StoryScape:
Fun Technology for Supporting Learning, Language and
Social Engagement Through Story Craft

by

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Submitted to the Program in Media Arts and Sciences,
School of Architecture and Planning,
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Abstract

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental disorder that affects approximately 1-in-68 persons and 1-in-42 boys. Challenges related to communication form a core characteristic of the ASD condition. Literature suggests the single most important prognostic indicator for young children diagnosed with ASD is communication ability. Yet, engaging children diagnosed with ASD in communication centered activities is one of the cardinal challenges presented by the condition and contributes to poor outcome.

This work explores the development, implementation and testing of StoryScape, a platform for engaging children diagnosed with ASD in communication centered activities. Through extensive work with the ASD community, I have sought to develop a more holistic learning technology around communication. The StoryScape platform connects web, mobile, and physical technologies through interactive stories, enabling fun and engaging learning through story creation and other activities.

While the main focus of this work is related to children diagnosed with ASD, I also present a number of exploratory studies conducted with neurotypical children. In total, six exploratory studies, three with children diagnosed with ASD and three with neurotypical children, are presented. These studies demonstrate the many uses of StoryScape, and were critical for eliciting feedback on usability and design features during its iterative development.

In addition, I present the results from a seven-week study of story co-creation, conducted as a whole-class activity with students diagnosed with ASD. Results show a statistically significant increase in vocal expressions during use of StoryScape. Students also demonstrate a strong preference for the StoryScape activity compared to other activities. Teachers reported being surprised by the high level of student engagement and cooperation with each other, and they reported that students looked forward to using StoryScape daily. While teachers reported meaningful communication improvements during use of StoryScape for all of their students, one student was described by his teacher as “a totally different student when using StoryScape.”

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There is no such thing as the success of an individual. Success is a gift, a reward that may often be embodied by one, but which is always dependent on many and supported by myriad factors. Success emerges from the interaction of many working in concert, whether loosely or tightly-knit; it is the product of community. We might call this community a family or a team, or it may take on some larger more abstract sense, such as a society. Whether small or large it is this community that gives rise to success and for which the individual must pay homage. The success of an individual is nothing more than the embodiment of community effort, symbolized through one. Success is truly a reflection of community.

Realizing this I, too, must pay homage to those who have helped me succeed and have provided me with community. Let me first thank my partner, who for many years has provided me with encouragement, care, and support, thus making even grueling years more joyful. I thank my sister and family for helping make me who I am today. To my friends who have always been family, your influences have been substantial in my life. Joseph Fucciello, without risks we would never have made it this far. Gil Henry, thanks not only for being a great mentor, but a great friend, All of the teachers that have taken the time to care and teach me, from Palomar to UCSD to MIT, I truly appreciate your efforts. I would also like to acknowledge the great folks at the MPLab, particularly Javier Movellan and Ian Fasel.

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Chapter 1

Introduction

1.1 Introduction

Over the last decade positive public awareness of Autism Spectrum Disorders (ASD) has grown significantly. This awareness, along with the real needs of the ASD community, has spurred an increased focus on the role of technology to assist individuals diagnosed with autism. Despite this awareness, the growing body of research that explores new technologies for supporting learning, communication, and language in the digital age focuses on the development of technology designed for neurotypical children. Those diagnosed with autism remain underrepresented and are left to appropriate those technologies that best fit their needs. In addition to the technology gap, many feel the multimedia targeting the autism community is not as aesthetically compelling. This is concerning as such challenged learners may benefit most from customized technologies and media.

Much of the current cutting edge technology and research in “learning” is focused on fostering “digital literacy” and engaging children as creators [37, 25]. Digital literacy involves the ability to effectively and critically navigate, evaluate, and create digital media from a range of digital technologies. It does not replace traditional literacy, rather it builds on the foundation of traditional literacy, research skills, technical skills, and critical analysis
skills taught in the classroom [37]. While consideration of all learners is given by leading researchers, there are few examples of cutting edge technology being developed for or from the autism community. Currently children diagnosed with ASD, and other complex learners, appropriate technologies developed with and for neurotypical children.

While there will be no panacea technology, focusing on the challenges of learners diagnosed with ASD may actually enable the development of innovative new technologies that support a wide variety of learners. In many ways those diagnosed with ASD may represent some of the most complex and difficult to engage learners, and hence the most challenging to design technologies for. The challenges facing learners diagnosed with ASD include the heterogeneous nature of autism, idiosyncratic interests, coordination among caregivers, individualized education plans, sensory challenges, non-verbal behavior, cognitive impairments, social engagement, and general engagement in learning activities. While ultimately learning technology should be user-agnostic and truly inclusive, it may be that we achieve this by intense focus on the most complex learners first, rather than waiting for “technology serendipity.”

The majority of “apps for autism” simply rehash traditional physical media and learning strategies and provide rote interactions. Is this the best we can do? What if the trends found in cutting edge learning technologies for neurotypical children were applied to development of technologies for complex learners too? In particular we feel that the principles of constructionism and participatory cultures are well suited to help inform new technologies for complex learners such as those diagnosed with ASD [37].

This dissertation explores the development, implementation, and testing of an inclusive creative learning technology, StoryScape, built on the principles of constructionism and participatory cultures for the purpose of addressing learning needs around communication for children diagnosed with ASD.
1.2 Motivation

Communication impairments are a core characteristic of autism, affecting social-emotional interactions and broader language skills. Literature suggests the single most important developmental prognostic indicator for young children diagnosed with ASD is communication ability [40]. As a result there is an intense focus on fostering communication skills in individuals diagnosed with ASD. An early and prolonged intervention of communication skills is critical for many diagnosed with autism. The development of communication skills takes place with multiple stakeholders and involves speech, reading, writing, and other expressive skills. A key challenge in this effort is actually engaging the child in communication. Engagement is critical to learning, yet the difficulty engaging children diagnosed with ASD in communication centered activities is one of the cardinal challenges presented by the condition.

This work explores the development, implementation and testing of, StoryScape, an inclusive creative learning technology. StoryScape was developed with consideration of the communication challenges of those diagnosed with ASD, the need to engage them in communication activities, and the need to support the people who support them. Through extensive work with and research about the autism community, we have sought to develop a more holistic learning technology around communication. We approach this challenge using principles of constructionism and participatory cultures to guide the development of StoryScape. We explore the application of the resulting technology with a wide range of learners, with respect to age and ability, to understand how the technology can be deployed across users and settings. Our ultimate goal is the support of a community of learners around language and communication.

1.3 Summary of Design

A brief description of the StoryScape platform and how it works is provided here for the reader as context for the remainder of the dissertation. The full description of StoryScape
Figure 1-1: Adding an NFC character to a story. In the left image the duck plush toy has an NFC chip inserted in it; notice that there is no duck in the digital scene of the mobile reader. In the right image the duck has been brought into contact with the mobile reader which triggers the appearance of the digital duck in the scene on the mobile reader.

is provided in Chapter 3. *StoryScape* connects web, mobile, and physical technologies around the story process. The story process is considered as a combination of activities: creating, reading, remixing, or sharing of interactive stories. The story format is that of visual narrative, i.e. the mixture of images and text. *StoryScape* provides authoring tools, story readers, and physical interactive technologies for the story process. The *StoryScape* platform enables many different usages, each with its own value. The following is a list of some of these usages:

- Reading of interactive stories created by others.
- Remixing pre-created stories.
- Creating stories from community art sets.
- Sharing stories with other people.
- Creating art sets for others to create stories from:
  - Static illustrations (stages).
  - Animated objects (actors).
- Interacting with physical story assets that augment story content or extend interactivity, e.g. a plush doll that appears in the digital story.
- Creating physical story assets that augment story content or extend interactivity (see Figure 4-6).
The web portions of *StoryScape* allow anyone to browse stories and artwork (see Figure 1-2). Users can also use a web-browser story reader to read any story (see Figure 1-4), though there is limited interactivity in the web based reader. Any story that has been published can also be downloaded to the Android mobile reader (see Figure 1-4). On the mobile reader the user can easily remix any story by moving elements, adding images, or adding sounds. In addition, it is only with the Android reader that the full interactive features of a story are possible.

