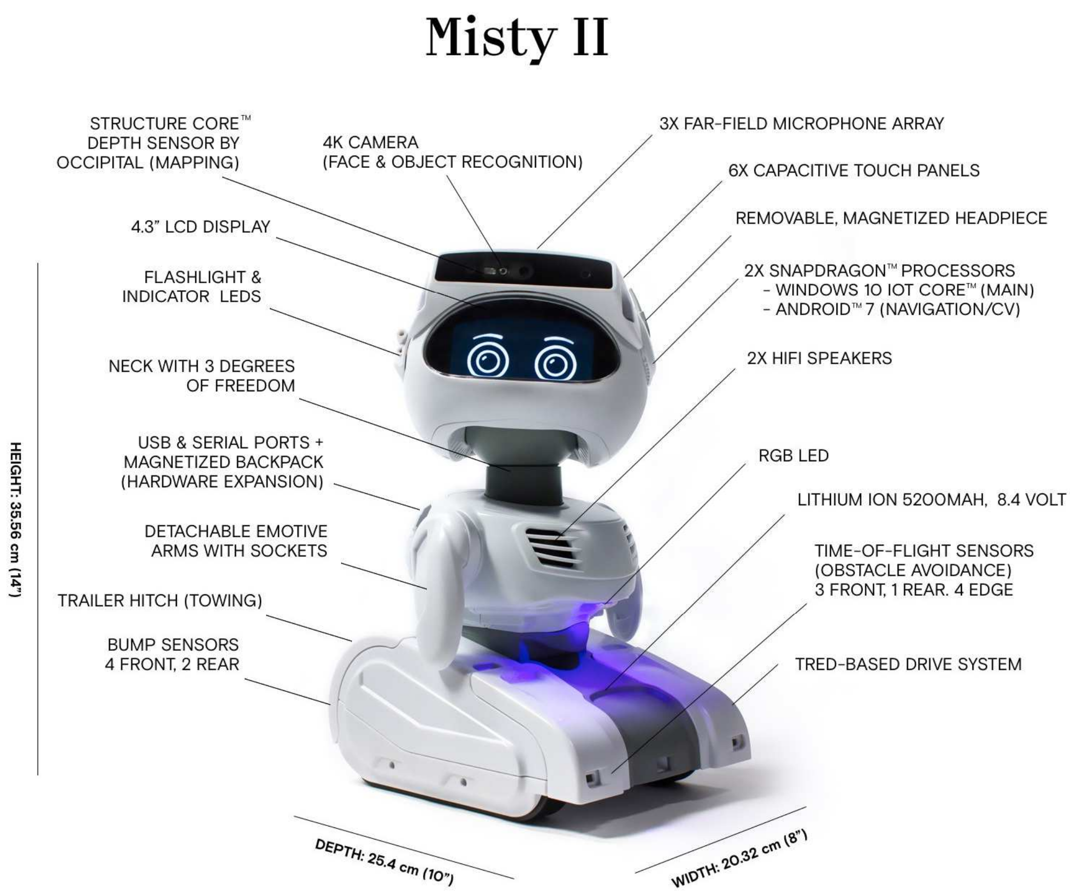

Figure 10. Misty II robot platform

Technical Architecture

The technical architecture of the approach I used consisted of a web-based application that enabled the MM teachers to control the robot engaged in their teaching sessions. I selected a web-based application architecture (see Figure 11) to enable access to the robot control application from any location. This avoided the need to install the application on multiple devices throughout the MM school. Furthermore, a web-based approach is end-point agnostic, meaning the teachers could access the system using any device (laptop, PC, Mac, Android, tablet, or phone).

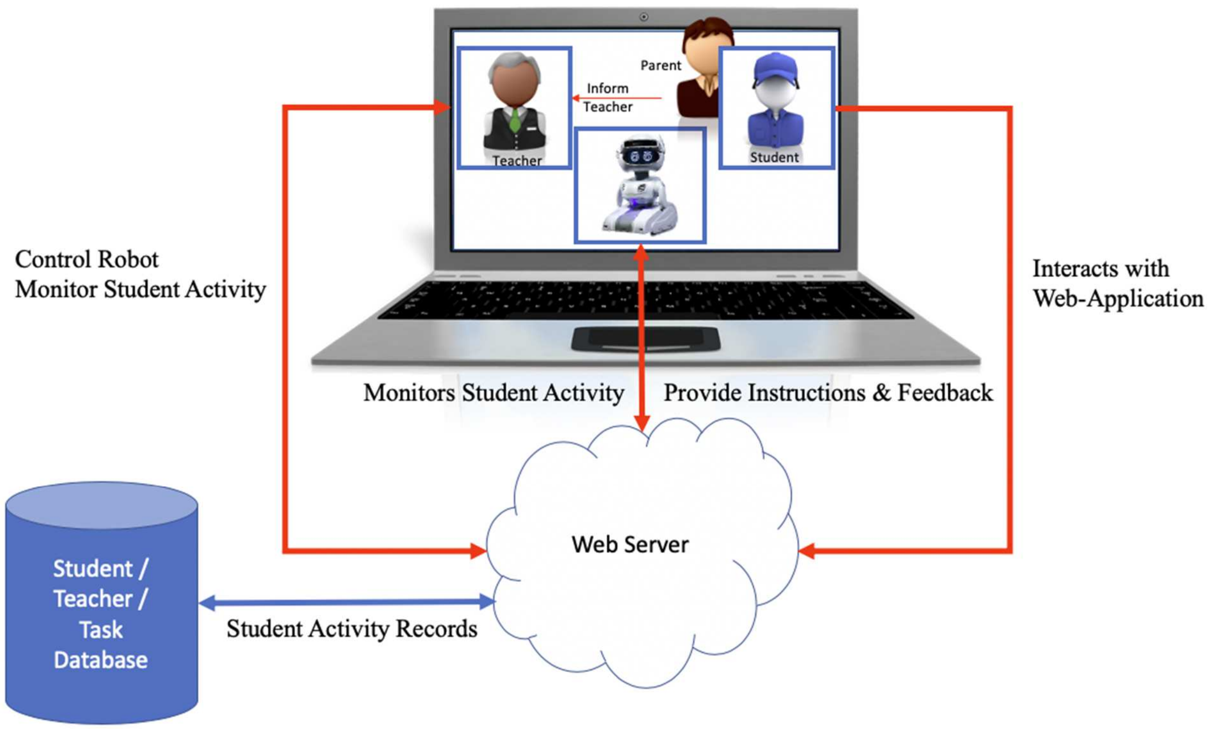

Figure 11. Application architecture

A web-based robot control application accessed and controlled the actions of a robot located at the robot hosting site. The study used three robots, one dedicated to each of the MM classrooms engaged in this study. Each robot was controlled through its own web-based control application. The hosting site also housed a dedicated database server running on a Mac Pro computer. The database was used to record student activity data. This database system was developed as a form of reciprocity for the MM school partnering in this study and was not a formal part of this study.

The following image shows the web-based robot control application (see Figure 12). Teachers had access to a suite of buttons that controlled the robot's arms, head, facial expression, and colored light on the front of the robot. An ad-hoc text box was available so that teachers could type in instructions or responses that did not have a pre-programmed button. On the right of their screen was a series of indicators and buttons that allowed teachers to record student actions in the database. Teachers could also record comments about the teaching session.

Figure 12. Web-based robot control application

To ensure sufficient internet bandwidth was available to conduct three teaching sessions simultaneously, the internet access speed of the site hosting the robots was upgraded to 1-gigabit. In addition, to increase the security, the robots and the database server were located on a separate Wi-Fi network from other equipment at the hosting site (see Figure 13).

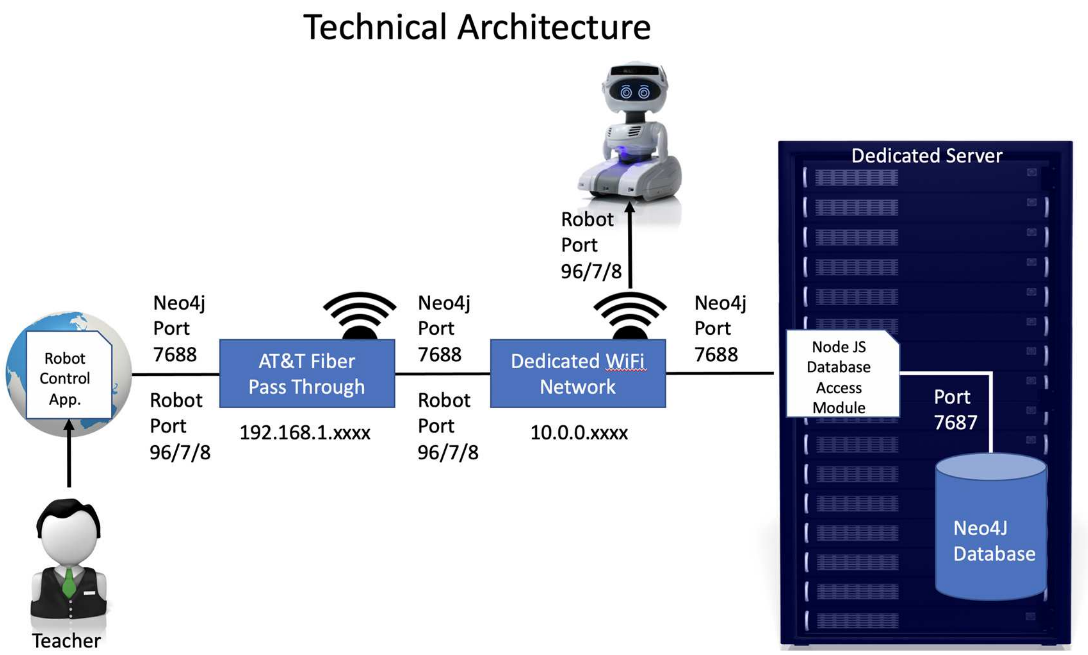

Figure 13. Technical architecture

I used three robots during this study, one dedicated to each of the three classrooms involved. Three versions of the web-based robot control software were deployed to a private web hosting site to enable each robot to be uniquely addressed and controlled. All internet-connected devices connected to the World Wide Web are assigned a unique internet protocol (IP) address. The AT&T Fiber router shown in figure 11 was assigned a unique IP address by the internet service provider at the location hosting the robots (in this case, AT&T). Instructions sent from any of the three web-based robot control applications were sent to the site's IP address where the robots were located. For added security, the instructions received by the AT&T fiber router from the web-based applications were then passed to a separate Wi-Fi network within the hosting site. This ensured that other devices at the site host the robots were unable to intercept instructions and data intended for the robots (and database) used in this study.

However, the site where the robots were located was accessed through a single IP address. A second IP address element can be used to ensure that instructions and data received at a particular site can be passed to a specific device at that location. This second address element is known as a port number. The IP address is used to ensure the delivery of the data to the site where the equipment is located. The port number is then used to deliver the data to the specific device at that location. To ensure that the instructions received at the site hosting were passed to the correct robot, each web-based robot application used a unique port number to signify which robot it was communicating with. I then configured the secure Wi-Fi network to use the port number to pass the instructions to the specific robot that the web-based robot control application was associated with.

Finally, data regarding the student's actions sent by the web-based robot control application were forwarded by the Wi-Fi router to a fourth dedicated Wi-Fi port that I had assigned to the database server. To ensure security, the IP and port address of the database server, where student data were recorded, was not exposed on the website where the web-based robot control applications were located. Instead, these applications forward the student activity data to the database server, where a dedicated application (Node.js) passed the data to the database. Only the Node.js application was aware of the actual database address.

Software Development Architecture

The software development architecture I adopted for this study used popular tools and platforms available at the time of this study to enable future modifications and extensions to the web-based application possible (see Figure 14). The teachers were able to connect to the web-based application using whichever device and web browser they wished (PC, Mac, iPad, Android, tablet, phone, etc.) I used the Tumult Hype 4, HyperText Markup Language version 5 (HTML 5) platform to develop the web-based application suite. HTML was the computer programming language used to develop web-based applications. HTML 5 was the most recent HTML language version at the time of this study and enabled sophisticated visual interfaces to be developed – for example, interactive graphics and video. The Tumult Hype 4 platform was selected due to its highly flexible, graphically oriented development environment, enabling rapid development of interactive solutions. I also chose Hype 4 as it was a popular HTML 5 development environment that was well documented and had a large support community that would enable future extensions and enhancements. JavaScript was one of the most popular web application programming languages and was supported by Hype 4. It was used to develop the programming functions that communicate between the web-based application and the database and the robot. When a teacher issued a command to the robot by pressing one of the function buttons (e.g., to get the robot to speak), the web-based robot control application executed a JavaScript function that performed the required action by sending commands to the robot's application programming interface (API). The Misty robot has a suite of application program interfaces (APIs) that enable computer programmers to access the features of the robot by sending specific commands to the appropriate robot API. For example, a JavaScript function written for, and connect to one of the web-based robot control application function buttons (e.g., to speak the phrase "Well done"), sends the appropriate instructions to the robot's speech API. The robot then executes the requested action. I wrote the JavaScript functions using Microsoft's Visual Studio Code application. Similarly, if the teacher pressed one of the buttons indicating a student action, for example, completing a task successfully, the appropriate JavaScript function sent the appropriate data to the Neo4J database via the Node.JS application (note, Node.JS is a publicly available application written to run JavaScript applications).

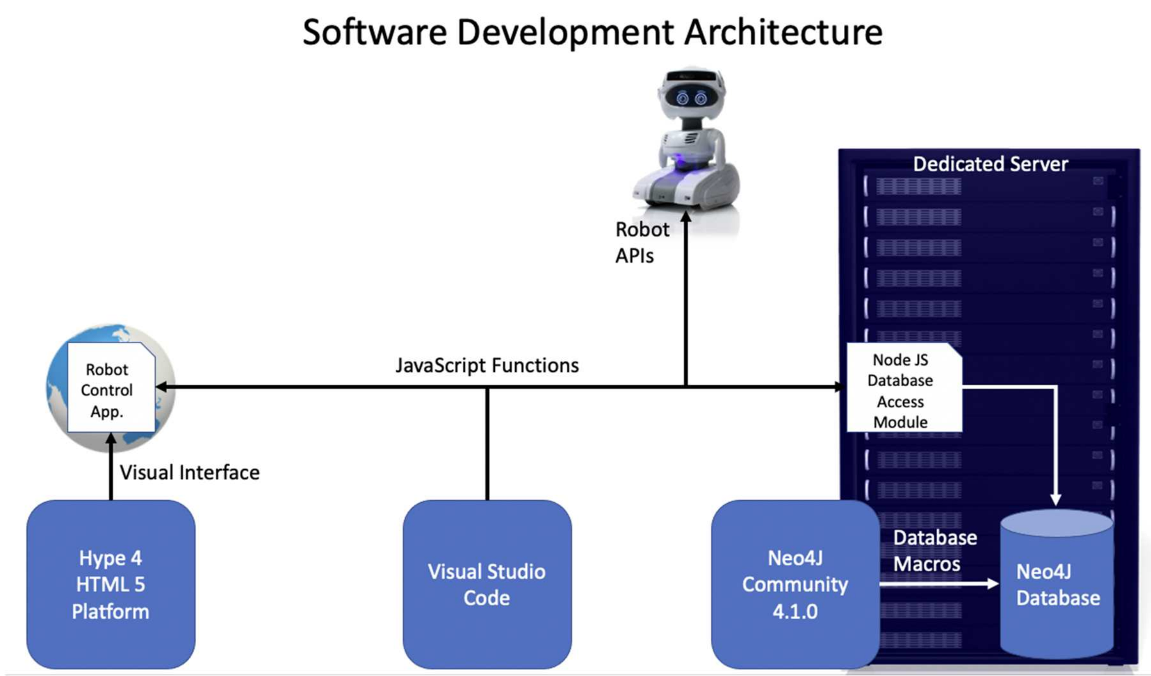

Figure 14. High-level software development architecture

Implementation Architecture

To enable the robots to be included in the video conferencing teaching sessions, I set up each of the three robots in a dedicated location within the hosting site. It was important to ensure acoustic isolation between these locations so that the sounds from one robot-assisted teaching session did not interfere with any other. I used a computer with an attached video camera to enable the robot to join the video session (see Figure 15). The video camera provided both video and audio transmission to the teacher and student. I established a Google email account for each of the three robots, providing each robot with its own email and calendar. I also established a Zoom video conference account for each robot. I was able to log each robot into its dedicated Zoom account and then join the robot to the teaching sessions it has been assigned to. The robot's email account enabled teachers to invite the robot to the video conferencing sessions. I maintained a master calendar of robot bookings to ensure each robot was added to the appropriate Zoom session at the right time.

Figure 15. Robot video conferencing setup

Database Architecture

In addition to the web-based application, I developed an electronic database system to hold the student records as the MM school currently has no electronic database system. Currently, all student data is captured manually on paper forms. This database, and the data it contains, is not a formal part of this study. I developed this database system as a form of reciprocity with the MM school. This electronic database will be used by the MM school, going forward, to hold student, teacher, and task details. In addition, student activity data were captured through the web-based application and stored in the database, as described above. These data record the tasks the student undertook, the date and time each task occurred, and each action taken in the student's attempt to complete each task. For security and privacy reasons, access to the web-based application and the database was located on a private server and was password-protected.

The database system I used for the MM database system was the Neo4j graph database platform. I selected a graph database approach as it is extremely flexible, enabling the storage of any combination of data items and, unlike other database systems, can be easily extended or modified without requiring the re-programming of the system. In addition, unlike other database approaches, graph databases can store both data items and the relationships between them. For example, in addition to storing the student's details, I used Neo4j to store the relationship between the student and the teacher who conducted the educational session, the assigned task, and the classroom they were both assigned to. Figure 16 gives a high-level overview of the graph database design that I used. I also decided to use a graph database approach due to its "whiteboard" design approach. This refers to the fact that the design of a graph database reflects the non-technical business terminology one might use when discussing the user's requirements on a whiteboard. I translated the teachers' whiteboard "picture" of what they wanted to store directly into the database design. This made the database system design more transparent and understandable by the MM teacher community and enabled me to more efficiently and accurately capture their requirements.