In addition to reading, remixing, and interacting, story users can author their own stories and artwork. Story authoring involves first selecting a community art set for use (see Figure 1-2). Once art has been selected the user would use the story authoring tool to construct the story (see Figure 1-3). The story authoring tools allow for the creation of scenes; each scene can have a background, actors, and text. In addition to creating stories, users can create whole art sets for their use and other's use. While the artwork would be created outside of the *StoryScape* platform, using other tools and methods, *StoryScape* allows for the construction of animations and interactive triggers specific to the *StoryScape* platform (see Figure 1-3). Furthermore, users are able to augment stories by dynamically loading artwork via NFC triggers or extend interactivity of the story into physical hardware or sensors using the IOIO prototyping board (see Figure 1-5).

### 1.4 Summary of Findings

A number of research explorations have been carried out over the course of the development of *StoryScape*. These explorations were critical in the development of the platform and allowed us to understand how *StoryScape* could be used across a diverse set of users and specific cases. In addition, over the course of seven weeks, a comparative study of *StoryScape* and two other activities was carried out as an integrated classroom activity with students diagnosed with ASD. The study was conducted to determine the benefits of using *StoryScape* to facilitate engagement of the whole class during story co-creation.

The research explorations included working with neurotypical children and adults, teachers,
and children diagnosed with ASD. With nerotypical individuals, we carried out a study comparing story creation of visual narratives vs. text only stories. In addition, we carried out explorations with two private schools to research the process of creating original art, animation, stories, and physical interactive elements. These explorations indicated that *StoryScape* can be used in traditional school settings to meet learning goals, while also facilitating the goals of digital literacy through integration of other digital tools.

In addition, we worked with three schools for children diagnosed with ASD. In these cases we explored the ability of teachers to create individualized education materials, story reading by children, story physical asset interactions, and story co-creation as a whole class activity. This work indicated that *StoryScape* can be used by teachers to create individualized learning materials for students. Likewise, not only did children enjoy reading and interacting with *StoryScape* stories but appeared to motivate some students to speak more during story reading activities. An exploration to determine how children would respond to the interaction between the digital story and physical objects showed that children were very excited by physical items appearing “magically” into the story. Our final exploration using *StoryScape* as a tool for story co-creation by the whole class resulted in teachers re-
Figure 1-3: StoryScape web-based story authoring tool (top) and artwork actor authoring toll (bottom)
Figure 1-4: *StoryScape* web-based story reader (top), and mobile Android reader (bottom)

Figure 1-5: *StoryScape* physical technologies. IOIO electronics prototyping hardware (left) and NFC tags (right)
porting highly engaged students collaborating and expressing more language than during
typical classroom activities.

We also conducted a larger, in-depth study of whole class story co-creation based on the
results of our previously mentioned research explorations. A mixed methods comparative
study approach was used to study story co-creation as a whole class activity. Our primary
research interest was determining if StoryScape facilitated social engagement during a lan-
guage activity. We compared StoryScape with work by Hourcade et al., which investigated
story co-creation via paper story drawing and digital story drawing as social engagement
activities for children diagnosed with ASD [35].

Overall, the research explorations and in-depth study show strong support for StoryScape
as a tool to support a wide range of users and use cases, with a particular benefit for
engaging groups of children diagnosed with ASD in a social-communication activity. Given
the well-known difficulty of engaging children diagnosed with ASD in social activities and
in communication activities these findings are of potential significance to the larger autism
community and other researchers.

1.5 Summary of Contributions

The contributions of this dissertation span several disciplines including autism technolo-
gies, learning technologies, interactive media, and human-computer interaction. The main
contributions are as follows:

- I present the first scalable, immersive, interactive, story platform (StoryScape) ca-
  pable of collecting usage data and connecting digital and physical story assets and
  interactions.
- I present a platform capable of supporting art activities and a public media library of
  artwork usable by anyone for the purpose of creating stories.
• I explore *StoryScape* as a tool to facilitate digital literacy with neurotypical individuals. I find that *StoryScape* supports traditional learning goals while broadening the use of other digital tools during story crafting activities.

• I explore *StoryScape* with teachers as a tool for creating individualized learning materials for children diagnosed with ASD. I find that *StoryScape* enables the creation of individual learning materials paralleling in-class materials.

• I explore the use of *StoryScape* during story co-creation as a means of facilitating engagement in a language-centered social activity. Our findings show increased social engagement and strong student preference for the *StoryScape* technology.
Chapter 2

Background and Related Work

This chapter begins with an overview of ASD. In particular, I focus on the communication challenges associated with ASD. In addition, I highlight the support network around individuals diagnosed with ASD. Next, I review ASD communication related technologies such as alternative and augmentative communication (AAC), computer aided instruction, tangible interfaces, and robotics. I conclude by highlighting works that use technology to facilitate social engagement.

2.1 Autism Spectrum Disorder

2.1.1 Autism Overview

ASD is a complex neurodevelopmental disorder that affects approximately 1-in-68 persons and 1-in-42 boys [20, 2]. The condition is characterized by qualitative impairments in social interactions, verbal and nonverbal communication, and imaginative ability coupled with restricted interest and repetitive behaviors [4]. Communication impairments are a core challenge faced by individuals diagnosed with ASD. These challenges result in difficulties in the acquisition, interpretation, and expression of verbal and nonverbal communication. Within the ASD community, expressive communication ranges from complete mutism, to
functional communication, to highly skilled language expression. Nearly 25% of individuals diagnosed with autism do not develop functional communication, while many more have impaired communication [60]. Ultimately, impairments are heterogeneous and affect multiple modalities of communication. Furthermore, communication challenges extend beyond the person themselves and affect their family, friends, and larger social network. Interwoven with these communication challenges are issues related to engagement. Engaging children diagnosed with ASD in communication activities is often very challenging, and issues of engagement present a significant obstacle to development of communication skills.

The importance of communication skills cannot be neglected, as literature suggests the single most important developmental prognostic indicator for young children diagnosed with ASD is language ability [40]. Because of the importance of communication skills there is significant effort directed towards enabling communication for individuals diagnosed with ASD. The interventions with the most empirical support for children diagnosed with ASD come from applied behavioral analysis (ABA) [24]. ABA is based on a behaviorist approach to learning and involves the use of clear instructions, repetition, practice, and reinforcement [5]. Early and sustained ABA intervention is suggested to be conducive to an increased positive outcome for individuals diagnosed with ASD [22]. Despite this potential for improved outcomes, nearly half of those diagnosed with ASD have a poor outcome – communication remains impaired and reading and spelling is poor into adulthood. Few have close friends, or permanent employment, and the number of adults diagnosed with ASD living independently is estimated between 4 and 12% [36, 11]. Results suggest that while ABA has the most empirical support, lasting outcomes are qualitatively still poor. This suggests that other approaches and technologies may provide added benefit above and beyond traditional approaches.

2.1.2 Autism Support Network

To fully understand ASD, and to develop technologies to support learning and communication, it is important to understand those diagnosed with ASD and their support network. Typically, there is a network of stakeholders involved in the education and support of chil-
dren diagnosed with ASD. This network includes family, friends, teachers, occupational therapists, speech and language pathologists, psychologists, and others.

Perhaps the most cohesive support network around a child diagnosed with ASD is the “school team.” The school team typically includes teachers, occupational therapists, speech and language pathologist, and psychologists. The school team works in collaboration with a student diagnosed with ASD and their parents. It is this support network that is involved in the day-to-day support, teaching, and therapy of children diagnosed with ASD. While different members of the support network may focus on particular needs of the individual, they all focus on engaging the child in social attention skills. This is particularly true for young children and those with significant communication impairments. It is easy to understand that without the ability to communicate little else is possible.

I mention the support network to provide a greater understanding of those diagnosed with ASD. It is important to understand that ASD is not only a condition that results in social impairment for the individual, but that requires a social support network. It is also important to consider this support network when designing technologies for individuals diagnosed with ASD. I feel that meaningful technologies for individuals diagnosed with ASD must accommodate the support network because of its importance improving the life and functioning of such individuals. While broadening understanding and design goals for this population may present initial challenges, I feel it will result in more meaningful and useful technologies.

### 2.2 Autism Communication Technologies

Over the last 15 years there has been a significant increase in research and testing of novel technologies to help those diagnosed with ASD. Active technology research areas for ASD include: Alternative and Augmentative Communication (AAC), computer aided instruction, robotics, tangible interfaces, intelligent tutors, robotics, and surface computing, and interactive media [63, 54, 51, 13, 7]. Communication skills are the primary focus of ASD technology research, this includes language specific goals as well as social-emotional
communication. Kientz et al. provide a thorough presentation of ASD technologies [38]. I focus on a review of relevant ASD technology literature related to communication.

2.2.1 Alternative and Augmentative Communication

AAC is a broad field of research focused on improving communication abilities for individuals with complex communication needs. The focus of AAC is to facilitate communication through methods that supplement or replace traditional communication modalities. AAC techniques and technologies may vary greatly and include: sign language, symbol use, text-to-speech devices, and even brain-computer interfaces [43]. The Picture Exchange Communication System (PECS) is one of the most commonly used AAC technologies.

PECS involves the use of image icons for communication purposes. For example, an individual may show an image of a glass of water to indicate that they are thirsty. Multiple images may be used together to form complex statements. The use of PECS has traditionally been via images printed onto paper and laminated. In addition, specialized AAC devices that leverage software and hardware designed specifically for AAC needs have offered an alternative to paper based approaches. Over the last several years there has been a significant shift to iOS based PECS software. Despite these digital based AAC devices, paper approaches remain common. The use of PECS has been proven to be successful with children diagnosed with ASD. Research has shown PECS use increases communication and reduces negative behaviors in children diagnosed with ASD [17, 42, 28].

While there are many benefits of the PECS system, it also has shortcomings. Picture cards are easily lost, cumbersome, and can be socially stigmatizing [44]. There are few tools for caregivers to create their own PECS media and common media used for PECS communication is of low standards. For individuals with large PECS vocabularies, shuffling through hundreds of cards is an obstacle to communication.
2.2.2 Social Stories

Social Stories are perhaps one of the best known examples of story use as a teaching and therapy tool for individuals diagnosed with ASD. Social Stories are short, accurate, and unassuming illustrated stories that teach a specific situation, skill, or concept [30]. The use of Social Stories is common across stakeholders [10, 57, 59]. Social Stories are most commonly presented on paper, while there are some digital presentation apps too. Typically a teacher, or other caregiver, will create custom Social Stories for those they care for. Despite the ubiquity of Social Stories in the autism community, there is a surprising lack of technology and research involved in their creation.

A notable work that explores the development of a platform for creating diverse social scripts for children diagnosed with ASD is that of Boujarwah et al. [14]. Their work explores the development and use of an authoring tool for creating social scripts, which can be used for learning purposes. The authoring tool allows for the creation of interactive instructional examples of social scenarios in which unexpected obstacles arise, guiding them through a problem solving process to overcome the obstacle. Because any particular social situation has many potential outcomes it is not possible for a teacher or parent to create the vast array of possible social scripts needed to explore a social situation. As a result, Boujarwah et al. explore the integration of human computation, crowdsourcing, as a means of creating a wide array of social scripts for any particular situation. To this end, they present an effective way to crowdsource rich and interesting data and organize it in such a way that makes it usable and useful. They describe an approach to using crowdsourcing to develop models of
social scripts. They also verify that the data collected can form complex and interesting social scenarios, possible obstacles that may arise in those scenarios, and potential solutions to those obstacles. Likewise, they evaluate how their system helps an author create social skills instructional materials [14].

Work by Constantin et al. reviews the literature and marketed products for creating Social Stories. They determine that there are no tools that provide sufficient features to support the needs of actual practitioners for creating Social Stories [18]. They report that most stakeholders use tools such as pen-and-paper, Microsoft Word, and Microsoft PowerPoint to create illustrated materials for use in Social Stories. The most widely used software package specifically designed for Social Stories and other AAC media creation used by practitioners is Boardmaker. Boardmaker allows for the construction of illustrated media that can be printed onto paper for subsequent use. Overall, they report a significant lack of quality tools for supporting the creation of illustrated media for the autism community. While Constantin et al. do not report on the quality of media used for creation of such media, it should be noted that Boardmaker media is of low quality. Furthermore, Social Stories made by practitioners using tools other than Boardmaker tend to have very low quality imagery in comparison to other visual narrative media intended for children.

2.2.3 Interactive Software Packages and Video Games

Treatment technology has primarily focused on the development of interactive software packages and video games that explore facial expressions and social scenarios. Notable software packages are Mind Reading: The Interactive Guide to Emotions and Transporters [6, 8] (see Figure 2-3). Mind Reading software allows users to explore over 400 examples of emotions. Each primary emotion is performed by six different people and includes audio and video. In addition, Mind Reading software contains a Learning Center with lessons and quizzes designed to help learn about emotions. The objective is to allow a user to study emotions and to learn the meanings of different facial and vocal expressions. The Mind Reading software has been shown to improve emotion recognition in individuals diagnosed with ASD.
Similar to the Mind Reading software, Transporters aims to help children diagnosed with ASD learn facial expressions and emotions. Unlike the Mind Reading software, Transporters is not an interactive software package. Instead, Transporters is a professional quality animated series of videos designed to teach children diagnosed with autism about emotions and social interaction. The development of Transporters was directed towards preschoolers and those with significant learning difficulties, as both groups are underrepresented in ASD research. From prior research, Transporters was developed to leverage the special interest around automobiles of children diagnosed with ASD. As a result, the characters of the Transporters stories are vehicles with human faces (see Figure 2-2). Golan et al. conduct a study with children diagnosed with ASD and report gains in emotion recognition when using Transporters [8].

There is also a great deal of interest in the development of video games that focus on helping autistic children. Within this domain, many games are focused on matching facial expressions or other social-emotional cues. The Facesay game is an example of a game that augments facial features with a focus on matching expression types between different people [33]. The Facesay game relies primarily on matching faces to emotional states. It also works to direct user gaze to the eyes region of the presented face, as a means of improving social gaze behavior. In a study of the Facesay software with children diagnosed with ASD
Hopkins reports that it increased social skills abilities in participants [32].