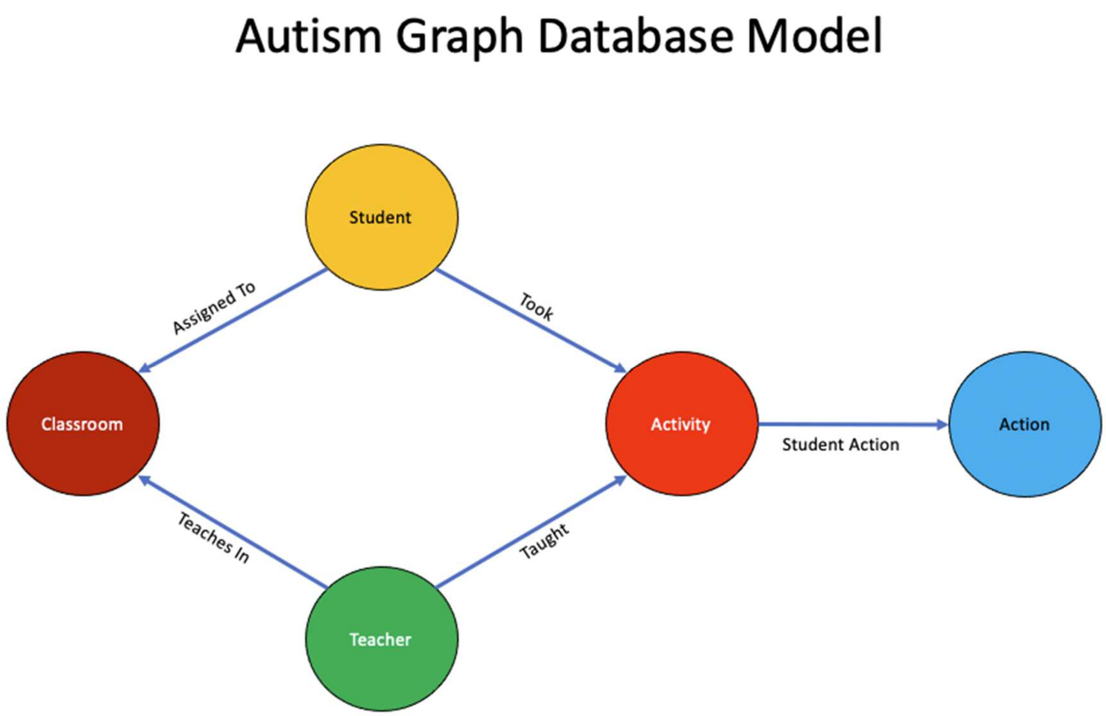

Figure 16. High-level graph database design example

Operational Strategy

The web-based application performed two broad functions (see Table 11).

Table 11
Web Application Functions

Function	Description
Task recording	The MM teachers have an existing suite of non-robot-based tasks they ask students to perform. The teacher monitored the student's progress by observing (via the video conferencing system) the student's activities. As the student performed their assigned tasks, the student's actions, as observed by the teacher, were recorded in the database by the teacher using the web-based application.
Robot control	The teachers were able to control the robot through the web-based interface manually. For example, to manually change the color of the light on the front of the robot, change the robot's facial expression, or cause the robot to issue audible sounds. The audible sounds included task instructions for the student or verbal feedback to the student on their progress (e.g., praise when a task is completed successfully). These verbal communications used a combination of realistic, professional, human-like voices that were pre-programmed into dedicated buttons that the teacher could easily and quickly activate. Second, via a text box where ad-hoc phrases could be typed in and then spoken using the robot's in-built, rather robotic-sounding utterances.

The online web-based application's high-level flow shows the teacher-student activity process flow (see Figure 17).

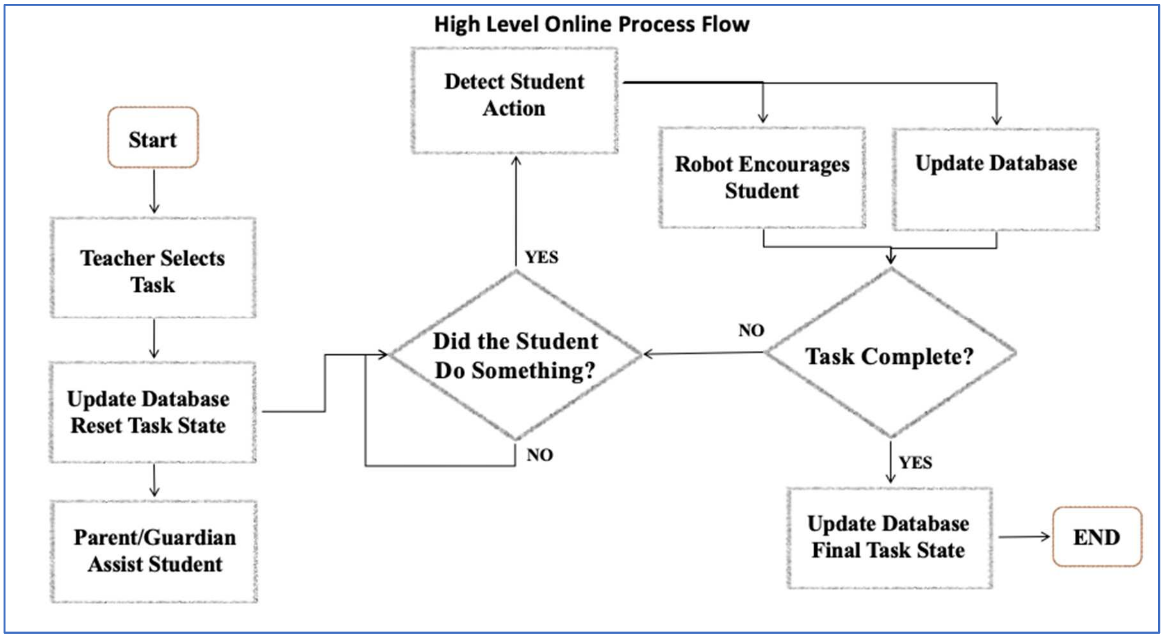

Figure 17. High-level online process flow

To ensure the robot-assisted sessions were conducted in a timely, quality manner, I adopted the following execution protocol (see Table 12).

Table 12
Execution Protocol

Process Step	Action
1	Each morning, each of the three was powered on and tested. These tests were designed to ensure that the robot was fully charged, was accessible from the internet, and was able to perform each of the key functions (change the color of the light on its front, could move its head and arms, and responded to requests to speak).
2	Five minutes before the scheduled teaching session, I logged the robot into the Zoom video call. In those instances where the Zoom call was already in session with another student, the robot's video and audio were disabled.
3	When the scheduled teaching session time was reached for the appropriate student (for whom consent had been given), the robot's visibility and audio were enabled. For the adult classes, where the classes involve many students, not all of whom had been invited/given consent to be included, the robot was entered into a separate Zoom breakout room. At the appropriate time, those students for whom consent had been given were moved into the breakout room by their teacher.
4	At the start of each session, I used the Camtasia video capture application to record the lesson being conducted. This enabled me to conduct post-session observations.
5	At the end of the session, the robot was withdrawn from the Zoom call, and the Camtasia recording was stopped.
6	The resulting Camtasia recording was exported and then copied to the main storage location on the Synology Network Attached Storage device.

I recorded all teaching sessions using Camtasia 2020. I transferred the captured recordings to a Synology Network Attached Storage (NAS) device for long-term storage and post-session observational review. I configured each of the three computers used to log into the Zoom sessions for each of the robots with 10 gigabytes of free disk storage to ensure that sufficient storage capacity was available, recording multiple teaching sessions before transfer to long-term storage became necessary. Each recording, on average, was around 1 gigabyte. In addition, I backed up the software development computer and the database server computer to the Synology NAS on a daily basis.

CHAPTER 5: FINDINGS AND RESULTS

Background

In this chapter, I present the experiences and perceptions of the ASD teaching specialists at the Magister Minster autism school in northern California based on their use of the Misty II social robot during their Zoom-based online video conference teaching session with their students on the autism spectrum. Note: Magister Minister (Latin for Teacher Assistant) is a pseudonym used to ensure anonymity and privacy for the teachers, students, and the school. I anonymized the names of all participants to protect their privacy. The teacher pseudonyms were based on robotics pioneers, while those of the students were based on pioneers in the field of autism.

The MM school granted me permission to work with teachers and students from three classrooms: the adult classroom and two of the younger student classrooms. The adult classroom is dedicated to ASD students aged between 22-60 years of age. The adult classes, which are run as a group, usually include 25-30 ASD adults, with typically three teachers administering each session. The younger student classrooms typically consist of 9-12 students, with a teacher conducting teaching sessions with each student individually.

The teaching sessions occurred between January and February 2021. During that time, the teachers conducted 25 separate robot-assisted teaching sessions, 14 with the younger student classrooms and nine with the adult students. These sessions involved a total of 14 teachers, seven from the younger student classrooms and seven from the adult class.

The data were collected through a series of one-on-one teacher Zoom-based video conference interviews, each lasting between 20-30 minutes, to capture individual teacher insights and perceptions. I also used an hour-long focus group session with all teachers to gather final perceptions across all participants. Data were also collected by observing video recordings of the online Zoom-based robot-assisted teaching sessions. Data were collected based on consistent interview and observation protocols.

Purpose

The purpose of this action-oriented study was to work collaboratively with ASD teaching specialists at the Magister Minister (MM) autism school in northern California to develop new ways of teaching ASD students. This was achieved by introducing the Misty II social robot platform (Misty Robotics, Inc., 2020) into the MM online teaching process and developing new web-based robot capabilities that assisted the MM ASD teaching staff in their educational activities. This qualitative study gathered the insights and perceptions of ASD teachers on the suitability and effectiveness of using a social robot teaching assistant in education.

Research Questions

The research questions guiding this study were:

- Do ASD teaching specialists perceive social robots as helping students with ASD to achieve their learning objectives more effectively/faster than traditional teaching methods?
- Which types of ASD students do ASD teaching specialists perceive social robots to be most helpful?
- Which types of ASD learning activities do ASD teaching specialists perceive social robots are most/least effective?
- Do ASD teaching specialists perceive social robots as a useful teaching aid?

Data Analysis Method

The data captured during this study consisted of three main elements: a) video recordings of the individual interviews conducted with each of the teachers engaged in the study, b) a video recording of the focus group session which included all teachers engaged in the study, and c) video recordings of the individual robot-assisted teaching sessions held between the teachers and their students. I imported all video recordings into the MAXDA software for analysis. MAXQDA is one of the most comprehensive qualitative data analysis software programs for document management and analysis in qualitative and mixed methods research. MAXQDA is capable of managing all types of documents enabling them to be analyzed, including text documents, PDFs, interview responses, images, video recordings, and audio files. The software enables researchers to conduct document analysis for any type of research, including, but not limited to, literature reviews, qualitative text analyses, and mixed methods approach. I used the software to code the video recordings to identify key elements and themes within each session and common elements across multiple sessions. I also coded the video recordings to identify links to the six elements of the enhanced persuasive technology framework, plus the characteristics of the teacher that I have added to the conceptual framework.

In addition to data storage and management, I used MAXQDA to code all notes and recordings. I coded data at the end of each teaching session as the video recordings became available using a constant comparative approach. Individual teacher interview data were then incorporated into the existing analysis as soon as each interview was completed, as was the final focus group data. I aligned these categories with the research questions addressed by this study. I transcribed each video myself rather than use an external transcription service. By conducting the transcription myself, as soon as possible after capturing the recording, while the discussion was still fresh in my mind, I was able to focus on the salient elements of the conversations and ignored all extraneous “small talk.” An external transcription service would have provided a word-for-word transcription of the video recordings, potentially obscuring key elements and making it harder to extract and understand the critical elements of the discussions. Furthermore, by conducting the transcription myself, I was able to establish a personal understanding of both what was said, the tone and inflection of what was said, and the body-language of the participants, thereby increasing the trustworthiness of the data analysis. Using MAXQDA, I was able to link my transcription elements to the appropriate segment of the videos. This enabled me to quickly access the appropriate video segment during the analysis phase.

Conceptual Framework and Coding

I conducted this study through the lens of the persuasive technologies (PT) conceptual framework (Fogg et al., 2002). Persuasion theory (Reardon, 1981) acts as the foundation for the PT conceptual framework. Persuasion theory identifies three influencers of an individual's attitudes and behavior: personal characteristics of the individual, the characteristics of the information being conveyed, and features of the context of the persuasive event. This framework intends to understand how these factors influence behavior and the intended attitude change.

Fogg (2002) defined persuasive technology as any computing system designed to influence an individual’s attitudes or behavior in a predetermined way. Using this definition, in 2013, the technology group of the Center on Secondary Education for Students with ASD (Center on secondary education for students with ASD) proposed a conceptual framework showing the variables affecting the use of technology for students with ASD based on persuasive technology principles. This framework identified three major components: the characteristics of the individual on the autism spectrum, the activity they perform, and the technology used during the persuasive event (Odom et al., 2015). However, in this study, I used an enhanced version of the Center on Secondary Education for Students with ASD framework, whereby I introduced a new, fourth component to the framework: the role of the influencer, in this case, the teacher (see Figure 18).

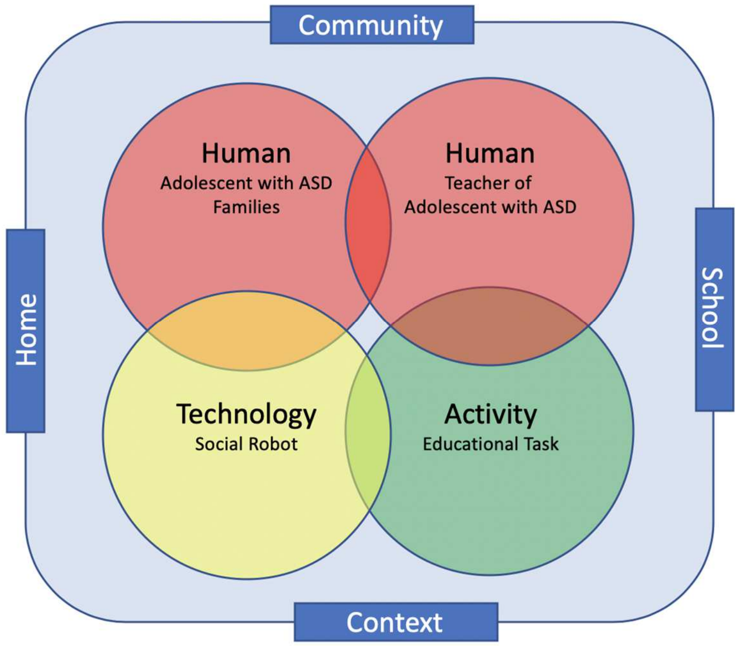

Figure 18. Enhanced conceptual framework

I coded the data with respect to the five elements of the persuasive technology framework, plus the sixth element that I added to that framework. These six elements are the personal characteristics (of the individual being influenced – the student), characteristics of the content, characteristics of the context, credibility, Kairos, and the personal characteristics of the influencer (the teacher). In addition, I then coded the data according to common themes that emerged through the interviews and observations. Both the conceptual framework categories and the thematic categories were then matched to the research questions.

Participants

The teachers engaged in this study were, for the most part, long-term autism teaching specialists engaged at the MM autism school. The average age of the teachers was 32 years, with most having some form of qualification in social work, child development, or special education. The age of the teachers ranged from 25-43. The majority of teachers are female (78%). The teachers who were approved to engage in this study were assigned to the classrooms, as shown in table 13. Note: I used pseudonyms for all teacher and student names throughout this report to protect participant confidentiality.

Table 13
Teachers

Classroom	Teacher Pseudonyms	Gender	Age (Years)	Tenure at MM School (Years)
5	Alice	Female	32	8
5	Crystal	Female	43	5
5	Madeline	Female	32	4
6	Cynthia	Female	28	3
6	Helen	Female	28	2
6	Kanako	Female	34	3
6	Victor	Male	34	14
Adult	Ayorkor	Female	36	4
Adult	Danielle	Female	29	13
Adult	Emily	Female	28	2
Adult	Ichiro	Male	29	4
Adult	Ruth	Female	37	2
Adult	Marvin	Male	39	1
Adult	Susanne	Female	25	3

Note: Pseudonyms have been assigned to protect participant confidentiality

The students engaged in this study ranged from 14-54 years of age. The students from the two younger age classrooms were less developed in terms of their social and verbal skills than the adult class students. The students who were approved to engage in this study were approximately evenly distributed in terms of gender within each classroom. Students were assigned to the classrooms, as shown in table 14.

Table 14
Students

Classroom 5	Student	Gender	Age (Years)
5	Bernard	Male	19
5	Ole	Male	20
5	Simon	Male	18
6	Kalle	Female	17
6	Temple	Female	18
6	Tom	Male	14
Adult	Carol	Female	33
Adult	Chuck	Male	28
Adult	Eric	Male	34
Adult	Eugene	Male	30
Adult	Gary	Male	38
Adult	Hans	Male	27
Adult	Judith	Female	21
Adult	Leo	Male	54
Adult	Lorna	Female	42
Adult	Margaret	Female	47
Adult	Michelle	Female	27
Adult	Portia	Female	21
Adult	Sarah	Female	36

Note: Pseudonyms have been assigned to protect participant confidentiality

The Data Gathering Process

The MM teachers conducted 25 separate robot-assisted teaching sessions, 14 with the younger student classrooms and nine with the adult students. These sessions involved 14 teachers, seven from the younger student classrooms and seven from the adult class. Once all robot-assisted teaching sessions were concluded, I conducted an individual video-conference interview with each teacher to gather their perceptions, using a consistent interview protocol (See Appendix D). I also conducted a focus group workshop with all teachers to gather final perceptions and suggestions for future development and research, using a semi-structured interview protocol (See Appendix E). The perceptions reported by the MM teachers were very consistent across all three of the classrooms. This reinforced the trustworthiness of the data.