TeachTown, a personal computer and web platform, is an example of an educational software package for teaching language and communication skills (see Figure 2-3). The learning exercises are primarily presented as multiple choice discreet trials. The focus of communication learning is around words, simple sentences, and social scenarios. Learning exercises are often paired with games, videos and other rewards as motivators. There is evidence to support improved cognitive and language outcomes for children diagnosed with ASD using the TeachTown platform [64].

2.2.4 Tangible User Interfaces

Some research in the field of tangible user interfaces has explored the use of tangible objects as a means of teaching emotional states and body language to children diagnosed with ASD.

The work of Blocher et al. integrates physical characters into a pedagogical animated show with the hope of creating a system that acts as a very patient teacher of emotions [12]. This led to a design focused on modeling antecedent interventions used in operant behavior conditioning, with lessons presented as discrete trials. The system presents on-screen videos to help teach emotion recognition to children diagnosed with ASD. During presentation, questions about emotions are presented to the viewer. The viewer must use plush dolls that are able to communicate with the system via two-way wireless communication to answer the questions. Each plush doll corresponds to a particular emotional state (see Figure 2-4).
Blocher et al. determined that the system was successful at engaging children and may be useful for teaching emotion recognition.

Paiva et al. [47] explored the use of a TUI doll (SenToy) that can be manipulated to change the emotional state of a corresponding video game character. SenToy is a doll with sensors in its arms, legs, and body, which allows the user to influence the emotional state of its controlled digital character by changing its body posture with the physical doll. Evaluation of SenToy has shown that users were able to express desired emotions through the physical interface corresponding to body postures to influence the synthetic characters, and that overall players liked the doll as an interface.
2.2.5 Robotics

With the continued development of robotics there has been an increased interest in the use of robotics as teaching and therapeutic companions, sometimes referred to as social assistance robots (SAR). Similar to computers, robots have the potential to act in controlled and repeatable manners while embodying social engagement features more similar to humans. Research has explored the use of robots as teaching assistance for young children and therapeutic purposes for those diagnosed with ASD (see Figure 2-5) [45, 46, 58, 41, 19].

For the most part, research with SAR and children diagnosed with ASD has focused on enabling learning and engagement in social-emotional skills. The seminal work of Dautenhahn and the Aurora project explores how autonomous robots can be used to encourage children diagnosed with ASD in a variety of activities and social behaviors. The focus of all SAR systems targeting ASD is to generate therapeutic interactions between the robot and human involving the elicitation, coaching, and reinforcement of social behaviors [56, 58, 55, 41].

Research has shown success at engaging children diagnosed with ASD in social behaviors using robots. While there are many exciting possibilities for the use of robots as initial teachers of social skills that scaffold the individual diagnosed with ASD to social skills abilities with other people, there are also many challenges facing realizations of these potentials. No long-term study has shown maintained engagement, and therefore it is not known if benefits result only from novelty effects. Furthermore, there are many challenges in machine learning and robotics that have still to be overcome before truly useful systems can be deployed.

2.3 Technology Facilitated Social Engagement

Outside of AAC technologies, there has been little research into the use of technology as a means of facilitating actual social engagement. While there is strong anecdotal support for the premise that individuals diagnosed with ASD like technology and may prefer it to
Figure 2-5: Robots developed for social interaction with children diagnosed with ASD. Nico robot (left), Keepon robot (middle), KASPAR robot (right).

interacting with people, there has been little research that has explored how to leverage technology as a means of facilitating communication and social engagement.

2.3.1 Surface Computing

The seminal work by Piper et al. first explored the use of surface computers as a means of facilitating social collaboration among children diagnosed with ASD. Their work uses the DiamondTouch table [21], a multi-user touch sensitive tabletop with top-projection display that is capable of detecting which user is touching the table. They developed a game that required four participants to coordinate the construction of a puzzle. The puzzle construction required participants to take turns and communicate with one another as a means of play. They report that participants that typically disengage quickly from group activities maintained engagement over the time of game play.

Other works have also explored the use of surface computers as a means of facilitating social engagement. Battocchi et al. explore collaborative puzzle building, but unlike Piper et al. they force physical collaboration. While Piper et al. relied on participants negotiating play through conversations, Battocchi et al. forced two students to physically collaborate as a requirement to move puzzle pieces. Their game required two different players to simultaneously touch and drag puzzle pieces during puzzle construction. Their findings suggest that enforced physical collaboration has a positive effect on collaboration and that participants enjoyed the activity [9].
Guisti et al. work to developed a set of collaboration patterns that can be used as design principles to create games that enhance social engagement. Using principles of Cognitive-Behavioral Therapy (CBT) that encourage or require joint-engagement they developed games that encouraged social collaboration [29]. Similar to the works above, they used a surface computing interface for game development and to facilitate social interaction. The following games present the collaboration patterns they developed with a short description:

- Choosing together pattern: In order to select an object more than one participant must touch it.
- Constraints on objects pattern: Object constraints that require collaboration, e.g., an object is too heavy and requires more than one participant to move it.
- Different role pattern: Collaboration that is required because participants have been assigned to play different roles, e.g., pilot and navigator.
- Ownership pattern: Collaboration that is required because the participants have ownership of different objects that need to be negotiated.

Guisti et al. conducted a study with children diagnosed with ASD to test the efficacy of their games developed using the collaboration patterns for facilitating joint-engagement. Sessions were conducted by an occupational therapist with CBT training, and two children diagnosed with ASD. In total eight children diagnosed with ASD took part in the study. A quantitative analysis of sessions revealed that patterns were successful in supporting joint-engagement. The games were determined to provide a balance between fun play and therapy.

### 2.3.2 Tablet Apps

While the above works all use expensive surface computers that have not seen significant adoption by consumers, the recent work of Hourcade et al. explores the use of tablet apps to encourage social interaction.

Hourcade et al. developed the Open Autism Software (OAS) package for use with children diagnosed with ASD [34]. The OAS is intended for use on touch enabled computers and
includes four applications. Of particular relevance is their drawing app, which they use for collaborative storytelling and self-expression (see Figure 2-6). The drawing app provides basic drawing through use of a mouse or finger input, as well as panning and zooming using the pinch gesture. It also includes a simple palette of colors.

A study by Hourcade et al. was conducted at a school with children diagnosed with ASD to determine if the tablet and apps facilitated social engagement [34]. To determine the effects of the tablet apps they compared it with non-tech alternative activities such as using pen and paper during story co-creation. Sessions were conducted by two researchers and involved two students working together to create a story. During each session, children were asked to create a story by taking turns drawing the current scene of the story they were creating. Children were instructed to first draw the scene and then explain the story. During turn taking the children were allowed to talk to each other about the story and drawing. Sessions were video recorded for later analysis.
Analysis of video focused on features of social engagement. They had human coders code the video recorded sessions for: verbal interactions, supportive comments, discouraging comments, physical interactions, atypical behavior, social missteps, and time off-task. They determined that verbal interactions and physical interactions were the only features that had a statistically significant difference between the activities. It was determined that the apps supported positive social interactions and resulted in increased social engagement during use [35].

2.4 Tablet Apps Targeting ASD

The introduction of the iPad in 2010 marked a significant change in the accessibility of technology for children diagnosed with ASD. The ASD community has been particularly strong adopters of the iPad and other Android based tablet computers. As a result a significant number of apps have been developed for or targeted at the ASD community. We conducted a review of apps targeting autism, with a focus on data collection, to better understand the offerings and focus of technology for individuals diagnosed with ASD.