As the focus of this study was on the MM teachers' perceptions, I present the findings of this study through the lens of the teachers by providing a series of vignettes that describe the teachers' experiences and reported perceptions. I also structure these findings according to the four research questions that guided this study. While I refer to the “robot” in this study, the teachers and students refer to it by the name “Misty.” In the following descriptions, the teachers and students frequently anthropomorphize the robot, referencing it and communicating with it as if it were another human participant.

Research Question 1: Improving Student Learning Outcomes

The purpose of this research question was to determine if the MM ASD teaching specialists perceived a social robot teaching assistant as helping their students achieve their learning objectives more effectively/faster than traditional teaching methods. Overall, teachers agreed that using the robot as a teaching assistant during their online teaching sessions led to positive impacts and outcomes for their students. The student reactions to the robot, however, ranged from neutral to positive. A few students, such as Simon, exhibited a minimal response to the existence of the robot. By comparison, Hans would become overly excited when he saw the robot and would lean close to the screen and shout into the microphone, waving his hands excitedly and saying, “Hi Misty!” Hans’ response is common amongst those on the autism spectrum, who can have difficulty comprehending social boundaries, and may be oversensitive to sensory stimulation (Boucenna et al., 2014; Kennedy et al., 2016; Kohn, 2020; Øhrstrøm, 2011; So et al., 2019). As indicated by the principles of persuasive technology (Odom et al., 2015, Fogg, 2002), establishing the trustworthiness and credibility of the technology was important. The teachers achieved this by, initially, in their first teaching session where the robot was used, introducing the robot as a friend of the teacher. Thereafter, at all subsequent teaching sessions where the robot was used, the teacher would remind the students that the robot was a friend, using a typical refrain of "Oh, look who has come to join us today. It's our friend, Misty." The teachers' general consensus was that the robot was a useful tool in helping them achieve student learning outcomes, as can be seen from the following examples.

Increased Student Interaction

Danielle was the program director of the Magister Minster school's adult program who was in her 13th year at the MM school. Her students are mostly highly sociable individuals with more advanced verbal and social skills than the younger students in classrooms 5 and 6. The adult classes are typically conducted with two or more teachers engaged and a student population of over 30. On this occasion, Danielle, Marvin, and Susanne met with a small class of six students in the Zoom breakout room they had set up for the robot-assisted session. Judith was one of the students who had joined the group. At the time of this study Judith was 21, and while not the youngest student in the study overall, she was the youngest member of the adult class to have been approved to engage in this research. She was a friendly young woman who smiled constantly. Judith liked to be referred to by the nickname that the MM teachers gave her some years ago when she was first starting to attend the MM school. Danielle arranged for the robot to address Judith by her nickname whenever the robot interacted with her. Being addressed by the robot in this familiar manner clearly delighted Judith and increased the trustworthiness and positive impact the robot had upon this student. Danielle recounted the impact the inclusion of the robot had on Judith: "Judith talked a lot more when with Misty. She had no problem asking Misty for help, which was surprising. Normally Judith is very timid – even to ask her parents for help." Danielle went on to describe the unsolicited response she received from Judith's mother:

> I just wanted to mention one of our adult students who really liked Misty. Ahm, it was really cool when I got an email from her mother saying that she told me today that she talked to Misty, like, on her own with no prompting. You know she is a student that doesn't typically initiate conversation like that. You have to initiate conversation with her. So, I think her mother was pleasantly, you know, surprised to have her initiate that talk about Misty. I think that that was really cool.

Both Danielle and Kanako speculated that the robot might have seemed less "threatening" to their students than a teacher might present. They felt that instructions from their human teacher could apply pressure on the student to respond. As Danielle explained, some students, such as Judith, can "freeze" when they are posed with a question from their teacher. However, this did not occur when the robot posed the question. Danielle described her experience when teaching Judith:

> One person who REALLY seemed to enjoy Misty was Judith. She's verbal but can sometimes get stuck. She's a really happy person and was really excited to see Misty – she likes cute things. She was able to answer questions and take her turn right away when Misty gave her directions. I think her excitement with seeing Misty helped her be more verbal and able to express herself.

English Comprehension

Ichiro and Ruth began their adult breakout class with the usual welcome and reminded their students that "Our friend Misty has joined us again today." Ichiro waved enthusiastically towards the camera as he asked the students to "Say hi to Misty, everyone." The students had seen the robot before, and I observed that they welcome it to their session as they would any other human participant. Ichiro explained that they would be doing the "Funny fill-in" activity. This activity involved the students filling in a series of boxes laid out in rows. As this particular activity was based on a scuba-diving adventure, the first box asked the students to suggest a faraway place. The teachers then asked the students to suggest words to fill in a series of boxes that referred to various English grammatical components, such as adjectives, nouns, past-tense verbs, etc. Ichiro reminded the students that they could always ask the robot for help. As the session progressed, Eric was asked to suggest an adjective to describe the faraway place that was previously entered. Eric was a 34-year-old male who lazed back on his sofa in his usual, casual manner. Despite his relaxed stance, Eric always remained fully engaged in his classes. He had well-developed verbal skills and was not shy about speaking up and contributing to the conversation. On this occasion, when asked to supply an adjective, he hesitated. Ichiro, who was both leading the teaching activity and controlling the robot, reminded Eric that he could ask the robot for help if he wished. Eric responded in his typical, neutral tone, "May I need some help please" (his grammar may not have been perfect, but his request was very clear). Ichiro, having predicted the request, had typed in the appropriate explanation into the robot and then pressed the "speak" button to cause the robot to explain what an adjective was and gives a couple of answers. Eric responded immediately, "Oh, now I get it!" Eric went on to exclaim, "This is much better than Keith [another teacher – not engaged in this study]. He is always letting us know loudly" – at that point, Eric was cut off by another student speaking. Later in this session, Margaret was asked to provide an adverb. Margaret, who was less verbal than the others in the group, thought for a moment and said, "peeuw." Ichiro laughed, repeating the word in a friendly tone, and proposed, "let's ask Misty for some suggestions on how we could use a word like peeuw." The robot suggested "smelly." Ichiro laughed again and asked Margaret what the robot just said. Margaret repeated the word, smelly. Ichiro then reinforced the connection between the word "smelly" and its use as an adverb by asking Margaret, "Hey Margaret. Misty said smelly.

Do you want to use smelly as an adverb?" Margaret confirmed that she did. These exchanges demonstrated the effectiveness of using the robot to help the teacher help ASD students grasp complex concepts, in this case, English grammar.

Trainer and Reinforcer

In their study of the roles, strengths, and challenges of robot-mediated interventions with students with ASD, Huijnen et al. (2018) identified six potential roles for social robots: provoker, reinforcer, trainer, mediator, prompter, and diagnostic information provider. During this study, I observed numerous examples where the MM teachers used the robot in a trainer/prompter capacity. For example, in the above case descriptions, when Ichiro caused the robot to explain to Eric what an adjective was and supplied some example words that the student could use. Ichiro then used the robot to prompt Eric to select one of the offered words or select one of his own. In addition, all teachers used the robot in a reinforcer capacity. Most reinforcer activities that involved the robot were simply to confirm to students that they had performed a good job or encouraged them to try again. Students often responded overtly to these reinforcement messages, for example, when the robot congratulated Temple for successfully selecting the correct food elements during a food construction exercise. Being 18 at the time of this study, Temple was challenged in terms of her ability to speak and was engaged on one of the tasks she regularly attempted: food construction. In this exercise, the teacher asked Temple to select the order in which food items must be constructed (e.g., bun, then the burger, then cheese). Once Temple had completed the sequence correctly, the robot gave Temple the congratulatory feedback of "Well done!" Temple was visibly delighted at receiving the acclamation from the robot, smiling broadly and saying, "Ah. Mmm." In a more advanced form of reinforcement behavior, Susanne used the robot's arm movements to demonstrate to her students when to raise their hand to signal they had a question or wished to be selected (e.g., to provide an answer).

In a different instance, Victor indicated that he used the robot as a fun reinforcer with his student, Kalle. At the time of this study, Victor had been with the MM organization for 14 years, and at 34 with a Bachelor of Arts degree in Fine Art, admitted that "I love my job because it's genuinely fun and I feel good about my work at the end of the day." Victor described his experience using the robot teaching assistant with one of his students, Kalle. Kalle was an energetic 17-year-old female with a keen interest in cars when she engaged in this study. Whomever she met, she wanted to know what car they drove. In one of her sessions with the robot assistant present, Kalle was in her bedroom, dressed in her customary multi-colored woolen hat and gloves. During their session together, Kalle asked the robot, "Misty, what car do you drive?" Victor was very used to Kelle's fascination with cars and got the robot to respond with, "I don't drive. I don't have hands." Kalle was clearly amused by that response. In keeping with the persuasive technology concept of Kairos, Victor proceeded to use the robot to reinforce his message by raising and lowering the robot's arms.

Danielle was able to utilize a feature of the robot that she, as a human, was unable to explain easily. One of the teaching exercises that Danielle used with many of her students was referred to (at the MM school) as the "zones of regulation." As Danielle explains:

> In my session, we did an activity about zones of regulation where we talk about the different colors of the zones and how they are associated with different feelings. I used the colored light on the front of Misty to change her color - and then asked the students, "Hey, what color is Misty feeling right now?" For example, Green means happy or comfortable. It was a good visual for them. They are all pretty familiar with the zones, but I feel adding that visual was helpful.

Research Question 2: Student Alignment

As indicated by Shane et al. (2012), it is important to match technological features to the student in conjunction with the appropriate instructional approach. Research question 2, therefore, sought to understand with which types of ASD student ASD teaching specialists perceived the social robot teaching assistant to be most helpful. This question also relates to the personal characteristics of the individual who is trying to bring about the change in attitude or behavior (Reardon, 2008). I found two broad aspects of a student's characteristics that impact the effectiveness of the robot as a teaching assistant. First, the student's verbal and social skills, and second, the student's personal interests. I also observed that no student had a negative reaction to the robot. This latter point was also confirmed by the MM teachers.

No Negative Reactions

One concern I considered prior to the start of teachers engaging the robot in their teaching sessions was whether any student would react negatively to the robot. The inclusion of the robot was, after all, changing the normal context of the online persuasive teaching event (Reardon, 1981) that the students were used to. In preparation for that eventuality, I tested to ensure that the teachers had the ability to remove the robot from the Zoom video conference sessions by turning off the robot's video and audio or ejecting the robot from the teaching session altogether. I informed the teachers on how to take these actions. In addition, I monitored the initial teaching sessions in which the robot was engaged, live to observe student reactions. I also monitored for adverse reactions through the recordings that I gathered from the teaching sessions. Arguably one of the most important findings of the study was that all teachers from all three classrooms reported that none of their students had a negative reaction to the robot.

Similarly, I did not observe any adverse reactions to the robot. Student reactions to the robot ranged from neutral to really excited.

Verbal and Social Skills

As indicated in Reardon's (1981) seminal work on persuasion theory, one of the influencers that determine whether an individual will be persuaded to modify their attitude or behavior is their personal characteristics. In this case, the personal characteristics of the student influence how well they are likely to be persuaded to modify their attitude or behavior. Teachers indicated that the impact achieved through the inclusion of the robot in the teaching sessions depended on two aspects of the student's characteristics. The first of these student characteristics was their verbal and social skills.

Teachers agreed that students who had more developed verbal skills and were more socially aware reacted more strongly and more positively towards the robot. While all three classrooms saw a mix of reactions, from neutral to positive, it was particularly evident amongst the adult students who, by virtue of their age and the number of years they had had to develop their verbal and social skills, interacted more with the robot. Those with less developed verbal and social skills (in all three classrooms) tended to have a lower level of reaction to the robot and, in some cases, appeared unaware of the robot's inclusion. For example, Danielle and Emily reported how one of their students, Chuck, proved to be uninterested in the robot. As Danielle explained, "Misty didn't make a huge difference with Chuck. He is always very distracted in our sessions, for example, looking at his phone. I'm not sure if he even realized Misty was there." Similarly, Crystal reported that "Ole came in and said 'Hi Crystal. Hi Misty' without being prompted, but then that was it."

Some students modified their reaction to the robot over time, as was clearly described by Alice. Alice was the 32-year-old lead teacher of classroom 5, with a degree in social work and moderate to severe special education qualifications. She described herself as having found her way into the work of ASD education accidentally:

> I honestly just fell into teaching. I had a roommate who worked at MM, and I literally had no interest because I heard all her stories of getting her hair pulled, getting scratched, etc. I was burned out from my case manager job (taking care of adults with disabilities), and I decided, on a whim, to apply. At my interview, I FELL IN LOVE with MM and just KNEW in my heart that that's where I belonged. MM is the best thing that's ever happened to me (next to my husband).

Just as Alice needed time to discover that educating students on the autism spectrum took time, so too "some students needed time to get used to the robot," she explained. For example, Alice described her experience of working with one of her students, Bernard, whose initial reaction to the robot was cautious. In the first session that Alice used the robot with the student, he spoke to the robot, saying, "Shhh. No." The student did not display any anxiety at the robot being present. He merely signaled [to the robot] that it should not speak. However, as Alice went on to explain, "Then at the next session, he would go like 'Oh, Hi!' [to the robot] It was cool to see the progression of that."

Student Interests

The second aspect of the student characteristics that I identified as having impacted how students reacted to the robot was the personal areas of interest of the student. Those students who were generally interested in and excited by technologically oriented entities, such as animation characters, science fiction films, robot film characters, or objects they found "cute" and attractive, reacted more strongly and more positively towards the robot. Ayorkor explained: "I think it's something new [the robot], and I knew that the students would enjoy it because Misty is not human, and they like Disney characters and robots, etc." Students like Sarah, whom

Danielle described as “loves dolls and cute things,” and Gary, who was known to be “really into and excited by technology, such as Alexa,” reacted excitedly at the robot’s inclusion. Similarly, Hans’ mother had expressed to the MM teachers that she was really excited for Hans to be included in the study. Danielle explained, “Hans really loves anything animated and in particular Wall-E” (note: Wall-E is an animated robot character portrayed in the Pixar movie, Wall-E). Danielle expressed the suspicion that Hans’ mother had told him about the robot. “Hans seemed excited and really interested in Misty,” explained Danielle.

Research Question 3: Activity Alignment

Similar to research question 2, research question 3 considered another aspect of matching the robot-assisted teaching activities’ technological features by reviewing with which types of ASD learning activities the ASD teaching specialists perceived a social robot teaching assistant to be most effective. I identified one major finding.

Simple Versus Complex Activities

In addition to the verbal/social skills of the student, teachers agreed that the nature of the activity assigned to the student also impacted the degree to which the robot could be usefully engaged in the activity, and hence the influence/impact the robot had on the student. Teachers reported that with simpler tasks like “Build the flower” (a more student-friendly form of hangman), they had time to integrate the robot into the activity as the students were undertaking the task. For example, while students were considering which letter they would choose next, the teacher had time to construct appropriate prompts and encouraging remarks for the robot to speak, such as “Good try, but we’ve already used that letter, try again.” This enabled the teachers to engage the robot in a more natural dialogue with the student.

Madeline described the interaction that one of her students, Simon, had, or rather, did not have with the robot during his lesson. Simon was known to be generally interested in technology, and Madeline had assumed he would, therefore, be very interested in the robot. However, that was not the case. As Madeline explained:

> Simon is generally quite interested in technical things, and so I had assumed he would be fascinated by Misty. However, he didn't seem very interested in her. His session was more complicated, so I didn't have much time to do very much with Misty. When Misty talked, he [Simon] was like, "whatever."

Madeline contrasted her experience with Simon with one of her other student's reactions to the inclusion of the robot:

> Bernard was much more into Misty. Today's session went really well. I think it's because he does much more simple tasks, doing blocks, so he was much more into her. He was talking back to her, which was REALLY good. I was really surprised by him.

More complex tasks required teachers to spend more of their time focused on the activity the student was performing, and hence, less time was available to engage the robot. On these more complex activities, the robot was, consequently, less frequently used.

Research Question 4: Overall Teacher Perceptions

The overarching question I sought to answer through this study was: Do ASD teaching specialists perceive social robots as a useful teaching aid? The answer to this question involved several themes. First was the question of the personal characteristics of the teacher.

Teacher Personal Characteristics

As described in chapter 3, the original persuasion theory developed by Reardon (1981) and the subsequent persuasive technologies theory develop by Odom et al. (2015) and Fogg et al. (2002), along with the conceptual framework developed by the Center on Secondary Education for Students with ASD (Center on secondary education for students with ASD), did not include the concept of the characteristics of the person attempting to accomplish the persuasive outcome.

I chose to make the role of the teacher, as the persuasive agent, explicit in the enhanced conceptual framework that I have used for this study (see Figure 19). The characteristics of the teacher are, therefore, an important element of my study.

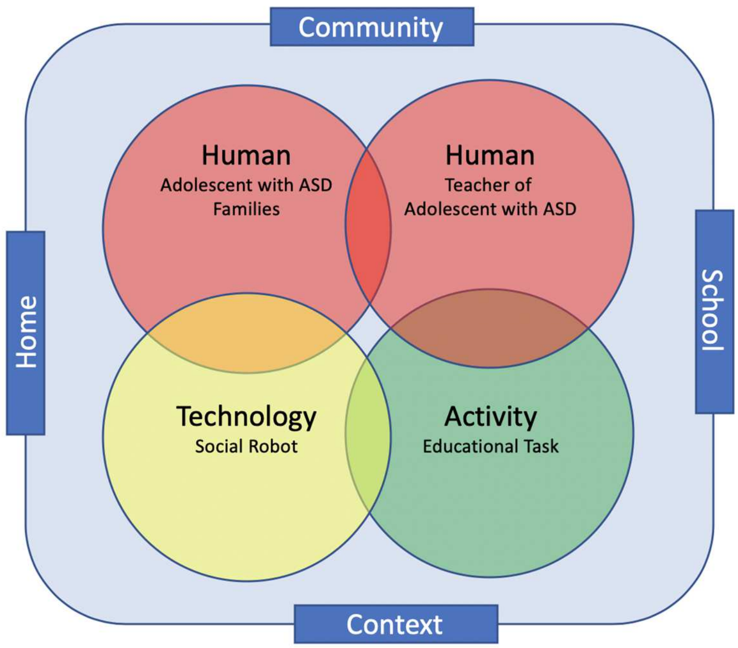

Figure 19. Enhanced conceptual framework

Teachers reported that they were, on average, comfortable with the use of technology. On a Likert scale of one to five, where one was "very uncomfortable," and five was "Completely comfortable," all teachers rated their comfort level at a three or above. This suggests that, while most teachers expressed initial challenges using the robot effectively due to unfamiliarity, the teachers were not reticent or uncomfortable embracing this new technology. Indeed, as Crystal commented: "I never used to be comfortable with technology. Now, through my distance learning experience, I am now a 4 or 5." Far from being timid about using the robot in their teaching sessions, I observed that all of the teachers were enthusiastic about using it.