A thorough search of the Internet, Apple App Store, and Google Play Store was conducted by three researchers to compile a list of apps for ASD. Ultimately we used the “Autism Apps” list from Autism Speaks, as it contained nearly all apps found by the researchers and because Autism Speaks is a leading ASD advocate and information source for the ASD community [1]. At the time of the review the list contained 430 apps. The Autism Speaks list also contains a “research rating” for each app. Ratings are: Anecdotal, Research, and Evidence. Anecdotal indicates “No specific or related scientific studies for this type of app.” Research indicates “There are some related scientific studies, but no direct research support for this type of app or technology.” While Evidence indicates “There is solid or specific scientific evidence that this type of app or technology is helpful.” These ratings were recorded for all apps.

A researcher conducted reviews of each app. The researcher would do at least one of the following to review the app: install the app on a tablet and use it briefly; or visit the
developer’s website and read the developers app description and features. In total 430 apps were reviewed by three researchers. Apps were categorized into eleven categories. The following is a brief description of each category:

- **Speech**: Apps that facilitated speech such as, PECS, text-to-speech, and other AAC applications.
- **Language**: Apps used for reading, writing, and spelling.
- **Math**: Apps for teaching mathematics.
- **Scheduling**: Apps used for scheduling events and daily activities.
- **Daily Skills**: Apps used for teaching daily skills, e.g. how to wash your hands or tie your shoes.
- **Motor Skills**: Apps used for hand eye coordination, e.g. popping bubbles.
- **Social**: Apps for presenting Social Stories or other social scenario lessons.
- **Soothing**: Apps used for soothing by color display or sound generation.
- **Behavioral**: Apps for tracking behavior.
- **Play**: Games such as Angry Birds and Fruit Ninja.
- **Other**: Apps not meeting criteria for above categories, e.g. Dropbox and weather apps.

Figure 2-7 provides an overview of the number of apps in each category. Speech and language apps account for the largest number of apps, with 92 and 103 respectively, or 45.3% of all apps for autism. This reflects the general focus and importance of communication and learning to the ASD community. Research ratings across all apps were as follows: Anecdotal 79.9%, Research 14.5%, and Evidence 5.6%.

We further considered app data collection because of the potential to use such data for reporting learning and other behaviors from app usage. We considered data collection “locally” and “shared.” Local data collection means that some form of data is collected and saved on the device, at least during the session. Shared data collection means that data can be collected and shared with others using cloud storage and the Internet. Typically, shared data was collected by the app and shared with the app developer, who may provide data analytics to its users. In addition, some apps allowed the user to share data with other
Figure 2-7: Overview of autism apps reviewed, their categories and the number of apps per category.

people via email or other means. With respect to shared data collection we also considered whether the apps were part of an ecosystem, i.e. if one developer authored multiple apps that each collected data.

Overall, we found that only 27% of all apps collect data, 20.5% collected data locally, and 6.5% shared (see Figure 2-8). Since communication apps made up the majority of all apps, we also considered speech and language apps separately. Only 14.6% of speech apps collected data, 11.2% locally and 3.4% shared. For language apps, 27.3% collected data, 18.9% locally and 8.4% shared. Lastly, when we considered data collection across an ecosystem of apps, we found that only 0.8% of apps were part of an ecosystem and collected data.

While data collection at the local level was greatest overall, 20.5%, it is worth noting many of these apps collected data only for a single session. For example, if the app was a spelling game it would record how many words were spelled right during a particular session, but this information was not saved or otherwise used between sessions. While 6.5% of apps
Figure 2-8: Review of data collection policies for apps reviewed. Upper left is for all apps reviewed. Upper right indicates those apps that are part of an ecosystem that collect data. Lower left are those apps in the speech category, while the lower left is language category.
allowed data to be collected and shared between sessions there were a negligible number of services that provided data analysis to the user.

While researchers did not record the intended target age for apps, they all noted that the vast majority of apps were intended for children under 12 years of age. The intended target age may account for the low number of apps that collect data. Data collection for children under the age of 13 years is regulated by the Children’s Online Privacy Protection Act (COPPA) [52]. While the COPPA rules do not prohibit collection of data from children under 13 years, developers may be cautious to collect data when developing apps for children.
Chapter 3

StoryScape Platform Design

3.0.1 Design Principles

There are many approaches to technology design. Within the autism technology literature, the most common design approach is participatory design. Participatory design attempts to actively involve all stakeholders in the design process to help ensure that the results meet their needs and are usable. While we also use participatory design principles in this work, we further consider design at a more fundamental level.

Supporting learning motivates much of our work in developing StoryScape. Our hope is that the platform can help support communication learning and expression. With respect to learning and therapeutic interventions in the autism community Applied Behavioral Analysis (ABA) has the most empirical backing [24]. As a result most autism technology is designed to implement the principles of ABA. While a full discussion of ABA is beyond the scope of this work, much of the technologies designed from ABA principles implement operant behavior conditioning through discrete trials with a specific answer and reward associated with a correct response.

Rather than follow other researchers we feel that the principles of constructionism and participatory cultures are well suited for guiding the design of new technologies to support a community of users. The following describes constructionism and participatory cultures.
3.0.2 Constructionism

Constructionism has its roots in Jean Piaget’s epistemological theory of constructivism. Constructivism describes what a child is interested in and able to achieve at different stages of development. The theory describes how children’s ways of doing and thinking evolve over time [49]. At the root of Piaget’s constructivism is the notion that knowledge is actively constructed. In terms of a child, they do not learn simply because they are told some fact, but they actively construct an interpretation of the world and hence their knowledge of it. Likewise, the heart of Papert’s constructionism is rooted in the notion of knowledge being constructed. Constructionism builds from constructivism, but focuses on the art of learning. The path to this learning is through making things, or “learning-through-creating.” Papert focused on how people construct knowledge most effectively when they are actively constructing objects in the world, whether they are physical or conceptional. The tools used for creating, the media, the context, and the process is all important to learning [3, 48].

3.0.3 Participatory Cultures

Participatory cultures represent constructionist principles with a specific focus on how communities are structured to facilitate learning. Jenkins describes a participatory culture as having the following characteristics: [37]:

- Culture with relatively low barriers to artistic expression and civic engagement.
- Strong support for creating and sharing one’s creations.
- Informal mentorship, whereby what is known by the most experienced is passed along to novices.
- Where members believe that their contributions matter.
- Where members feel some degree of social connection with one another.
From constructionism we see that the process of creating and the artifacts of learning are important. For this reason, whether in the digital or the physical media, the tools for creating knowledge are important. As a result, there is little focus on creating rote exercises and a great deal of focus on creating tools that allow learners to create. Constructionism also has strong support for sharing and remixing media. Sharing allows for learning through examples, while remixing is seen as a valid learning expression. Participatory cultures further define how communities facilitate learning and how they should be structured. In designing StoryScape, these principles have been a constant influence, with our goal being a platform to support a community of learners around the story process of reading, creating, sharing, and remixing content.

3.0.4 StoryScape Features and ASD Motivations

The design and subsequent features of StoryScape have been motivated by the needs of individuals diagnosed with ASD and their support network. While the remainder of this chapter provides an in-depth description of the StoryScape platform, we present an overview of StoryScape features and motivations here. The following list presents StoryScape features with short descriptions of the motivations for the feature.

- **Story Remixing** (pertains to the changing of visual elements of story)
  - Allow user to change visual scene of story for self-expression.
  - Encourage play.
  - Encourage interest in creating story.
- **Audio Remixing** (pertains to the changing or adding of audio to a story)
  - Encourage child to use their voice for narration and sound effects.
  - Allow caregivers to modify/personalize story for child specific support.
- **Image Remixing** (pertains to the adding of images to the story)
  - Allow for images of special interest objects to be added to story.
  - Allow modification/personalization of story.
  - Encourage interest in creating story.
- **Shared Artwork Library**
- Allow anyone to create stories from pre-created artwork.
- Allow anyone to create art to share with others for creating stories.

**Shared Story Library**
- Allow anyone to share stories with others.
- Allow the ASD community to create a media library useful to their community.

**Story Authoring Tools**
- Need within caregivers community for tool for creating story based media, such as Social Stories, etc.
- Allow creation of hyper-personalized media for individuals diagnosed with ASD.
- Allow for learning and therapy that uses the story craft activity as a motivation for communication and social engagement.

**Artist Authoring Tools**
- Allow anyone to create custom artwork for their own story creations or sharing.
- Some individuals diagnosed with ASD have strong interest and abilities in the creation of artwork.

**NFC Interactions** (pertains to making a physical object appear in the story as a digital representation. See Figure 4-6)
- Individuals who struggle to relate digital representations of objects to corresponding real-world examples.
- Motivate engagement through “magical” interactions.

**IOIO Interactions** (pertains to connecting digital assets to hardware and sensors)
- Highlight contingencies between digital actions and real-world responses.
- Motivate engagement through “magical” interactions.

### 3.0.5 StoryScape Platform Overview

*StoryScape* is comprised of five main systems. The first is a set of web-based authoring tools for creating interactive art sets and authoring stories. The second is the media library that contains all art for use in story creation. The third is a mobile story reader, *StoryScape* Reader, an application built for Android powered devices. The forth is a set of NFC tagged objects. The fifth is a Bluetooth enabled hardware and sensor network using the IOIO
Figure 3-1: Adding an NFC character to a story. In the left image the duck plush toy has an NFC chip inserted in it; notice that there is no duck in the digital scene of the mobile reader. In the right image the duck has been brought into contact with the mobile reader which triggers the appearance of the digital duck in the scene on the mobile reader.

electronics board. The entire system is integrated around the authoring tools and StoryScape Reader. Published stories are available online or via download to the StoryScape Reader. Only stories on the StoryScape Reader can take full advantage of the many interactive and remix features. Stories can leverage the StoryScape Reader’s sensor platform and connectivity to create unique interactions with the story. The platform connects web, mobile, and physical technologies around the story process.

Story construction can include creating original artwork, choosing artwork for use in a story, the choosing of individual scene backdrops, the choosing and layout of actors within a scene, the construction of the story dialog, the actual typing of words and sentences, and the integration of physical assets. The full process of creating a story includes the construction of visual grammar, textual grammar, and story grammar.

3.1 StoryScape Description

Each of the following five sections cover a core feature of the platform along with motivation from personal experience and/or from the literature that supports the feature’s inclusion.
3.1.1 Story Reader

Perhaps the most straightforward and accessible way of using StoryScape is by consuming stories created by other people. Stories can be read from any of three formats: mobile app, web, or on paper.

3.1.1.1 Mobile Reader

The mobile reader is an Android application intended for Android 4.0 and higher devices (see Figure 3-2). The mobile reader allows for public stories to be downloaded and read on the device. Furthermore, it is only on the mobile reader that all of the interactivity and physical interface features are possible. On the mobile reader stories have the capacity to respond to the following user inputs: touch, sound, shaking, location, Near Field Communication (NFC), and IOIO events (hardware input and output events). These input triggers were chosen to provide the story creator and story reader with unique forms of interaction. The advanced interactions add a new dimension to the story experience.

Figure 3-2: Screen capture of StoryScape Reader, an Android application intended for tablet computers.

Any publicly published story can be downloaded to the mobile reader. In addition, any story created by users is automatically synced to the mobile reader. Once a story is downloaded to the device it can be opened and interacted with.

Motivation for the mobile reader was driven by the adoption of tablet computers by the autism community. In addition, the personal nature of tablet computers allow for the collection of usage data over time and location that could be of value in understanding learning
behaviors. Furthermore, the mobile reader’s rich sensor platform and network connectivity allows for the development of unique story interactions. Allowing for multiple modalities of interaction motivated the creation of different interaction triggers. In particular, we were motivated to encourage vocalization in those individuals that seldom use their voice, or who struggle with speech.

3.1.1.2 Web Reader

A web-based reader (web-reader) allows any published story to be read through use of a common web-browser (see Figure 3-3). The web-reader allows users to read the story at its default size or in full screen mode. Each page of a story has navigation to move forward or backward in the story. In addition, actors that are animated will play their animation and respond to click events. The web-reader has limitations that do not allow actors with other animation triggers, such as shake or sound, to trigger animations. The web reader provides trigger simulation buttons for triggers that are only possible on the mobile reader. Unlike the mobile reader it is also not possible to remix the web-based story. In addition, physical asset interaction with NFC and IOIO is not possible through the web-reader.

Figure 3-3: StoryScape web-based reader.
3.1.1.3 Paper Reader

In addition to the digital interactive story formats, it is possible to read stories in a paper version. The web-reader interface contains two format links for each active story that allow for the story to be downloaded as a PDF for printing from a standard printer. The first format presents each page as a single 8.5" by 11" scene on a sheet of paper. The second format is called “Oksbo,” which is a format that arranges 8 scenes onto a single 8.5" by 11" sheet of paper in a specific pattern to allow for the paper to be folded and cut into an 8 page flip book (see Figures 3-5, 3-4).

![Figure 3-4: StoryScape printable story format Oksbo. Allows for 8 pages of story to be printed on one page and then folded and cut to create a flip book. Works best with stories that are multiples of 8.](image-url)
Figure 3-5: Instructions provided with printable Oksbo for how to fold and cut paper to create an 8 page flip book.

3.1.2 Story Remixer

Each story, whether created by the user or someone else, can be remixed on the mobile reader. Remixing can entail shifting, resizing, or rotating visual elements of a scene. In addition, sound effects and narration can be added to story elements. Finally, new images can be inserted into the story using the device camera or from local storage (see Figure 3-6).

These remixing features include allowing the user to play with the story, i.e., the story is not fixed and can be changed. In addition, it may serve as scaffolding to allow children to explore their imagination and help progress in creating their own stories. The sound and image modification features also allows for stories to be hyper-personalized. If we consider a parent and child, a parent may want to put a motivating or meaningful piece of media into a story to engage the child. For some children this hyper-personalization might motivate usage and therefore engagement with story and language.
Both the heterogeneity of ASD and the restricted interest of many individuals diagnosed with ASD motivated the remix and personalization features. Unlike neurotypical learning materials, there is a need for very specific and sometimes unique learning materials for each child diagnosed with ASD. StoryScape tries to support this need by allowing personalized remixing of media. In addition, because many individuals diagnosed with ASD are motivated by their personal restricted interest, sometimes referred to as their affinity, we wanted to allow for the easy inclusion of personally motivating visual elements. Furthermore, remix features lower the barrier of creating media.

### 3.1.3 Story Author

The StoryScape web-based story authoring tool can be used by anyone to create their own interactive, animated story. Story authoring involves first selecting an art set to use for the story (see Figure 3-7). Once an art set has been selected, the user can use drag-and-drop tools to construct different scenes of the story. Actors and backdrops can be combined in any order the user wants. Each scene comprises a background and 0 to N actors. Actors
can be placed and resized as the user wants to construct the visual elements of the scene. Actors can also be animated. Finally, text can be added to the scene to further develop the written story.