Both Alice and Danielle commented upon the positive impact that Ichiro had when he introduced elements of his own character into the robot's responses. In particular, he injected an element of humor into the responses he created for the robot. All three of these teachers remarked that the students reacted very positively when that happened. Danielle went on to suggest that enabling teachers to imbue the robot with characteristics of themselves by having the robot respond with a style of language that the teacher would normally use would be helpful. This should be the subject of future research, as other literature indicates that making robots too human-like can have a detrimental effect on the perceived acceptability of robots by children (Stower et al., 2021).

Fun and Exciting

All teachers reported that they and their students found the inclusion of the robot in their teaching sessions fun and exciting. This element of fun and excitement relates to the personal characteristics of both the teachers and students as both parties are, quite naturally, more likely to engage with a technology they enjoy. Furthermore, I conclude that students are more likely to be persuaded by a technology they find fun and exciting. Crystal expressed particular interest in expanding her experience with the robot by using it in the classroom, explaining:

> I feel it would be a significant help in the classroom. That's where I want to see it – in the classroom, even more than on Zoom. I'd like to take it a step further and do real activities like math problems and word problems where she [the robot] reads out questions. That would be awesome.

A New Way of Teaching

Several teachers commented that introducing the robot into their teaching practices added a new and exciting addition to their teaching sessions. They added that the robot provided students with greater variety in their online lesson experiences. For example, Kanako pointed out that, "It was nice. It was a different way to approach our teaching," while Alice added, "Overall, I think it added a whole other level to the sessions." Several teachers expressed the opinion that the robot gave them the opportunity to break from their traditional role and have the robot take on some of the tasks of providing the student with instruction and feedback. Teachers perceived this provided the students with increased variety, which kept them more engaged and enabled the teachers to spend more time recording data about their student's performance on the task at hand.

Operational Challenges

While the teachers universally considered the use of social robots as a teaching assistant as beneficial, that is not to say they did not have any challenges.

Simultaneous Teaching and Robot Control

One of the most common responses from teachers regarding using the robot during their teaching sessions was the complexity of trying to conduct their instruction while simultaneously controlling the robot. The MM teachers agreed that the issue of simultaneously conducting the teaching sessions and controlling the robot was particularly challenging when the activity the student was asked to perform was more complicated. More complex tasks required the teacher to pay close attention to what the student was doing, leaving less time to engage the robot in those activities. This was less of a challenge when conducting simpler activities. However, most teachers agreed that this was largely due to inexperience in using the robot and that they expected their ability to use it effectively would improve over time as they became more familiar with its capabilities and operation.

Coordination between multiple teachers. While simultaneously conducting the teaching sessions and controlling the robot was challenging for a lone teacher, there was agreement that having two (or more) teachers made this far less challenging. One teacher was able to lead the instruction, while a second teacher controlled the robot. However, while this alleviated the challenge of lone teachers having to divide their focus between the activity the student was conducting and controlling the robot, it introduced another issue that several teachers reported: coordination between the instructor and robot operator. Teachers reported that it was not always easy for the teacher conducting the lesson to communicate to the person controlling the robot what response they wanted the robot to give and when. The fact that the teaching sessions were conducted over Zoom video conferencing and the instructor had to rely on "hints" to communicate to their co-teacher what they wanted the robot to do exacerbated the issue. This led to delays in the robot's response, impacting the Kairos impact of the robot's responses.

Time Consuming Typing

The web-based robot control application consisted of a number of pre-programmed buttons that caused the robot to react, for example, to speak a professionally recorded voice message or to tilt its head from side to side. I designed these buttons to enable the most frequently used phrases and actions to be enacted with a simple press of the button, thereby making the robot's operation as quick and simple as possible. Pre-programmed buttons were continuously added as teacher feedback was received through each of the action-reflection cycles. The robot control application also included a text field where teachers could add ad-hoc custom messages that the robot would then speak using its inbuilt text-to-speech conversion capability. Several teachers pointed out that typing into this text box could be time-consuming, leading to delays in the robot responding to the student. One student, Eric, found the delays particularly noticeable and frustrating, while other students were seen to be excitedly waiting for the robot to respond.

More Pre-Planning

Most teachers agreed that greater experience of the robot's capabilities, and familiarity with operating the robot, would improve their ability to use the robot effectively. Some teachers also commented that they felt it was important for teachers to pre-plan how they intended to use the robot in each teaching session so that they knew when and how they would incorporate the robot. This was especially true if there would be two or more teachers in the session, where one teacher conducts the instruction and another operates the robot. This again was seen as an issue that would improve over time with greater experience and familiarity with the robot, how the robot could be usefully engaged in an activity, and how different students react to the robot.

Summary

The MM teachers' overwhelming perceptions were that the use of a social robot as a teaching assistant was beneficial and that they would use one in the future. They observed that most students found the robot an exciting and stimulating addition to the teaching sessions. Importantly, no students showed any form of negative reaction to the inclusion of the robot in their educational sessions. Student reactions to the robot included in their sessions ranged from neutral/passive to overt interest and excitement. The degree to which students were engaged with the robot depended on their verbal and social skills and their general level of interest in technological devices or objects they find attractive and exciting. The complexity of the activity the student was engaged in also impacted the level of engagement of the student and the time the teacher had to integrate the robot into the teaching session. More complex activities required the teacher to pay closer attention to the student and the task they had been assigned, and consequently, less time available to operate the robot.

Teachers highlighted a number of challenges in operating the robot while simultaneously running their educational sessions. Most teachers felt that this challenge would become less of a problem as they acquired greater experience with using the robot. Teachers also felt that with greater experience with using the robot, they would be better able to pre-plan how they would integrate the robot into their teaching activities. Several of the teachers indicated that the robot introduced a new approach to their teaching – a new way of engaging their students and communicating with them.

CHAPTER 6: CONCLUSIONS

This study explored teacher perceptions of the role of social robots as teaching assistants in the online teaching of students with autism spectrum disorder. The study was conducted at the MM autism specialist school in northern California. I was granted permission to work with teachers and students from three classrooms: the adult classroom and two of the younger student classrooms. Seven teachers and 13 students from the adult classroom participated in the study, along with six teachers and six students from the two younger age group classes. I identified eight themes through the exploration of the following four research questions:

- How do ASD teaching specialists perceive the impact of social robots in helping students with ASD to achieve their learning objectives more effectively/faster than traditional teaching methods?
- For which types of students with ASD do ASD teaching specialists perceive social robots to be most helpful?
- For which types of ASD learning activities do ASD teaching specialists perceive social robots to be most/least effective?
- How do ASD teaching specialists perceive the role of social robots as an effective and useful teaching aid?

The teaching sessions occurred between January and February 2021. During that time, the teachers conducted 25 separate robot-assisted teaching sessions, nine with the adult students and 14 with the two younger student classrooms. I will address the study's conclusions in three key areas: student implications, teacher implications, and overall teacher perceptions. Recommendations for practice will be presented at the end of these three areas.

Student Implications

While this study's focus was teacher perceptions of the use of a social robot as a teaching assistant, teachers are unequivocal in their motivation for teaching: to have a positive student impact. That sentiment was expressed by every teacher engaged in this study. Therefore, it is fitting that this chapter starts with a consideration of the student implications before moving on to the teacher-related implications. As I discuss the conclusions I draw from this study, it should be remembered that each student with ASD is unique. As indicated by the Autism Society of America (2008), "If you've seen one person with autism, you've seen one person with autism." Not only are ASD students different from one another, but they can also exhibit different reactions and behaviors from one day to the next. The findings of this study reflect the reactions and behaviors of the MM students at the time they were exposed to the robot during the data gathering stage of this study. Therefore, the student reactions and behaviors could be different at other times or may evolve over time.

No Negative Reactions

Arguably one of the most important findings of the study was that there was unanimous agreement amongst the MM teachers that none of their ASD students had a negative reaction to the inclusion of the robot teaching assistant into their online video conference-based teaching sessions. These teacher perceptions were also consistent with the observations I made of the online video conference-based teaching session recordings. This acceptance of robot technology confirms earlier research conducted by Pioggia et al. (2008), who observed that ASD students were unafraid to walk up and touch the face of an android robot. In addition, while this study only involved students who were on the autism spectrum, my findings are consistent with Boucenna et al. (2014), who found that ASD students appear to be less alarmed by a robot than those students not on the autism spectrum. My findings suggest, therefore, that further research into this area can be safely undertaken. Nonetheless, caution should always be taken to ensure that only appropriate subjects are selected for any future research and that precautions are taken to ensure that the robot technology can be deactivated/removed from an active educational session should a participant experience distress.

Robot Impact Affected by Student Verbal and Social Skills

The MM teachers involved in this study agreed that the use of a social robot as a teaching assistant had a positive impact on most students. The study found that the verbal and social skills of the student determined how strongly the student reacted to and was impacted by the inclusion of the robot technology. The relationship between verbal and social skills and the reaction of students to the robot was particularly evident with those students who had had time to develop these personal characteristics more fully, such as the adult ASD students. This relationship to each student's personal characteristics confirms earlier findings reported in the literature that the use of technology must be matched to the student as different students are more or less receptive to different features of the technology (Breazeal, 2002). This finding also aligns with the personal characteristic influencer identified in persuasion theory (Reardon, 2008) and the principles of persuasive technology (Odom et al., 2015, Fogg, 2002). However, a student's initial reaction to the robot should not be assumed to indicate how a student will react in the future. I found that students can modify their reactions to the robot. Students can become more receptive to the robot as they become more familiar with the robot's presence. Students were observed to migrate from a cautious reaction to the robot when it was first introduced into the teaching sessions to an overtly positive reaction as the student became more familiar with the robot as it was included in subsequent sessions. I judge this reaction accords with typical human behavior where initial reticence to speak or engage with a new member of a group, or when joining a new group, is replaced with open acceptance and activity as familiarity grows.

Robot Impact Affected by Student Personal Interests

Student personal interests influenced the way they responded to the robot. Teachers reported that students whom they knew to have an interest in items with similar characteristics to the robot, such as robot movie characters, or toys they found cute and attractive, were more interested in the robot and reacted more positively towards it. This quality of the robot is not directly accounted for in the conceptual framework. However, when considering the enhanced conceptual framework that I have proposed, it can be viewed as a combination of the “personal” characteristics of the robot when viewed as a teacher and the credibility of the technology. For those students who responded to the robot in this way, the robot was able to modify their normal behavior, causing them to talk more and be more able to express themselves when the robot was present. Furthermore, some students were observed to display a tendency to respond more quickly to instructions when given by the robot and to ask for assistance and help more than they would normally do of other humans, including their parents. The willingness of ASD students to respond more with the robot than with their human teachers may be a result of viewing the robot as creating less stress for the student than their human teachers. As Boucenna et al. (2014) indicate when presented with a robot “face,” the heart rate of individuals on the autism spectrum are unaffected, whereas those not on the autism spectrum experienced elevated heart rates, suggesting that ASD students may be less alarmed by the face of a social robot. This acceptance of robot technology was further demonstrated by Pioggia et al. (2008), who observed that ASD students were attracted to an android, unafraid to walk up and touch its face while ignoring the presence of human attendants involved in their experiment.

Robot Impact Affected by the Characteristics of the Activity

In addition to the personal characteristics of the students, I also found that the characteristics of the activity being undertaken influenced the degree to which students were impacted by the inclusion of robot teaching assistant technology. This finding agrees with the research conducted by Shane et al. (2012). I found that the complexity of the activity undertaken also had an impact. This was due to two things. First, simpler activities enabled teachers to more easily integrate the robot into those activities. Simple student activities tend to involve fairly simple actions and responses from the robot. For example, the robot may only be required to give short, predefine responses such as “yes,” “no,” or “well done.” These responses are both common and predictable, and I had assigned to pre-programmed buttons on the web-based robot control application that I developed for this study. Functions of the robot that I developed in in advance and assigned to specific buttons made operating the robot significantly easier, enabling teachers to use those functions in a timely manner. Second, a timely response from the robot increases the technology effectiveness as a persuasive influencer, as indicated by concept of Kairos (Fogg et al., 2002).

When the activity that the student was asked to undertake was more complex, the ability of teachers to integrate the robot into the activity became more difficult. Again, I conclude this was for two reasons. First, it is less likely that common, predictable robot actions and responses will meet the wider variety of situations that complex activities involve. This requires teachers to develop custom robot responses on-the-fly. For this study, I had developed the ability for teachers to the ad-hoc text into a text field, which the robot would then speak. However, typing ad-hoc custom responses into the text field takes time and is susceptible to the typing speed and proficiency of the teacher. Second, as the activity becomes more complex, teachers must spend more of their time focused on the student and their execution of the task at hand. Therefore, teachers have less time to focus on operating the robot when engaging their students on more complex tasks.

It is clear that the nature of the activity the student is asked to undertake has a direct impact on the ability of the teacher to integrate the robot into the teaching session. This finding indicates that teachers should consider which activities they choose to use a social robot teaching assistant with.

Robot Credibility Influences Student Receptivity

As indicated in the principles of persuasive technology (Odom et al., 2015, Fogg, 2002), I also found the credibility of the robot technology was influential in how students reacted to the actions of the robot to provide both instruction and feedback. As Mintz and Aagaard (2012) described, the introduction of the robot by the MM teachers established the robot's credibility by virtue of the credibility and trust that existed between the students and their human teacher. This credibility was established at the start of the first robot-assisted teaching session and then reinforced on each subsequent teaching session. Given the challenges some on the autism spectrum can experience in empathizing or appreciating what others (such as their teachers) may be thinking or feeling (Cabibihan, 2013), the teachers' overt reinforcement of the trustworthiness of the robot at the start of each robot-assisted teaching session was an effective approach.

Robot Ability to Mimic and Extend Human Teacher Characteristics

By using features of the robot to mimic the way teachers convey messages to their students, the teachers were able to use the robot to reinforce those messages and encourage the students to modify their behavior. For example, by causing the robot to raise its arm, the teachers were able to demonstrate to the student that they should raise their hand to get the teacher's attention or request to be called upon (e.g., to answer a question). This ability to use the robot to reinforce the persuasive message being sent to the student is one of six potential roles for social robots identified by Huijnen et al. (2018). While the teachers have typically demonstrated the desired behavior themselves, by using the robot to show the behavior, the teachers were able to introduce a degree of variety into the lessons. Teachers perceived that this variety increased student engagement. In other instances, teachers were able to employ features of the robot that they, as human teachers, were not able to communicate, such as using the colored light on the front of the robot to indicate a particular mood. This aligns well with persuasion theory, in which the characteristics of the information being conveyed are identified as one of the influencers of an individual's attitudes and behavior (Reardon, 1981).

Training Students to Interact with Interactive Objects

Throughout the online robot-assisted teaching sessions, students were encouraged to interact with the robot. In some instances, students received either instructions or feedback via the robot. On other occasions, the students initiated the interaction by speaking directly to the robot, greeting it, or asking it questions. These student-robot interactions demonstrate the role of social robots as a trainer, one of the six potential uses of social robots that were identified by Huijnen et al. (2018). In addition to interacting with non-human objects like a social robot in an educational setting, students are also surrounded by interactive objects in their homes and everyday life. In his review of trends in the application of artificial intelligence in education (AIED), Dillenbourg (2016) identified several trends that he believed would influence the future of AIED. These trends included new forms of physically connecting with technology, such as smartphones and interactive home automation devices. These interactive objects are often referred to as "smart devices" and include things like the Amazon Alexa or Google Home devices. Like the robot used in this study, smart devices are frequently voice-enabled. The findings of this study suggest that a robot teaching assistant used in an educational setting may help those on the autism spectrum learn how to engage with voice-enabled smart devices in their world beyond the school environment. This would need to be evaluated through future research.

Teacher Implications

The conceptual framework developed in 2013 by the Center on Secondary Education for Students with ASD technology group (see Figure 20) was based on persuasive technology principles (Odom et al., 2015, Fogg, 2002). The PT framework identifies three major components: the characteristics of the individual on the autism spectrum, the activity they perform, and the technology used during the persuasive event (Odom et al., 2015). However, in this study, I introduced a fourth actor into the framework: the role of the influencer, in this case, the teacher. I have, therefore, used an enhanced version of the Center on Secondary Education for Students with ASD framework for this study (see Figure 21). This section will now discuss the implications of and for teachers.

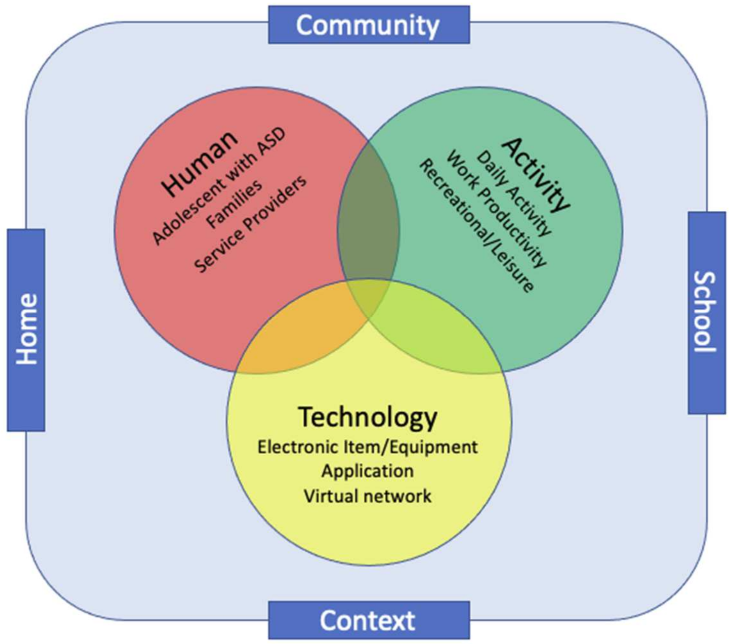

Figure 20. Conceptual framework

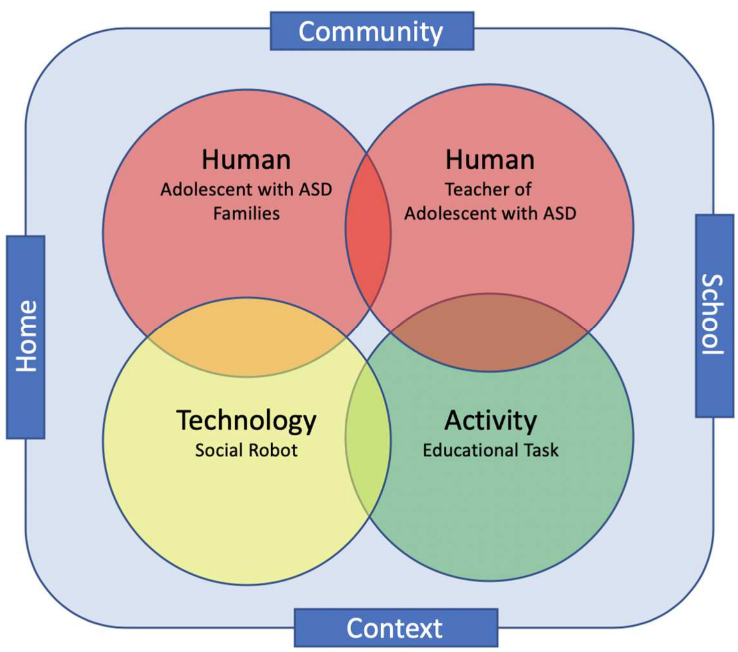

Figure 21. Enhanced conceptual framework

A New Approach to Teaching

Teaching is fundamentally a human endeavor, relying upon the teacher's ability to communicate effectively with their students (Popenici & Kerr, 2017). This can be a challenging task for teachers, given the difficulties those on the autism spectrum can have in engaging in effective communication with students (Jordan, 2008; Pennisi et al., 2016). Furthermore, the challenge teachers can face in trying to communicate effectively with their students can be further complicated because ASD affects each student differently and to varying degrees (Busby et al., 2012; McBride, 2017). The teacher-student interactions that I observed throughout this study exemplified the challenges that the literature highlights. The study included students as young as 14 and adult students as old as 54 years of age. The skill sets of these students also reflected a broad spectrum of abilities, from those who were almost non-verbal and socially introspective to highly sociable and verbally adept individuals. I found that teaching such a diverse community of individuals required the teachers to adopt a variety of online teaching techniques and activities. This included simple block-building activities where teachers asked students to select colored blocks to be stacked on top of one another in a given sequence, to more intricate tasks involving the construction of complex English statements.

In their research into the trends of artificial intelligence application in education (AIED) over the period 1991 to 2016, both Dillenbourg (2016) and Timms (2016) found that technology, such as artificial intelligence and robots, offered opportunities to engage students in new ways. This study showed that teachers were able to use the robot to interact with this diverse students/student population in two different ways. First, teachers used the robot to mimic what they would normally have done. These actions ranged from having the robot provide simple encouragement and feedback, as in "Well done" or "Wow!" through to more involved instructions for the students to follow to complete a task. The second approach involved teachers using the robot to interact with the students in ways that the teachers themselves were not able to do. For example, to indicate a mood through the use of the colored light on the front of the robot or by displaying its eyes with embedded heart symbols. The ability of teachers to use the robot in these ways offered a new way for teachers to impart the information they wanted to convey to the student. Furthermore, the ability to off-load some of the normal activities of the teacher to the robot assistant had two main benefits. First, it provided variety for the students. The increased variety resulted in an increased tendency for students to take notice and to remain engaged in the teaching session. Second, having the robot share in the workload, and in particular, repetitive tasks, such as constantly having to tell students to unmute, gave some respite to the teachers. This enabled teachers to use their time more effectively to conduct other important tasks that can get overlooked or short-changed, such as recording student notes.

The perceptions of the MM teachers engaged in this study concur with the findings of Huijnen et al. (2018) and Pennisi et al. (2016), who identified robots as a means of providing teachers with a new means to connect to students with autism. As Timms (2016) projected, robot technology use in the educational field has continued to improve. The Misty II (Misty Robotics, Inc., 2020) robot platform that I selected for this study, for example, has an array of advanced artificial intelligence and robotic capabilities that I was able to use to develop sophisticated robot control capabilities for the MM teachers to use when integrating the robot into their teaching sessions. These advanced features included the robot's ability to display a wide variety of images on its "face" and text-to-speech, which enabled teachers to type custom text that they wanted the robot to speak to the students. The Misty II platform is also fully programmable, which gave me the ability to develop custom features that the MM teachers wanted the robot to undertake. This ability to customize the robot capabilities was important in ensuring that I could evolve the robot to meet the teachers' specific needs as they used the robot to engage their students in new ways.

Imbuing the Robot with Teacher Characteristics

I found that the injection of the teacher's style of speaking into the robot's responses can positively impact the receptivity of the message on the part of the student. For example, including elements of the humor that a teacher would normally use. The teachers were also able to inject their own personalities into the robot interactions with the students by typing custom responses into the text box I provided in the web-based robot control application. The teacher then used the associated "speak" button to cause the robot to say those words to the student (see Figure 22). Social robots are a relatively new branch of robotics designed to enable humans to interact with technology in a more natural and engaging manner (Breazeal, 2002). As Breazeal points out, humans are a profoundly social species. Based on the results of this study, I too feel imbuing robot technology with social qualities, such as hearing, speech, and vision, makes them more acceptable and easier to interact with and understand, adds to their credibility. However, this may not always be the case, and over anthropomorphizing the robot could also have a negative effect. For example, a meta-analysis of existing research by Stower et al. (2021) suggests that "where children played a game with the robot, human-like attributes had a *negative* effect on competency trust." Stower et al. define competency trust as the perceived competency or reliability of the robot. This is an area I recommend for further study.

Figure 22. Custom text feature of the web-based robot control application

Fun and Exciting

In addition to the teaching methods, studies have also shown that teachers of students on the autism scale place different priorities on educational outcomes than their counterparts who are teaching non-ASD students. Teachers of ASD students rank friendship, social skills, and emotional development as more important, possibly reflecting their ASD students' specific learning needs (Petrina et al., 2017). My observation of the MM teachers and how they interacted with their students to be fully consistent with Petrina's findings. The MM teachers' approach to their students is deliberately and genuinely friendly and encouraging. The teachers take care to use positive reinforcement and avoid negative terminology.

Based on my experience working alongside the MM teachers, I programmed the web-based robot control application to use positive responses. For example, instead of having the robot tell a student they had gotten a response wrong, I programmed the robot to say "Not quite. Try again" in a friendly tone. I observed that both the teachers and students found interacting with the robot to be a fun experience and that the enjoyment aspect of using the robot in their sessions added to their experience in a positive way. My perception of the role fun and excitement played in the teaching sessions was confirmed by the teachers when I spoke with them during the individual interviews and the focus group discussions. Quite naturally, both those on the autism spectrum and those who are not are more likely to engage with a technology they enjoy. The findings of this study indicate that the fun and excitement aspect of using a social robot in educational sessions is important. Furthermore, I judge that students are more likely to be persuaded by a technology they find exciting and fun. Similarly, I found that teachers are enthusiastic about engaging and experimenting with technologies they too find fun and exciting, especially when these technologies are also shown to be effective in helping them communicate with their students.

Operational Challenges

The MM teaching staff unanimously agreed that using a social robot as a teaching assistant was perceived as beneficial for both the teachers and the students. However, the study also identified a range of challenges experienced by teachers.

Simultaneous Teaching and Robot Control

One of the most common challenges identified through this study was the difficulty teachers can experience when simultaneously teaching and controlling the robot. Controlling the robot was particularly challenging when the activity the student performed a more complex task. The severity of this challenge also depended on the technology the teacher used to control the robot. If the device used to access the web-based robot control application is small, as is the case with a smartphone, then the control elements (e.g., the control buttons on the web-based root control application developed for this study) are necessarily small and can be hard to navigate. I recommended, therefore, that teachers access the robot control application using a device with a large screen. Through the individual interviews, I also found that teachers perceived this challenge was due to their lack of experience in using the robot. I expect this issue would be alleviated to some degree as teachers become more familiar with the robot's capabilities and operational controls.

Coordination Between Multiple Teachers

While simultaneously conducting the teaching sessions and controlling the robot was challenging for a lone teacher, using more than one teacher during a teaching session can alleviate this issue. However, having one teacher control the delivery of the educational content while another controls the robot can create challenges in coordinating activities between the teachers involved. A lack of coordination between the teachers can result in disjointed robot actions and responses and reduce the impact the robot's inclusion has on the student's educational session. For example, difficulties in conveying the action required of the robot can lead to either incorrect or less effective actions or responses from the robot. It can also take time for the teacher conducting the instruction to get their requirements communicated effectively to the person operating the robot and for the person controlling the robot to then cause the robot to issue the required response. This was especially true during this study as the multiple teachers involved in the educational sessions were using the online Zoom videoconferencing system and were, therefore, remote from one another. This can result in a noticeable delay between the event (e.g., the student giving a correct or incorrect answer) and the robot issuing the corresponding feedback. Such delays are unfavorable to the concept of Kairos (Fogg et al., 2002) and having the robot interact in a timely manner. I recommend that teachers collaborate in advance and determine a) when and how the robot will be engaged in the activity and b) which responses are deemed appropriate for a given circumstance.

Time Consuming Typing

My analysis of the teacher interviews, and observation of the teaching session video recordings, highlighted the challenge of delays caused by typing ad-hoc text into the text box for the robot to speak (see Figure 22). The web-based robot control application consisted of a number of pre-programmed buttons that caused the robot to execute a range of actions, such as speaking a professionally recorded voice message or tilt its head from side to side. The pre-programmed speech buttons were designed to enable the most frequently used phrases to be enacted with a simple press of a button. This made the operation of the robot fast and simple. For most simple tasks, these pre-programmed buttons covered the majority of spoken actions required; however, as the activity increased in complexity, so the need to include ad-hoc robot speech responses also increased. Typing the desired text into the text box for the robot to speak was time-consuming, leading to delays in the robot's response to the student. Such delays are unfavorable to the concept of Kairos (Fogg et al., 2002) and having the robot interact in a timely manner. I recommend that the robot control interface should be developed to a) include as many pre-programmed buttons as possible and b) that the teachers are provided with the ability to record their own pre-programmed buttons in advance of the teaching session so that they can quickly and easily cause the robot to respond without having to type in ad-hoc text during the lesson. Furthermore, I recommend that the robot control application include the concept of teacher/activity profiles so that teachers can develop a suite of pre-programmed buttons that get selected and presented based on the teacher and the activity they plan to conduct.

More Pre-Planning

Like the use of any tool, using a social robot teaching assistant requires careful planning beforehand. I observed that some teachers were less familiar with and hence less proficient at using the robot. I also observed that the teachers' proficiency improved as they used the robot in more teaching sessions over time. To use a robot teaching assistant efficiently and to maximum effect, it is important that teachers first familiarize themselves with the robot, its capabilities, and the mechanisms for controlling it. While a teacher training session was conducted at the beginning of this study, too little time was set aside for the teachers to practice what they had learned. Second, once teachers have become familiar with the robot, it is important to think through how they will engage the robot in each of the teaching sessions they plan to use it in. This is especially true if the intent is to have more than one teacher engaged in the teaching session, where one is acting as the instructor and the other as the robot controller, and close coordination between the teachers is required.

Limitations

Due to the prolonged duration of the COVID-19 pandemic, the MM teachers had to conduct their teaching activities using online videoconferencing and computer-based technologies. The teachers engaged in this study reported they were comfortable using technology and were comfortable using the robot in their teaching sessions. I was not able to identify if other teachers, under other circumstances, would be equally comfortable engaging a social robot teaching assistant as the teachers engaged in this study. This is an area for future research. Furthermore, as indicated by the Autism Society of America (2008), each student with ASD is unique - "If you've seen one person with autism, you've seen one person with autism." Not only are ASD students different from one another, but they can also exhibit different reactions and behaviors from one point in time to the next. The findings of this study reflect the reactions and behaviors of the MM students at the specific points in time in which they were exposed to the robot during the data gathering stage. Therefore, the student reactions and behaviors could be different at other times or evolve over time.

Overall Teacher Perceptions

This study's overarching purpose was best summarized in research question 4: Do ASD teaching specialists perceive social robots as a useful teaching aid? The overwhelming perception of the MM teachers and my own perception based on my analysis of the teacher interviews, the focus group feedback, and the video recorded observations were that the use of a social robot as a teaching assistant was a useful teaching aid. This finding agrees with a common theme in the research regarding the positive role of robots in education (Gleason & Greenhow, 2017; Gulson et al., 2018; Ivanov, 2016; Popenici & Kerr, 2017; Timms, 2016). The inclusion of the robot in the online teaching sessions added a new dimension to the lessons and provided teachers with a new, fun, and exciting way to engage their students. Teachers unanimously agreed that they would use a social robot teaching assistant in the future.

Recommendations for Practice

I include the following recommendations that address this study's findings in the areas of student impact, teacher impact, and overall teacher perceptions. In some instances, the recommendation may apply to findings that I identified in both the student and teacher impact areas.

Recommendation 1: Explore the Use of Social Robots as a New Approach to Teaching

It would be natural for teachers to be cautious about introducing a social robot into their teaching processes where a vulnerable population, such as ASD students, are involved. However, this study included students from across the autism spectrum and ages ranging from 14 to 54. None of the students showed any sign of distress or discomfort at the robot's inclusion. Nevertheless, mechanisms were in place to remove the robot had any student shown an adverse reaction. In addition to the finding that students showed no signs of a negative reaction to the inclusion of a social robot teaching assistant, teachers indicated a strong positive reaction to their use. Social robot teaching assistants can provide teachers with new ways to interact with their students, add variety to the educational sessions, and increase student interest and participation. In addition, teachers can use a social robot's features to communicate with their students in ways they, as humans, cannot. For example, using the robot's ability to light-up, or to play videos on its face. An Internet-connected robot would also have access to vastly more information than a human teacher. This would enable the robot to respond to the questions posed by students with greater depth and speed than human teachers.

The findings of this study support the recommendation that teachers consider using social robots as a useful tool to help them engage their ASD students in new ways. The findings further indicate that mechanisms should be put in place to monitor student reactions and to be able to withdraw the robot should a student show signs of distress or discomfort at the robot's presence.

Recommendation 2: Select Suitable Students

Students react to social robots in an educational setting in different ways, largely dependent upon their verbal and social proficiency and personal interests. The student's interests might include a liking for technological devices, movies or cartoons involving animated characters similar to robots, or human-like objects they find attractive, such as dolls or animated toys. Based on the findings of this study, I recommend that, when selecting students to be included in teaching sessions involving a social robot, teachers should select students who have more developed verbal and social skills. The study also found that teachers should include students who have shown a personal interest in objects and devices that indicate the student is likely to be predisposed towards the inclusion of a robot into their educational sessions.

These recommendations do not mean that students who do not immediately fit these two criteria should be excluded from robot-assisted activities. As was found in this study, it is difficult to predict how ASD students will react. The study also found that students can evolve their reaction to the robot over time, and their familiarity with the technology grows. These recommendations, therefore, suggest a means of making initial student selections for inclusion in robot-assisted educational sessions. As teachers gain experience using the robot, they could add additional students and observe how they react to the robot teaching assistant.

Recommendation 3: Select Suitable Activities

The complexity of the student's activity during an educational session determines how much time and attention the student and the teacher can devote to interacting with the robot. The findings of this study support the recommendation, therefore, that teachers use social robot teaching assistants in activities where they believe they will be able to integrate the robot's actions usefully and where the inclusion of the robot will not adversely impact the student's focus on the task.

Recommendation 4: Establish Robot Credibility and Trustworthiness

The student must perceive the robot teaching assistant as credible and trustworthy to achieve positive learning outcomes. As the robot will initially be a new participant in the educational activities, the student is not likely to automatically ascribe those qualities to the robot. However, the student will have developed a relationship with their teacher, whom they will have come to see as a credible and trustworthy individual. This study found that teachers should use the credibility and trust they have earned with their students to introduce the robot as a credible and trustworthy participant that the teacher is vouching for. I further recommend that teachers reinforce the robot's credible, trustworthy credentials on each educational session in which they use it.

Recommendation 5: Add Teacher Personality Traits

ASD students are inclined to react positively towards their teachers as they have learned that they provide credible advice and instruction and can be trusted. A teacher's personal qualities, such as phrases they use when they speak to their students, are a key social cue to the students that they are interacting with someone they know and can trust. The findings of this study found that to increase the robot's impact on their students, teachers should inject some of their mannerisms into the robot's interactions with the student. This might be achieved, for example, by the teacher customizing the robot's spoken responses to include phrases or humor that the teacher might typically use. Care should be taken, however, not to over-mimic the teacher. For example, a literal recording of the teacher's voice that the robot they plays-back could confuse the student regarding whom the student was interacting with. Furthermore, some research exists that indicates, over-anthropomorphizing the robot could result in a reduced learning outcome.

Recommendation 6: Educate Teachers on How to Use a Social Robot Teaching Assistant

A social robot teaching assistant is a new tool in the teachers' arsenal, and like any new tool, it requires practice to master the skill of using it effectively. The findings of this study indicate that teachers undergo initial training on how to use a social robot teaching assistant. This training should include the operational aspects of using the robot, such as controlling the robot's actions, and the pedagogical aspects, such as integrating the robot into the teachers' educational activities constructively. The findings also indicate that teachers should be provided with ample time to practice using the robot and become familiar with its use before introducing the robot into their students' educational activities.