Figure 3-7: StoryScape web-based story authoring tool.

A key aspect of story authoring is the use of an art set. This art set may or may not have been created by the story author. Art sets have pre-created animations and interaction triggers associated with them. During story authoring, the author can test the animations and interactions through the authoring tool.

The story author can choose to create a linear story, or can create non-linear stories. Stories ultimately can be published for public view or privately. Public stories can be viewed via the fully functional mobile reader, a reduced functionality web-reader, or in PDF formats.

The authoring tools were motivated by several factors. Many teachers working with students diagnosed with ASD spend significant time creating learning materials for their students. These materials tend to be static and paper based. A goal of StoryScape was to support creating these materials in a digital, shareable, remixable format to reduce future media
creation and increase overall use. Another major factor in creating the story authoring tool was to engage children diagnosed with ASD in the story creation process. Very little current technology for the ASD community engages the users as creators, thus we were motivated to adapt StoryScape to be similar to a systems like Scratch to engage the users as creators.

3.1.4 Artwork Author

The artwork creator, or artist, is the power-user of the StoryScape platform. The artist has the ability to create illustrations, animations, and assign interaction triggers when creating such assets. Illustrations and animations would be created with tools other than StoryScape. This media may be digital art or traditional art, in either case a digital representation would be created at some stage to be uploaded to the StoryScape artist tools.

The artist tools allow for the creation of art sets, backdrops and actors. The artist can upload backdrop images and actor images to StoryScape. Backdrops are single non-animated bitmaps. Actors can be a single non-animated bitmap or multiple bitmaps that form an animation (see Figure 3-8).

When constructing the actors, the artist can assign different actor animations to different input triggers; this includes the ability to assign IOIO (physical hardware) output signals and input signals. This later part allows for any digital actor to be connected to any sensors or hardware via a IOIO board. Furthermore, once actors have been defined the artist tools allow for the actor to be published to NFC. Further discussion of physical assets, NFC, and the IOIO follows this section.

There are multiple motivations for the author tools. Motivations include the ability to allow anyone to contribute art that others can use to create stories. The ability to create animated objects that can be used to show actions. The animations may be beneficial for both general engagement and for teaching concepts that include action. The need for many types of art and symbols to allow for extensive use of the platform by others requires tools to allow for the upload, creation, and sharing of art assets.
3.1.5 Physical Assets Author

Physical assets can take many forms, but ultimately either NFC or the IOIO board connects them to StoryScape and the story. With respect to NFC, the artist tools allow the artist to publish an actor to NFC. This creates a unique identification that can be assigned to any NFC tag to associate the corresponding digital asset to the physical NFC tag. Once this has been done the NFC tag can be associated with almost any physical item (see Figure 3-9). Once a tag has been encoded with an actor id, any mobile device with an NFC reader can read the actor id from the NFC tag. When this happens the digital assets are retrieved and displayed in the current story scene (see Figure 4-6). In addition, entire stories can be associated with a NFC tag to allow an entire story to be connected to a physical object.

The artist tools allow for each actor to accept input signals from the IOIO board, or to send output signals to the IOIO board (see Figures 3-8, 3-11). With respect to input signals, this allows sensors or other hardware to be created to capture user input or other environmental signals that can then make a story actor react. For example, a force sensor that is bent
might send a signal to the IOIO board that is then sent to the MSR where a specific actor responds with a funny bend animation.

Likewise, output signals can be sent from an actor to the IOIO board. In this case, when an actor is touched one of several digital signals may be sent to the IOIO board. Sensors or other hardware would then respond to the digital control signal. For example, a relay switch that controls a light can be connected to the IOIO board and respond to an actor being tapped by turning a real light on or off.

These features were motivated by anecdotal evidence suggesting that many individuals diagnosed with ASD struggle generalizing between digital and physical media. These features allow for the blending of digital and physical interaction. In addition, these features were seen to add novel interaction and support interest and engagement with the platform.

![Physical Asset + NFC Tag + Digital Asset](image)

Figure 3-9: Creating a StoryScape NFC asset involves a physical representation (left), a NFC tag (center), and a digital representation (right).

### 3.1.6 StoryScape Motivation Conclusion

In conclusion, the driving motivation behind the design of the StoryScape platform has been the desire to support learning needs around communication for individuals diagnosed with ASD. Through extensive work at a school for children diagnosed with ASD during
Figure 3-10: Since the NFC digital asset resides within the StoryScape Android reader application it can appear within any story when the corresponding NFC tag is brought into contact with the NFC reader of the Android device. NFC character (left) is brought into contact with the tablet (right) making the digital character appear in the story (right).

Figure 3-11: IOIO electronics prototyping board and relay circuit that can be controlled by a story asset.
my Masters thesis [23], in addition to further interaction with parents, family members, teachers, therapists, academic researchers, and individuals diagnosed with ASD, it became clear that it was necessary to develop systems capable of supporting a community of users. This community of users, even if only those diagnosed with ASD, is diverse and has different needs and interests. For some they will only need, or want, to read stories made with StoryScape. Others will want to remix (change) stories to fit their needs, while others will wish to create their own stories. Still others may wish to create artwork for use by others, while some may find the physical assets of interest.
Chapter 4

Research Explorations

*StoryScape* was designed, developed, and tested with participation from the autism community using the principles of constructionism and participatory cultures. Over the course of developing *StoryScape*, we have carried out a number of research explorations to understand the users, use cases, and design issues of the *StoryScape* platform. These explorations have been conducted across a variety of users, use cases, and settings.

These research explorations include work with children diagnosed with ASD and without, in addition to work with teachers and other adults. We have explored a number of use cases, including story creation, art and animation creation, immersive story creation, story reading, learning materials creation, and story co-creation. This work has been carried out in private schools, public schools, and personal settings.

For the purposes of reporting, we have split the research explorations into two primary categories: advance learners and complex learners. The advance learners category is so named because all work in this category has been conducted with neurotypical students in advance placement classes in primary school or with individuals attending college. The complex learners category is so named because all work has been conducted with students or teachers at special education classrooms, primarily serving students diagnosed with ASD. We first present research explorations with advance learners followed by complex learners.
4.1 Advance Learners

4.1.1 Study 1: Visual Narrative vs. Text-Only Story Creation

At its core, StoryScape is a platform for creating immersive, interactive, visual narratives. Visual narratives are created in a story format, primarily through the use of illustrations and text. It is common, especially with children’s books, for a visual artist to create the illustrations of visual narratives while a writer constructs the text of the story. StoryScape enables anyone to create interactive visual narratives, which mix static illustrations, animated objects, and text. In addition to providing the tools to create visual narratives, StoryScape also provides a library of artwork that story creators can use to create their own unique stories. The format and process of creating stories with StoryScape is very different than traditional text-only stories.

To better understand how creating a story with StoryScape differs from a traditional, text-only story we carried out a user study with eight college-age participants. The participants each wrote two short stories, a StoryScape story and a text-only story. The story format was randomly selected, so that it was not the case that users always started by writing a text-only story first. To facilitate the activity, a writing prompt was given for each story, and all participants used the same prompts. For half of the participants, the prompt for the StoryScape story was “write a story about a sister and brother visiting their aunt and uncle,” while for the text-only case the prompt was “write a story about a lost troll.” For the second half of participants the prompts and formats were switched. Each story prompt had a corresponding art set (see Figure 4-1 and 4-2).