Recommendation 7: Employ Multiple Teachers

Operating a social robot teaching assistant requires a focus on the part of the teacher operating the robot. This can detract from the amount of time and focus the teacher can assign to the student and the activity. This study found that, where feasible, two or more teachers be engaged in robot-assisted educational activities. This will allow one teacher to focus on the session's instructional element while a second teacher operates the robot. However, when the teacher conducting the instruction is not the same teacher who controls the robot, care should be taken by teachers to coordinate in advance of the educational session. See recommendation 9.

Recommendation 8: Ensure Teacher Coordination

To be effective with ASD students, the robot teaching assistant's actions and responses need to occur within an appropriate amount of time. Too great a delay between the event that prompts a response from the robot (for example, the student taking some action) and the robot responding can result in a disjointed and ineffective use of the robot. In situations where two or more teachers are engaged in a robot-assisted educational activity, it is important that the robot response initiated by the teacher controlling the robot is synchronized with the events initiated by the teacher who is instructing the student. The findings of this study indicate that to achieve this synchronization, teachers should meet prior to the educational session and agree on what robot actions should be used and under what pedagogical circumstances.

Recommendation 9: Pre-Plan Robot Use

Like recommendation 9, the smooth and effective use of the robot teaching assistant requires planning on the part of the teachers who intend to use the robot in their educational sessions. Knowledge and experience of the robot's features and capabilities and how it can be used to affect student outcomes is a prerequisite to this planning activity (see Recommendation 7). The findings of this study indicate that armed with this knowledge and experience, teachers should plan, in advance, how they will use the robot during their educational sessions. These plans should include when and how the robot will give the student instruction and what reactions and responses the robot should provide to the student. This pre-planning is especially important in situations where two or more teachers are engaged in a robot-assisted educational activity such that one teacher is focused on the instructional element of the session while a second teacher operates the robot.

Recommendations for Future Research

This study explored the perceptions of specialist teachers from the Magister Minister (MM) autism school in northern California on the role of a social robot teaching assistant in their online video conferencing-based teaching activities with their students on the autism spectrum.

The MM school granted me permission to work with teachers and students from three classrooms: the adult classroom and two of the younger student classrooms. Seven teachers and thirteen students from the adult classroom participated in the study, along with six teachers and six students from the two younger age group classes. I provide recommendations for future research in two main areas: a) enhancements to the robot control application identified by the MM teachers and/or my observations, and b) my recommendations for additional research areas into the use of social robots as teaching assistants.

Enhancements to the Robot Control Application

I employed an action-reflection (McNiff, 2017) approach during the execution/data collection phase so that the features provided to the teachers to control the robot were modified and enhanced based on teacher experience gained in using the robot during the study. I updated the web-based robot control application periodically throughout the execution/data-gathering phase. However, given the finite time allocated by the MM school for me to gather data, additional modifications and enhancements to the web-based robot control application were identified by the MM teachers and myself during the individual teacher interviews and the focus group session. Indeed, it is the nature of software applications that users continually request modifications and enhancements for the lifetime of the application. The MM teachers identified the following modifications and enhancements they recommend to the web-based robot control application after completing the data collection phase.

More pre-programmed/customizable buttons. The provision of more pre-programmed buttons would cut down on the amount of ad-hoc typing required by teachers during active online lessons. These buttons could be associated with one or more teachers and/or activity types so that a teacher has access to their unique combination of pre-programmed buttons based on the activity they select when logging into the web-based robot control application.

In addition, providing teachers the ability to create their own customized buttons would enable them to integrate their personal characteristics into the robot interactions. These personal characteristics could include the teacher's sense of humor or style of speech. Teacher profiles would also enable teachers to develop and select the suite of robot control buttons customized for each student/task combination.

Robot personality. As was described under the section on "Teacher Characteristics," this study found that the robot had greater receptivity and impact on students when it displayed more human-like characteristics—for example, humor. Furthermore, teachers explained that it would be beneficial if the robot could engage students in a more human-like dialogue. Providing the robot with its own profile would enable the robot to have its own personality. The robot profile should incorporate typical facts that a student could dialogue with the robot about. For example, for the robot to answer questions posed by the student, such as "what is your favorite food" or "where do you live." These same personal elements could also be used proactively by the robot to initiate a conversation by saying things like, "My favorite food is pizza. What's yours?" Future research should also investigate the impact of adding these types of anthropomorphic elements to robot teaching assistants to determine if, and at what point, they have a negative impact on ASD student receptivity and comfort levels with this technology.

Additional Areas of Research

In addition to the research potential of further modifications and enhancements to the web-based robot control application, I identified the following areas of further research through this study.

Parent perceptions. This study focused exclusively on the perceptions of the MM teaching specialists. However, the parents of each of the students who took part in this study were present during the online robot-assisted teaching sessions, albeit from a discrete distance in some instances. These parents, therefore, have first-hand observational experience of how their students reacted to the inclusion of the robot from the student-side of the Zoom-based video sessions. In addition, these parents are also in a position to express their perceptions of their student's reactions to the inclusion of the robot assistant once the Zoom sessions closed. These post-teaching session parent perceptions were best exemplified by Judith's mother's feedback, who wrote: "Judith liked the robot. And when we had lunch, and she started making her lunch, she said (unprompted and delightedly) 'I talked to Misty'." Further research is required to explore parent perceptions of social robots' inclusion as teaching assistants, both in the classroom and in online video conference-based activities.

Long-term impact. I conducted this study over a short period, between January and February 2021. Future research that involves using the robot as a teaching assistant over a longer period will identify if similar or new findings emerge. Long-term research could also study if social robot-based teaching assistant impact on student behavior is sustained over time.

Classroom-based impact. The Misty II robot offers a broad range of features (see Figure 23). However, due to the COVID-19 pandemic, this study was conducted using the social robot as a teaching assistant on the online video conference-based teaching sessions that the MM school was conducting. Due to this study's online nature, I was only able to utilize a limited set of the Misty II robot features. For example, I used the visual display to present different "eye" images that depicted various emotions, such as "happy" and "surprised." I also used the speech capabilities of the robot extensively. However, it was not feasible to use the robot's locomotion capabilities or facial recognition features.

Figure 23. Misty II robot features

As the COVID-19 pandemic abates and schools resume normal in-classroom teaching activities, future research should look at the impact of using the robot in the classroom. When the robot is engaged in the classroom, it will be feasible to use additional robot features that were not possible during this study. Future research could also repeat this study in a hybrid mode where some activities are conducted in the classroom, some online, or with the teachers/students in the classroom, and the robot joined into their teaching sessions via a video conference session conducted on the teacher's laptop or tablet device.

Home-based impact. This study was conducted in a formal school-based setting, albeit in an online video conference mode. Future research using the robot in the home environment could evaluate the role of a social robot as a reinforcer (Huijnen et al., 2018) of the educational content presented by their teachers and as a fun companion by using the robot in a less formal, game-based mode to help reinforce life skills in the home.

Additional teaching environment. I conducted this study at the Magister Minister school in northern California, which specializes in the education of individuals on the autism spectrum. Therefore, this study's limitation is that it only reflects the teachers' perceptions at this particular school. Further research should be conducted to see if teachers in other teaching environments identify similar perceptions.

Teaching engagement with other technology-based devices. One perception I identified through this study was that the robot assistant helped students engage in a back-and-forth dialogue. Research needs to be conducted to see if a robot-based teaching assistant can help those on the autism spectrum learn how to engage with intelligent voice-enabled devices they increasingly find in their homes, schools, and communities.

The Use of a Social Robot as a Teaching Platform

In this study, the social robot I used enabled the MM teaching specialists to cause the robot to issue activity instructions and provide various visual and audible feedback to the ASD students. However, there is significant potential for robots to be used more broadly as a teaching platform. The Misty II robot (Misty Robotics, Inc., 2020) is a highly flexible platform offering a broad range of hardware and software features (see Figure 23). The robot software and hardware

are accessible to software developers, enabling them to create custom applications that can gather data from the robot and control the robot's actions. Due to this study's online nature, I was only able to utilize a limited set of the Misty II robot features. For example, I used the visual display to present different "eye" images that depicted various emotions, such as "happy" and "surprised." I also extensively used the robot's speech capabilities. However, it was not feasible to use the robot's locomotion capabilities or facial recognition features. Similarly, the MM teachers only used the robot in a limited capacity to issue simple activity instructions and to cause the robot to issue visual and audible feedback to the students. It is feasible to develop robot-based games and activities that run on the robot platform. Using games and activities running on the robot itself would enable the robot to act as a teaching platform, able to detect student actions and react automatically, without teacher intervention. Further research is required to investigate the benefits of using a social robot as a teaching platform.

The Use of Social Robots as Teaching Assistants Beyond the Field of Autism

This study focused specifically on the role of social robots as a teaching assistant for teachers who have students on the autism spectrum. However, the benefits of using social robots in a teaching assistant capacity may be equally applicable to other educational situations beyond the autism and special education environments. Research should be conducted in other educational environments to determine if using social robots as teaching assistants yield similar benefits identified in this study.

CHAPTER 7: THE RESEARCHER'S DISSERTATION JOURNEY

The purpose of this chapter is to reflect upon my dissertation journey and to illuminate some of the key decisions I took along the way. My intent is to explain the rationale for my decisions in the hope they will be helpful to other researchers in the future.

Personal Motivations

At the age of 62 and having retired from corporate America, I was not a typical doctoral candidate. Indeed, I was very uncertain whether the University of the Pacific (or any university for that matter) would accept me as a doctoral student. After all, I did not need to do this degree. It was not going to advance my career or enable me to change the world – or was it? As I later discovered, not only are you never too old to learn, but you are also never too old to have an impact. But more of that later. I am the first in my family to go to college and have always loved learning. I would describe myself as curious about everything. I have always found the world around me fascinating and enjoy nothing more than pulling something apart (physically or logically) to see how it works. I have also been blessed with a great imagination. My natural curiosity, combined with my imagination, has resulted in my ability to be creative. Innovation, therefore, has been a hallmark of my career.

Given my love of learning, I had always promised myself that once I retired, I would complete my education. I was fortunate that when I did retire, having spent many wonderful years as a Vice President of Innovation at Cisco Systems, I was immediately engaged by the University of the Pacific (UOP) to help launch their newly designed Master of Science in Data Science program. I often jokingly explain that I "failed at retirement," but in truth, while my head knew I had retired, my heart was reinvigorated by working with Pacific's amazingly smart and passionate people. This reinforced a belief I have long held and serves as a lesson to others who may be uncertain about their ability to continue their education - you are never too old to learn. Clance and Imes (1978) explained the feeling of being an imposter, a fraud, or unworthy when considering undertaking further education is common. Do not let those feelings deter you!

So began my immersion in the wonderful world of academia. It did not take long before my promise to myself that I would complete my education began to resurface. The question, however, was which degree to undertake? The answer came fairly easily: I was working at a university with a team of highly qualified educational experts, all of whom possessed doctorates of various kinds, and I liked the whole concept of learning. The obvious choice, therefore, was a doctoral degree in education. However, my second desire was to undertake a degree that would result in action that would demonstrably help someone, not simply to add to the world's body of knowledge (valuable though that is). Fortunately, UOP offered the ideal solution: an action-oriented, innovation-based educational doctorate (EdD).

My Dissertation Decision

Going into the EdD program, I was fairly sure my dissertation would involve technology in some way. After all, technology had been both a life-long passion and the basis of my entire career. Of course, as a doctoral student, you are advised to keep an open mind and allow yourself the freedom to select your dissertation topic once you gain a firmer grasp on the topic of education and innovation. In addition, as Roberts (2010) recommends in her book "*The dissertation journey: A practical and comprehensive guide to planning, writing, and defending your dissertation*," it's important to choose a dissertation topic you are genuinely interested in and excited about. I followed that guidance by creating a two-column list where I asked myself, "what would I find inspiring to do for my dissertation" versus "what would I not find interesting or exciting." The list was reasonably short, with technological ideas emerging as a constant theme under the "like" column.

Why social robots? The idea of using social robots did not occur to me at that early self-brainstorming event. The potential to use social robots came from my initial literature review that I conducted during the first semester on the EdD program. Knowing that my dissertation was likely to involve technology in some way, I conducted an initial literature review of technology use in education. I discovered that a wide range of technologies, including artificial intelligence (AI), had been used in various forms in education, including robots (Gleason & Greenhow, 2017; Gulson et al., 2018; Popenici & Kerr, 2017; Roll & Wylie, 2016; Timms, 2016). As AI was of specific interest to me, and as I had worked with a close friend and colleague of mine at Cisco Systems on various robotics-based projects, I was immediately intrigued by the idea of exploring the use of robots in education. Further literature reviews identified trends in the application of artificial intelligence in education, including the role of robots (Dillenbourg, 2016; Timms, 2016). Timms projected that in the future, robots would work alongside human teachers as collaborative robots. I had found the technology that I wanted to base my dissertation upon.

Why autism? My decision to explore the use of social robots in educating those on the autism spectrum was pure serendipity. It was the December holidays of my EdD program's first year, and I was at home with my family. My eldest son and his family had joined us for Christmas lunch. My grandson, who is on the autism spectrum, was in the living room, in front of me, perusing a huge stack of DVDs. On the autism spectrum, my grandson is classified as high-functioning, and like many ASD individuals, he had an almost singular interest in one topic: movies. I watched him review each DVD in turn, talking to himself about the actors, who the director was, when the film was first released, and which company had released the DVD. He had an encyclopedic memory of movie information. At that point, when observing him review each DVD in turn, as he had done every time he visited us, the final piece of my dissertation topic fell into place. I had enrolled in the UOP EdD program specifically because it was action-oriented. I wanted to "do" something that would benefit others. I knew I wanted to use technology when I started the program, and my literature review had helped me narrow "what" technology I would use. Now I had found the "why"– to help the autism community.

While Dillenbourg (2016) and Timms (2016) independent reviews of literature surrounding the role of robots in education had indicated that robots could play an important role, the efficacy of robots in teaching those on the autism spectrum also presented challenges. Some educational professionals were cautious (Ivanov, 2016; Kennedy et al., 2016), feeling that, while the use of robots may be initially exciting, children with low-functioning ASD may quickly lose focus and interest. So et al. (2019) concluded that it was not certain whether robots could effectively teach students with social and communication skill challenges. Importantly, the literature on the use of robots in the education of ASD students indicated that studies undertaken to test the effectiveness of robots in this area have been limited and inconsistent. The literature indicated that more research is required in this field (Pennisi et al., 2016).

Why teachers? Having determined that I wanted to explore the use of social robots in autism education, my immediate thought was to see how robots had been used with students on the autism spectrum. I, therefore, continued my literature review, searching for materials on autism in general and the role of robots in autism education, in particular. The literature indicated that a significant amount of research had been undertaken on the clinical/therapeutic uses of robots in the field of autism (Diehl et al., 2012), while less research had been conducted on their application in an educational setting (Huijnen et al., 2016; Odom et al., 2016). Therefore, the literature showed that most research had focused on the use of robots from the perspective of those on the autism spectrum. Less research appeared to have focused on those charged with educating those on the autism spectrum. I had found the gap I was looking for. I would focus on the role social robots could play in assisting teachers who were charged with educating individuals on the autism spectrum.

Finding a Partner

Once I had determined my dissertation topic, the next challenge was to determine how I would undertake the research. While many schools had students who were on the autism spectrum, I doubted that many would have had sufficient students, or sufficient experience with ASD students, to make my research viable. I, therefore, reached out to specialist autism schools in both California and Georgia (I have a home in both states) to see if they would be willing to work with me on my dissertation. I initially emailed the schools that I had identified, explaining my idea and my study's purpose. Three schools responded, indicating an interest in what I was proposing. I then spoke with each of these schools to further discuss my idea and to help me make a final selection. I prioritized these schools based on the experience they had with ASD students. I also considered their history of exploring innovative new approaches to ASD education and their proximity to where I lived so that I can meet with them on a regular basis.

I met with the executive director and program director of my first-choice school, the MM specialist autism school in northern California. The MM school had a long-standing history of pioneering new approaches and techniques in the education of ASD students and sharing their findings with others in the autism community. In my discussion with the MM executives, they were clearly excited to work with me on my dissertation. They saw this study as an ideal opportunity to investigate the potential benefits of new, modern technologies such as social robot teaching assistants and realized that both MM's students and teachers would gain valuable experience from using social robots in their teaching sessions. I explained the doctoral process to the MM executives, pointing out that this would require a long-term relationship. They readily agreed to partner with me for the duration of my dissertation.

Learning About Autism

While I had some experience of autism through my grandson, I knew that I only understood autism from that one narrow perspective. Furthermore, the literature largely focused on autism from the perspective of the person on the autism spectrum. I decided that if I wanted to understand autism education from the perspective of teachers, I needed to immerse myself in the teachers' world. I approached the MM executives and asked if I could engage with their teachers to see for myself what challenges they faced. I was enthusiastically embraced by the MM teachers, who frequently used volunteers to assist them. I spent approximately one day per month over the following two years working as a non-paid volunteer teacher assistant at the MM school. The MM executives had assigned me to assist in the two younger classrooms that I would later conduct this study with.

I realized the only way to truly understand the challenges teachers with ASD students faced was to work alongside them in the classroom. I quickly realized what the Autism Society of America (2008) meant when they stated, "If you've seen one person with autism, you've seen one person with autism." Not only was each student different from their classmates, but they could also act very differently themselves, day by day or even hour-by-hour. The MM teachers had to develop each student's profile to know how to interact with them in the most effective way. In addition, the teachers had to judge each student's mood every time they met with them to understand what mood the student was in, and hence, what the student was most likely to respond to on each occasion. This makes teaching ASD students challenging.

I also discovered how quickly situations in the classroom could change. For example, one of the more challenged students became overly stressed during one of my MM school volunteer working sessions. He began to quickly "meltdown," becoming both verbally and physically aggressive. I observed how the teacher working with the student immediately backed-off, giving the student physical space, and started speaking to him in a calm, reassuring manner. The classroom lead teacher also joined in the process of calming the student down. While this was happening, I noticed how other teachers immediately sought to reassure the students they were working with and keep them out of the impacted area. In speaking with the teacher of the stressed student afterward, I learned that in this particular student's case, he feels threatened by proximity when he gets stressed. The teacher likened it to claustrophobia, where the student needs physical space, with no one near them, so they can calm down. I also learned from the classroom manager that, not surprisingly, a sudden surge in energy in the room (e.g., when a stressed student starts to scream like this) can cause other students to become overly stressed as well. Unless handled very swiftly, it can quickly escalate out of hand.

Despite all of the challenges working with ASD students can present, I also understood the rewards the MM teachers obtain from working with their ASD students. Some on the autism spectrum do not feel that they need to be "fixed," and as some have explained, "normal for me is to be abnormal" (Autistic UK, 2018; Think Autism Guide, 2020). Even small achievements can mean a great deal to those on the autism spectrum and to their families. The MM teachers do not focus on academic skills alone. They also teach important life skills, such as preparing meals, brushing one's teeth, or simply having fun by dancing to music. Helping their students attain academic and life skills, no matter how small, is a clear source of satisfaction and inspiration for those who teach students with special needs. My experience working with the MM teachers proved invaluable.

Switching to an Online Study

My initial plan was to use the social robot in the MM classrooms that I had been approved by the MM executives to engage with. I did not take the robot into the classrooms as I did not have IRB approval to do that during my time as an MM volunteer. However, I explained to the MM teachers the purpose of my study, showed them a picture of the robot and shared my preliminary thoughts on how I would conduct the study. I also explained that I would most likely conduct my data gathering activities by bringing the robot into their classrooms for them to use with their students towards the end of 2020. In early 2020 signs of the COVID-19 virus started to emerge in the United States. By March 2020, a pandemic was announced, and a widespread lockdown was implemented across the country. Consequently, the MM school, like most other schools across the country, closed for physical, in-classroom activities and moved all teaching online. At that point, the plan that I had for executing my study was no longer viable. While my study could not be implemented as originally planned, the MM school's move to online teaching presented me with a new, unique opportunity. I realized that it was very unlikely that any research had been previously conducted to capture the perspectives of teachers using social robots in the autism education field during a pandemic. The MM school closure due to the pandemic had, inadvertently, provided me with an opportunity to conduct even more distinctive research.

Technical Decisions

At this point, I had redefined my research to focus on teacher perceptions of the role of social robots as teaching assistants in the online teaching of students on the autism spectrum. I had forged a partnership with an autism specialist school that was willing to work with me for the duration of my EdD studies, and I had selected the robot platform I would use for the study. It was now time to turn my attention to the design of the robot-based teaching assist solution that I would develop for the MM teachers to use.

One of the first technical design decisions I took was how to develop a mechanism for the teachers to use the robot in their educational sessions. The Misty II robot is controlled through a suite of application program interfaces (APIs) that enable computer programmers to access the robot's features by sending specific commands to the appropriate robot API. For example, to cause the robot to speak the phrase "Well done." In designing an appropriate mechanism for the teachers to control the robot, I needed to consider that the MM teachers and their students would all be in different physical locations (e.g., their homes). The robot would also be in a different physical location as it would no longer be joining the teachers and students in the MM classroom. In addition, the MM teachers each use different devices to conduct their online Zoom sessions, with some using Windows-based personal computers, others using Apple Macintosh laptop computers, and some using tablet computers. The design of the robot control mechanism, therefore, had to be very flexible. I decided upon a web-based design for the robot control application for several reasons. First, a web-based solution is device agnostic. That means any device that the teachers might use would be able to use the web-based robot control application as long as their device could access the internet.

Once I had decided on a web-based approach to developing the robot control application, the next decision was to decide on the web software standard that I would use. Most web applications are developed using some variant of the Hyper-Text Markup Language (HTML). Other web development approaches exist but are beyond the scope of this discussion. HTML has evolved through a number of versions since it was first introduced (Berners-Lee, 1990). The latest version of HTML, and the version I selected, is HTML 5. I selected HTML 5 as it enables the development of sophisticated visual interfaces that I wanted for the robot–based application I was considering. I then experimented with a variety of HTML 5 software development tools. My initial approach was to use the Unity game development platform. Unity is one of the most popular game development tools in the world and has been used to develop highly sophisticated and highly lucrative commercial games for both the Windows, Mac, PlayStation, and Xbox game platforms. While extremely powerful, my early experiments with Unity allowed me to discover that it was overly complex for the solution I was attempting to develop. The robot control application I needed to develop involved simple, low-fidelity graphical elements rather than highly detailed, commercial-grade gaming interfaces. I, therefore, decided to use the Tumult Hype 4 HTML 5 development platform. Hype 4 was selected due to its highly flexible yet simple to use, graphically oriented development environment, enabling the rapid development of interactive solutions. I also chose Hype 4 as it is a popular HTML 5 development environment that is well documented and has a large support community.

While not a formal part of this study, I also develop a database solution to hold data pertaining to the robot-assisted teaching sessions, including the activities assigned by the students and the actions taken by the students. I developed this database as a form of reciprocity in appreciation of the MM school’s willingness to partner with me on this study. The database system I decided to use for the MM database system was the Neo4j graph database platform. I selected a graph database approach as it is extremely flexible, enabling the storage of any combination of data items and, unlike other database systems, can be easily extended or modified without requiring the re-programming of the system. In addition, unlike other database approaches, graph databases can store both key data items and the relationships between them. For example, in addition to storing the students' details, I used Neo4j to store the relationship between the student and the teacher who conducted the educational session, the assigned task, and the classroom they were both assigned to.

Participant Privacy

Protecting the anonymity and privacy of the study participants was of paramount importance. As described throughout this report, all teacher and student names have been disguised through the use of pseudonyms. In selecting the pseudonyms to use for the teachers and students, I wanted to pay homage to pioneers in the fields of autism and robotics. Unfortunately, too few women have been recognized as pioneers in the male-dominated robotics community, and so teacher pseudonyms were based on a combination of robotics and autism pioneers. By contrast, student pseudonyms were based exclusively on autism pioneers, which seemed more fitting given the students are on the autism spectrum. Care was taken to ensure that the teacher and student pseudonyms were unique to avoid confusion in the narrative of this report. Care was also taken to ensure that none of the pseudonyms corresponded to an actual teacher or student's real name. Table 15 provides the derivation of the teacher pseudonyms, while table 16 shows those of the students.

Table 15
Teacher Pseudonyms

Teacher Pseudonym	**Robotics/Autism Pioneer**	**Pioneering Work**
Alice	Alice Agogino	Known for her research into artificial intelligence, computer-aided design, and intelligent learning systems.
Crystal	Crystal Chao	A pioneer and expert in Human-robot interaction (HRI) software architecture and development.
Madeline	Madeline Gannon	Her pioneering work on the design of robotics, and human-computer interaction systems, in earned her the nickname "The Robot Whisperer."
Cynthia	Cynthia Breazeal	A professor at MIT, where she is director of the Personal Robots group at the MIT Media Lab. Chief Scientist at Jibo, a personal robotics company.
Helen	Helen Greiner	Co-founder of iRobot and served as Chairman and President of iRobot Corporation for 18 years.
Kanako	Kanako Harada	An expert in the development of surgical robot technology.
Victor	Victor Scheinman	An American pioneer in the field of robotics.
Ayorkor	Ayorkor Korsah	Ashesi Professor in Robotics and Artificial Intelligence at the university of Asheshi in Ghana. A recipient of a 2013 Tribeca Disruptive Innovation award.
Danielle	Danielle Applestone	An expert in the development of machines, and machine control software suitable for students.
Emily	Emily Cross	Professor of Social Robotics, Institute of Neuroscience & Psychology, at Glasgow university. Co-director of Social Brain in Action Laboratory.
Ichiro	Ichiro Kato	Leader of the first humanoid robotics research at Waseda university, and the most celebrated roboticist in Japanese history.
Ruth	Ruth Sullivan	Co-founded the Autism Society of America, the first and largest grassroots autism organization.
Marvin	Marvin Minsky	An American cognitive and computer scientist concerned largely with research of artificial intelligence, co-founder of the Massachusetts Institute of Technology's AI laboratory.
Susanne	Susanne Bieller	General Secretary of the IFR, the International Federation of Robotics.

Table 16
Student Pseudonyms

Student Pseudonym	Autism Pioneer	Pioneering Work
Bernard	Bernard Rimland	An American psychologist. Rimland's first book, Infantile Autism, changed attitudes toward the disorder.
Ole	Ole Ivar Lovaas	A Norwegian-American clinical psychologist best known for his research on teaching autistic children through positive reinforcement.
Simon	Simon Baron-Cohen	Professor Sir Simon Baron-Cohen is a British clinical psychologist. He is the Director of the Cambrdge University's Autism Research Centre.
Kalle	Kalle Reichelt	Reichelt achieved dramatic learning and behavior improvements in autistic children with a gluten free diet.
Temple	Temple Grandin	Well known for her trailblazing work as a spokesperson for people with autism.
Tom	Tom Willis	Co-founder of The Institute for Applied Behavior Analysis.
Carol	Carol Gray	Director of The Gray Center for Social Learning and Understanding, and is recognized for her international contribution to people with ASD.
Chuck	Chuck Gardner	Co-found of the MIND institute.
Eric	Eric Schopler	An American psychologist whose pioneering research into autism led to the foundation of the TEACCH program.
Eugene	Eugen Bleuler	A Swiss psychiatrist and eugenicist. He coined many psychiatric terms, such as schizophrenia, and autism.
Gary	Gary LaVigna	Clinical Director of the Institute for Applied Behavior Analysis in Los Angeles, and co-founder of The Institute for Applied Behavior Analysis.
Hans	Hans Asperger	An Austrian pediatrician, for whom Asperger syndrome is named.
Judith	Judith Gould	Co-founder of The Centre for Social and Communication Disorders.
Leo	Leo Kanner	A Ukrainian-Austrian-American psychiatrist, was the first scientist to clearly define autism.
Lorna	Lorna Wing	Co-founder of The Centre for Social and Communication Disorders (now the Lorna Wing Centre for Autism).
Margaret	Margaret Bauman	A distinguished pediatric neurologist and pioneer in the study and treatment of autism.
Michelle	Michelle Garcia-Winner	Specializes in the treatment of social learning challenges. Founder and CEO of Social Thinking.
Portia	Portia Iversen	An Emmy-winning art director and a vigorous proponent of autism research.
Sarah	Sarah Gardner	Co-found of the MIND institute.

The Researcher's Changed Perspective

My final reflection on my dissertation journey is the way in which my personal perspective has changed. As described at the start of this chapter, my initial object was self-oriented: I wanted to complete my education. As a retired individual (albeit working at UOP for fun), I had no aspirations of using my degree. I was studying education because I wanted to. Because it would be fun. That said, I also wanted my dissertation to be action-oriented and to be focused on helping people, whether that was one individual or an entire community. However, my initial thinking was that my research would enable others to use the results to impact the world. Completing my terminal degree would signal the termination of my working life. That changed.

The EdD experience changed my outlook. It reinvigorated me. As I progressed through the design and then execution of my study, I realized that obtaining my terminal degree was simple the completion of my formal education. It was also the start of the next phase of my life: to take the results of my research and take action, myself, to bring social robot teaching assistants to the autism education community. The UOP EdD program also helped me realize that I cannot scale this solution on my own. Therefore, I have begun the process of designing a social entrepreneurial business approach which I hope to scale through partnering with existing educational institutions. That will be the subject of chapter 8.

Summary

The summary of this chapter is simple. The EdD program changed my outlook. While I started my journey uncertain of my suitability to undertake a terminal degree at my time of life, it has ended with a newfound confidence in my ability to conduct research – real research! I learned about a new community of wonderful people and how my passion for technology could be applied to the world of autism - and beyond. And as challenges to my research unfolded, I found ways of adjusting my approach and continuing on, regardless.

While I initially considered this degree to signal the culmination – the end of my academic endeavors, and envisioning myself drifting gracefully into retirement, it has, in fact, signaled the start of a whole new phase in my life. Apologies to my wife and family...

CHAPTER 8: SCALING THE SOLUTION

This action-oriented study's overarching purpose was to determine if teachers of students who are on the autism spectrum perceive a social robot as a useful teaching assistant in an online educational setting. As was shown in chapters 5 and 6, teachers at the Magister Minister specialist autism school in northern California overwhelmingly agreed that using a social robot in this capacity was useful. The teachers identified a number of benefits they perceived in helping them teach their ASD students. Moreover, my intent on embarking on the University of the Pacific's action-oriented EdD program was to have a tangible impact in the world. Having demonstrated that using a social robot as a teaching assistant in an online educational setting is perceived, by teachers of ASD students, to be beneficial, it is now necessary for this solution to be made available as a practical solution that schools can take advantage of. This chapter describes some initial thoughts on how this could be achieved by establishing a social entrepreneurial business. What I present is not intended to be a fully developed business plan. For this discussion, I will refer to this as the Social Teacher Assistant Robot (STAR) Corporation (note: by using the term Corporation, I am not implying that the social entrepreneurial business will necessarily be a fully incorporated entity. A simple partnership would most likely be sufficient, at least initially). The objective of the STAR Corporation would be to maximize social impact rather than seek a profit motive. Nonetheless, the STAR Corporation would need to maintain a small profit to sustain the business long-term and provide sufficient funds to fuel the expansion of the social robot teaching assistant business. This would include funding for marketing, training, software development, and business operations.

Solution Challenges

An immediate challenge with making a social robot solution available to schools is the cost of social robots. The Misty II robot retails at around $2,500 each, which is more than most schools can realistically afford. The cost challenge becomes even more severe if a school needs to use the robot solution in more than one classroom simultaneously. On the other hand, teachers are unlikely to want to use a social robot assistant in every class. Given the limited budgets that many schools are faced with, it is assumed that few schools would be able to afford to purchase sufficient social robots to make using them a viable solution.

A second challenge that this solution presents is that the software required to operate a robot in an educational setting does not exist. In addition, new, purpose-built games and activities that take advantage of the advanced capabilities offered by a sophisticated robot platform, such as the Misty II from Misty Robotics, Inc., do not exist.

A Cost-Effective Social Robot Teaching Assistant Solution Strategy

The social robot teaching assistant solution will consist of three broad components -first, the physical robot technology itself. Second, a robot control application. And third, a suite of games and activities that can be run on the robot platform that teachers can use in their educational sessions with their students. Each of these components could be made available through a different approach. I will describe my initial thoughts on how each of these components could be provided.

Time sharing the robot hardware. Given that schools would only require access to a social robot on a periodic basis, it would not be necessary for each school to purchase its own robot hardware. Instead, schools could be provided with access to a centralized pool of robots. Schools could rent time on the robots at a fraction of the cost of purchasing the robots themselves. This approach has the added advantage that schools would be able to manage their budgets more effectively, renting time on the robots as demand and budget allow.

Scaling the robot pools. Creating social robot pools that schools could access to rent time on the robots could be undertaken in two ways. First, I propose establishing the STAR social entrepreneurial business that would acquire a set of robots and make them available as a shared pool. However, this approach would require significant up-front capital investment and may be constrained in terms of size and speed of growth. A second approach would be to leverage the existing educational infrastructure. In this model, universities and colleges would purchase the robots and make them available to smaller, less well-funded schools in their communities. By leveraging the existing educational infrastructure of the United States, the robot hosting pools could be scaled much faster.

To obtain the cost benefits of robot acquisition at scale, I propose the STAR business would purchase the robots on behalf of all hosting entities. This would also enable the STAR Corporation to make any required modifications to the robots prior to onward shipping them to the hosting entities. These modifications could include the uploading of speech files, videos, and custom application files. Regardless of which entity ultimately acquires the robot hardware, the robot-hosting entity could recover their robot acquisition costs through a time-share rental fee (see Figure 24).

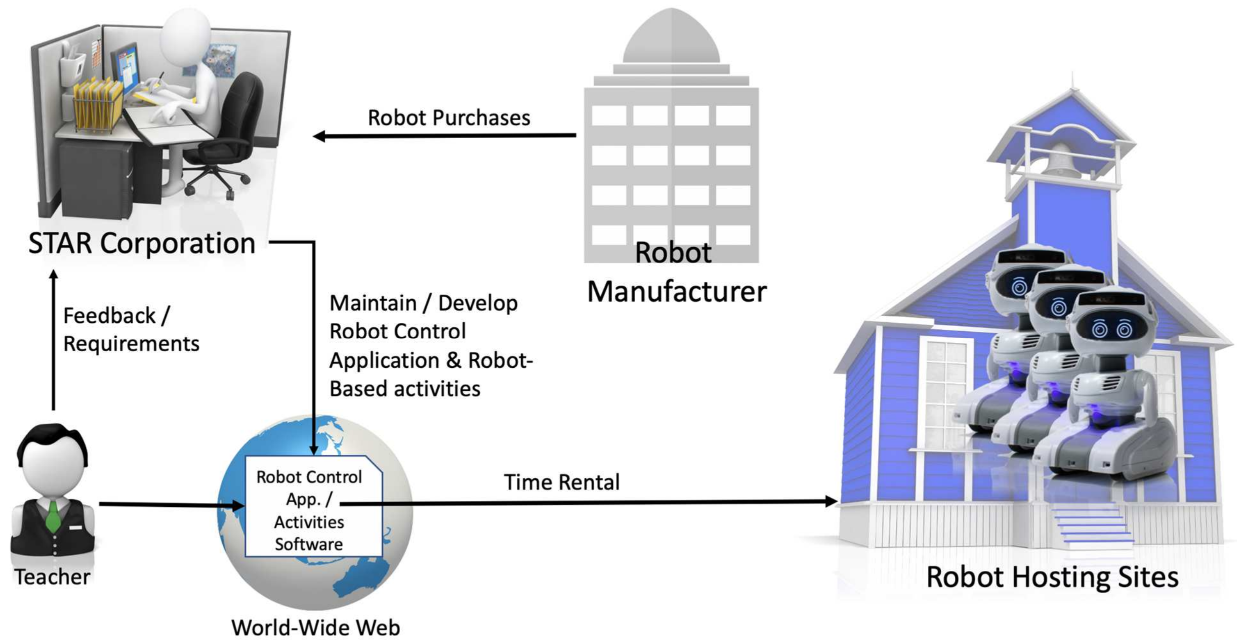

Figure 24. The social teaching assistant robot (STAR) business architecture.

Software Solutions

Maintaining the ongoing development of the robot control application would be undertaken by the STAR Corporation. The cost of developing this control software could be recovered through a nominal fee based on usage or through an annual subscription model. Development of new robot-based games activities that would run on the robot platform, that teachers could use in their education sessions, would also be developed by the STAR Corporation. These games and activities could be purchased by each school for a one-time fee or through an annual subscription model.

Training Services

Teachers will require training on how to use social robot teaching assistants from a pedagogical perspective. They will also require training on how to access and use the robots that the various robot hosting entities make available. The STAR Corporation would undertake this training.

Potential Funding Sources

I plan to investigate numerous potential funding sources for the establishment and ongoing operation of the STAR Corporation (see Figure 25). These fall into five main categories.

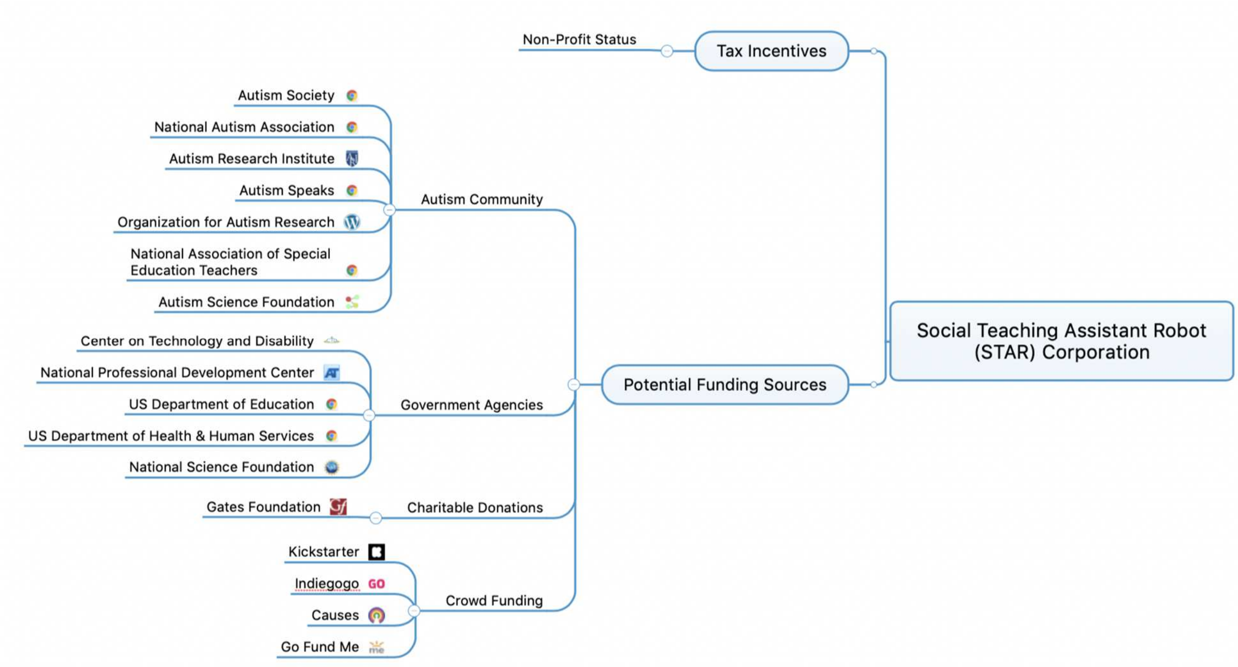

Figure 25. Potential funding sources.

The autism community. The autism community consists of a number of large organizations that are focused on various aspects of autism. These include autism research, support services for those on the autism spectrum and their families, and those involved in providing services to the autism community, such as educational institutions. Many of these organizations have dedicated funds they make available for research or the provision of autism support services.

Government agencies. Agencies exist at both the Federal and State level to aid in the research and provision of products and services to support the autism community. These include broad-ranging agencies, such as the US Department of Education, and the National Science Foundation, to more targeted departments such as the Center on Technology and Disability.

Charitable donation organizations. The world of philanthropy potentially offers a rich source of investment for the STAR Corporation. This community includes nationally recognized organizations, such as the Bill and Melinda Gates Foundation, and private investors. As I state in chapter 1, students with autism spectrum disorder are the fastest-growing group of children with special education needs (Guldberg et al., 2017), and ASD affects individuals from all walks of life (Busby et al., 2012). I anticipate, therefore, that a large number of affluent individuals who have philanthropic interests may also have family members impacted by autism. These potential donors/investors may be keen to assist the establishment and support of a social robot solution that aids in the education of those on the autism spectrum.

Crowdfunding. Crowdfunding may be a less orthodox source of funding for a non-profit seeking entrepreneurial business. Crowdfunding uses the internet to offer small, individual investors the opportunity to invest in speculative, innovative new products and services. These crowd-funded opportunities are typically offered through purpose-built crowdfunding websites, such as Kickstarter, and Indiegogo. The objective of most investors who use these sites is to invest in creative new products at a very early stage in their development (often when these products are still at the drawing-board idea stage) in the hopes of obtaining the product at a highly reduced price. However, crowdsourcing sites also attract investors interested in investing in solutions to achieve social impact in an area they are passionate about.

Summary

This study has demonstrated that teachers who are charged with educating students who are on the autism spectrum perceive the social robots as a useful teaching assistant tool in helping them educate their students. For this study to have a direct tangible impact, the social robot teaching assistant solution needs to be made available to schools and teachers involved in educating students on the autism spectrum. However, robot technology is too expensive for most schools to afford, and the software to operate a social robot in an educational setting does not exist. Therefore, I propose establishing a social entrepreneurial business that will provide this solution in the most cost-effective way.

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APPENDIX A: INFORMED CONSENT – PARENTS

THE ROLE OF SOCIAL ROBOTS AS A TEACHING AID AT THE MAGISTER MINISTER SCHOOL

Dear parent,

As you know, we at the Magister Minister school continually strive to enhance our teaching practices and find new ways to improve the way we support your childs. To that end, we have been working with Rick Hutley from the University of the Pacific to help us conduct a short study to explore the potential of using a social robot to assist our teachers. We will be holding a video conference session shortly to explain what we are doing and answer any questions you may have.

The robot we will be using is small and non-intimidating. Indeed, research shows that childs find robots fun and engaging:

The robot will assist the teacher by joining the Zoom video conference sessions with your child. Your child's teacher will have full control over the robot at all times and will be able, if necessary, to deactivate the robot and disengage it from the teaching session. Prior research into the use of robot technology with children on the autism spectrum has indicated that children find interacting with robots fun and that they can be very effective in helping children learn. The teachers will use the robot for a period of two to three weeks, during December.

There are no known risks to your child. Your child will conduct the same learning activities with their usual teachers, just as they do today. The robot will be there to assist the teacher and, under direct teacher control, and will provide fun and friendly feedback to your child. For example, to congratulate them on a job well done.

All information gathered during this study will be held in strict confidence, and no information regarding your child will be disclosed at any time. No personally identifiable information (e.g., names, addresses, etc.) will be used in the findings of this study. Your decision whether or not to allow your child to participate in this study will not affect your child's grades or participation in school and will not involve any penalty or loss of benefits to which you or your child are otherwise entitled. If you decide to allow your child to participate, you are free to discontinue your child's participation at any time without penalty or loss of benefits to which you or your child are otherwise entitled. Your child's participation in this study is completely voluntary, and you will not be induced to participate through any form of compensation.

Your signature below indicates that you have read and understand the information provided above, that you willingly agree to allow your child to participate and that you understand you may withdraw your consent at any time and discontinue your child's participation. You will be offered a copy of this signed form to keep.

If you have any questions about this study, please call me. If you have any questions, or concerns about this research study, its procedures, risks and benefits, you should ask the lead researcher: Rick Hutley, 678 296 2924, rhutley@pacific.edu

Independent Contact: If you are not satisfied with how this study is being conducted, or if you have any concerns, complaints, or general questions about the research or your child's rights as a participant, please contact Human Subjects Protection in the Office of Research and Sponsored Programs to speak to someone independent of the research team at 209-946-3903 or IRB@pacific.edu.

B. B.
Executive Director
Magister Minister

Child name:

____

Parent name:

____

Parent Signature Date

___________________________ ______________________________

APPENDIX B: INFORMED CONSENT – TEACHERS

TEACHER PERCEPTIONS OF THE ROLE OF SOCIAL ROBOTS AS TEACHING ASSISTANTS IN THE ONLINE TEACHING OF STUDENTS WITH AUTISM SPECTRUM DISORDER

Lead Researcher: Rick Hutley

You are being invited to voluntarily participate in a research study on the use of a robot as a teaching assistant. The purpose of this study is to work collaboratively with you and other Magister Minister teachers to evaluate whether social robots (robots used in a social setting – such as a classroom) can be usefully used to assist you in your teaching activities. The robot we will be using is small and non-intimidating (her name is Misty):

Prior research into the use of robot technology with students on the autism spectrum has indicated that students find interacting with robots, both fun and engaging. Similarly, it has been shown that the use of robots in the teaching process can have a number of benefits in helping students learn.

Your participation in this study will involve you using the robot as part of your normal online teaching activities, conducting learning activities that you have typically undertaken with your students before. The robot will appear as an additional attendee in your online Zoom video conference sessions, and you will have full control over what the robot at all times. You will be able to control the robot and make it interact with your students in a way that you deem most appropriate. For example, you may have the robot provide your student with guidance on what they need to do to perform the assigned activity rather than to do that yourself. Similarly, the robot may provide encouragement and feedback to your student in the form of a congratulatory message (audible) and/or a smile. In order to not interfere with your teaching sessions by participating in the Zoom calls myself, I will record the Zoom sessions so that I can observe the robot's impact after the lessons have been completed. The recordings will be held in strict confidence, seen by myself only, and stored in a secure, password protected area. All recordings will be destroyed after the three year retention period required of research studies.

Your participation will not involve any additional time during your lessons with your students. However, I would like to hold a quick Zoom call with you for approximately 20-30 minutes after the first week, and I will hold a joint focus group Zoom call with you and all of the other teachers involved in the study at the end of the second week. I estimate the focus group call will last between 30 to 60 minutes.

There are no known risks associated with this study. Your use of the robot in your teaching sessions will be under your control at all times, and you may cease to use the robot at any point. There are no direct benefits, however the societal benefits which may reasonably be expected to result from this study include first-hand experience for you and your students of using innovative robot technology in your teaching practices; direct experience for the MM school in using this state-of-the-art teaching technique; the ability to inform others in the autism educational space of teacher perceptions of social robots as teaching assistants. Your decision whether or not to participate in this study will not affect your employment at the MM school in any way or any other benefits to which you are entitled.

Your participating in this study is completely voluntary, and you will not be induced to participate through any form of compensation.

If you have read this form and have decided to participate in this research project, you understand that your participation is entirely voluntary, and your decision whether or not to participate will involve no penalty or loss of benefits to which you are otherwise entitled. If you decide to participate, you are free to discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled. You have the right to refuse to answer particular questions.

Data from this study will be held in secure, password-protected folders on a private, secure, password-protected server. The data will not be shared with or seen by anyone except the lead researcher. Your identity will be anonymized and will be known only to the lead researcher. The findings of this research will not contain any information that could be used to link back to the MM school, your students, yourself or your participation in this study.

If you have any questions, concerns, or complaints about this research, its procedures, risks, and benefits, contact the lead researcher, Rick Hutley, at 678 296 2924 / rhutley@pacific.edu or the Faculty Research Advisor, Dr. Rod Githens, 916 739 7332 / rgithens@pacific.edu..

If you are not satisfied with how this study is being conducted, or if you have any concerns, complaints, or general questions about the research or your rights as a participant, please contact Office of Research and Sponsored Programs to speak to someone independent of the research team at (209)-946-3903 or *IRB@pacific.edu*.

I hereby consent: (Indicate ***Yes*** or ***No***)

- To be video recorded during this study:
  ___Yes ___No

- For such video records resulting from this study to be used for robot impact analysis by the lead researcher:
  ___Yes ___No

The extra copy of this signed and dated consent form is for you to keep.

Your signature below indicates that you have read and understand the information provided above, that you have been afforded the opportunity to ask, and have answered, any questions that you may have, that your participation is completely voluntary, that you understand that you may withdraw your consent and discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled, that you will receive a copy of this form, and that you are not waiving any legal claims, rights or remedies.

SIGNATURE ___________________________________ DATE ________________________

Research Study Participant (Print Name): _____________________________________

Researcher Who Obtained Consent (Print Name): _Rick Hutley_____________________________

APPENDIX C: OBSERVATION PROTOCOL

Observation Protocol

Observations will be used to capture both student and teacher interactions with and use of robot technology. As the educational sessions will be fully online, the observations will take the form of video recordings of the online education sessions. Observations will be part of the data collection used to answer the following research questions:

- Do ASD teaching specialists perceive social robots as helping students with ASD to achieve their learning objectives more effectively/faster than traditional teaching methods?

- Which types of ASD students do ASD teaching specialists perceive social robots to be most helpful?

- Which types of ASD learning activities do ASD teaching specialists perceive social robots are most/least effective?

Protocol includes:

- All observations will consist of video recordings of the online teaching sessions.

- The video recordings will be transcribed, and field notes recorded. These will include:
    - Date, time, duration of each observation.
    - Student and teacher details.
    - Description of activities observed.
    - Direct quotations or paraphrasing of dialogue.
    - My perceptions and thoughts on the observation.

- Each observation will last 5-30 minutes as this is the time allocated by MM to each student activity.

- Multiple observation sessions will be held with students from each of the three classrooms, and across multiple days/weeks.

- As soon as the teaching session video recordings become available, I will augment my existing field notes. These updates will include:
    - Thoughts about the observation I find relevant to the study.
    - Additional questions or concerns that arise.
    - Possible next steps for further collection or analysis.

APPENDIX D: TEACHER INTERVIEW PROTOCOL – INTERIM REVIEW CYCLE

Introduction

Thank you for using the social robot solution (Misty). The purpose of this interview is to gather your perceptions of using the robot to assist you in your teaching activities. There are no right or wrong answers. I am interested in your honest experiences and perceptions of using the robot – good or bad. Your candid response is very much appreciated. Your responses will be held in strict confidence. Only I will see the answers you provide.

I would like to explore three broad areas:

- Your overall perception of the effect of including the robot in your educational activities with your students.
- With which types of students did you perceive the robot to be most/least helpful.
- With which types of learning activities did you perceive the robot to be most/least helpful.

To explore your experiences, let me ask a series of short questions. These are simply intended to start the conversation – please feel free to describe your perceptions and experiences in your own words, and in as much depth as you wish. Please feel free to give specific examples where possible.

Your Experiences

Let us start by exploring your experiences in using the robot in your educational processes:

- Which types of students do you feel benefit from your use of the robot, and why?
- Which types of students do you feel would not benefit from your use of the robot, and why?
- Which types of activities do you feel the use of the robot to be helpful, and why?
- Which types of activities do you feel the use of the robot was not helpful, and why?
- Overall, what were your personal experiences of using the robot to help you in your teaching activities?

Refinement

I would like to understand if there are any improvements I can make to the robot solution to make it more effective and useful for you. Based on your experiences you described:

- Should we remove any students from the study?

- Should we remove any activities from the study, and if so, why?
- Should we add any robot-based features/capabilities to the study? If yes:
    - What feature/capability would you like added, and why?
- Should we modify any existing robot-based features/capabilities? If yes:
    - Which features/capabilities should be modified?
    - What changes do you feel would result in a better outcome?

Wrap-up

Is there anything else you'd like to say about your experience in using the robot in your teaching processes?

It is essential that I have completely and correctly captured your perceptions. I will, therefore, write-up my notes and share them with you so that you have a chance to verify my understanding.

Thank you for your time.

APPENDIX E: FOCUS GROUP PROTOCOL – FINAL REVIEW

Introduction

Thank you all for using the social robot solution in your teaching activities. I would like to thank you for your feedback on the individual interviews. The purpose of this focus group is to discuss your collective perceptions to see if there are any learning outcomes we can glean from each other. I do not want to repeat questions we have previously explored, so I will focus on the highlights of our previous coommunications.

To explore your collective experiences, let me ask a series of short questions. These are simply intended to start the conversation – please feel free to describe your perceptions and experiences in your own words and in as much depth as you wish.

Experiences

Let us start by exploring your experiences in using the robot in your teaching processes:

- What did you perceive about the way students reacted to/interacted with the robot, and why?
- Do you think using a robot to assist in your teaching activities is more, or less appropriate for some students than others?
- What did you learn about the most useful or least useful ways of using the robot in your teaching activities?
- What are your overall perceptions of using the robot as a tool to help you teach your students?

Suggestions for the Future

Having used the robot in your teaching activities, I am interested in any suggestions you may have regarding how to improve the impact and usefulness of a robot-based teaching assistant tool like Misty:

- Are there any changes you would suggest about the way the robot is used during a teaching activity?
- Are there any robot-assisted activities that you would change? If yes, please explain what changes you believe would be helpful:
- Are there any activities or ways of using a robot to assist you in teaching your students that you would suggest adding? If yes, please explain what changes you believe would be helpful.

Wrap-up

Is there anything else you'd like to say about your experience in using the robot in your teaching processes?

It is essential that I have completely and correctly captured your perceptions. I will, therefore, write-up my notes and share them with you so that you have a chance to verify my understanding.

Thank you for your time.

APPENDIX F: STUDENT ASSENT FORM

ASSENT FORM (Student)

Student's Name: ______________________________

We are interested in knowing if you like using a robot during your activities with your teachers so that one day we can try to help people who find it hard to concentrate on things, and we'd like you to help us.

We'd like you to let Misty, our robot, join you in your video lessons with your teacher. Your teacher will use Misty to talk to you, but you don’t have to do anything, just have fun.

If you want Misty to stop speaking to you, just tell your teacher--you won't get into any trouble! In fact, if you don't want Misty to join you and your teacher at all, just let your teacher know.

If you do want Misty the robot to join you and your teacher, please sign your name on the line below. Your parent(s) have already told us that it is alright with them if you want Misty to join your lessons.

____