Participants were given 10 minutes for each story creation method. After both stories had been completed, users completed a questionnaire with 3 Likert scale questions pertaining to the difficulty of writing the story, the fun of writing the story, and how much they liked their story (see Figure 4-3). In addition to the questionnaire, we conducted semi-structured interviews with participants for further qualitative analysis.

For each question, a t-test analysis was conducted to compare the text-only story results to
Figure 4-1: A preview of backgrounds and actors from the “Meandering Dreams of Home” art set provided on StoryScape for use in creating stories. The art was originally created by ink painting, from which photographs were taken and digital images derived. Simple animations were created for actors and constructed using the StoryScape art set authoring tools.
Figure 4-2: A preview of backgrounds and actors from the “Looney Toons” art set provided on *StoryScape* for use in creating stories. The art was originally created using digital image creation software. Simple animations were created for actors and constructed using the *StoryScape* art set authoring tools.
How easy was writing this story

<table>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>super hard</th>
</tr>
</thead>
</table>

How fun was writing this story

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<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Lots of fun</th>
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</table>

How much do you like the final story

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<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>The best story I ever read</th>
</tr>
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</table>

Figure 4-3: Questionnaire using 7 point Likert scale questions to measure users responses for “difficulty of writing,” “fun of writing,” and “liking of story” for comparison of text-only story creation and StoryScape story creation.

those of StoryScape. When considering the ease of writing we found a statistically significant difference between the formats. StoryScape was considered easer, \( p < 0.05 \), with a mean response \( m = 3.00, std = 0.84 \) vs. text-only \( m = 4.67, std = 0.51 \) (see Table 4.1).

When considering the fun of writing the story, we found a statistically significant difference between the two activities. StoryScape was considered more fun, \( p < 0.05 \), with a mean of \( m = 5.50, std = 1.05 \) vs. text-only \( m = 4.00, std = 0.89 \). Consideration of liking of story revealed no statistically significant difference between StoryScape and the text-based stories (see Table 4.1).

In addition to the questionnaire, semi-structured interviews were conducted with participants after both stories were completed. The following presents the qualitative results.

There was only one participant that considered themselves a writer, while most made statements similar to “I don’t write.” While the art sets imposed constraints on what kind of story could be constructed it also made creating the story easier. The art was easier to work with. A participant stated that the Looney Tales art was “fun and whimsical, it let me go into a child way of playing and thinking, I did not do that with the text document.” It was also the case that participants felt that starting from blank with the text-only condition
Table 4.1: Participant Likert responses for text-only and StoryScape story creation activities. Responses for each activity are for difficulty of writing (DOW), fun of writing (FOW), and liking of story (LOS), i.e. do they like their own story. A high value indicates story was difficult to write for DOW, that story was fun to write for FOW, and that the writer liked their story for LOS.

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<td>FOW</td>
<td>LOS</td>
<td>DOW</td>
<td>FOW</td>
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</tr>
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<td>$std = 1.47$</td>
<td></td>
</tr>
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</table>

was hard, it was “nice to have the pictures to get the story going.” As one participant put it, “with blank page I kept writing randomly, I had no plot. With StoryScape I was able to look at all the pictures and pick characters I wanted to use. I then could base my story on those characters.” Another participant captured the quality of StoryScape that may have helped most when he stated, “I liked the pictures, I was able to write with the pictures then put down the words and vice versa.”

One participant was very insightful and related that much of a story is actually descriptions of people, places, and things. StoryScape and the images made it easy to describe the people, places, and things. It reduced a lot of the creative effort and made a lot of the writing easy.

It was also noted that there were limits to StoryScape. The textbox and layout imposes constraints that some did not like. One participant felt it was easier to express emotions and details of the story with words and that the images often did not allow for this expression. Interestingly, even though people reported that StoryScape was easier and more fun to use there was not a strong liking of either story. It may be the case that participants did not consider themselves storytellers and as two people stated were self-conscious about their writing. Another participant commented that while he felt both of his stories were not
that good the *StoryScape* story looked nice. This “nice looking” story may be a factor of motivation for some. Participants felt they would need motivation to use it again, the ability to collaborate with friends, or to get ratings or badges. One participant commented, “I would write again if people read my story and left comments or suggested how to improve it.” Overall participants felt it was easier to write a story with *StoryScape*, they also all made reference to the challenge of coming up with a story.

We present a comparison of one participant’s stories as an example of the difference between the formats. Note that neither story was completed. First, we present the text only story for the prompt “write a story about a sister and brother visiting their aunt and uncle” as written by the participant:

```
Jack and Jill where a common brother and sister, except they weren’t that common. And when they would visit their aunt and uncle, it was just a normal visit, except it wasn’t. Their aunt and uncle, not a normal aunt and uncle lived, far away in the middle of a desert and spending time with them was never boring. There was the one time when uncle P had taken all the dogs from around his house and tried to organize a canine barking orchestra. It never worked, the dogs didn’t really like the music and started to chase their tails or the tails of other dogs but it sure was a fun time. There was also that other time when aunt R wanted to bake the largest pizza ever baked and since they lived in the desert they would just use the hot desert sun to bake it. But since a proper giant pizza needs giant tomatoes and giant cheese and giant sausage, the idea didn’t go far. But it sure was fun.

This time, Jack and Jill where going to visit after many months of not hearing from their aunt and uncle so they were very excited. What would they be up to these days? Maybe they are building a hot air balloon, said Jill. No maybe they are digging a hole to China said Jack. In any case, it would be fun.

When they got there, aunt R and uncle P were nowhere to be found. They looked in all the rooms, the attic, the basement, even the looked through the
```
windows of the little house in the yard. Where could they be? Jack and Jill
were sitting on the steps wondering where their aunt and uncle might be when
suddenly they felt a huge breeze that turned into a strong wind and a big roaring
sound. But they could hear it but they could not see anything, anywhere.

The same participant’s StoryScape story from the prompt “write a story about a lost troll”
is seen in figure 4-4. While there are significant differences between the story formats one
can see how the images and format of StoryScape may have helped with his story. No formal
analysis was conducted to compare the content of the stories. The text-only story uses 321
words vs. 116. While there are limitations with StoryScape it proved easy and fun for even
resistant non-writers to use.

4.1.2 Study 2: The Artwork of Stories

Traditional visual narratives, and even most digital visual narratives, are created from a set
of illustrations. These illustrations, or pages, are typically a single composite illustration
comprising a location, characters, and objects, and cannot be altered. StoryScape takes a
different approach to visual narratives. It works with modular art assets that can easily
be recombined to create unique scenes. In addition, the art assets can be animated and
interactive. These features of StoryScape require artwork to be considered and created in
a different manner than traditional visual narratives. To better understand the production
of artwork and the learning opportunities associated with it, we worked with a local school
in the production of “picture books.”

Shady Hill School is an independent day school for neurotypical children from pre-kindergarten
through 8th grade. Each spring the students in the 6th grade classes take part in a special
project to create their own picture books. Picture books are visual narratives that combine
artwork and text to tell a story. Typically, the children work to create a paper bound book.
As an exploration of artwork production and learning opportunities associated with it we
worked with a single class of 6th graders who used StoryScape for their picture book project.
Figure 4-4: Six scenes from a participants story about a lost troll, created with StoryScape.
The participating class had 16 students between 11-13 years of age, a primary class teacher, and a supporting technology teacher. Over the course of 6 weeks we held 1 class per week working with the students to create their picture book. I was present during sessions for support and for taking observational notes. Each session was 50 minutes long. In addition to the class time, students also worked on their picture book project outside of class. As the picture book project was an established part of the curriculum, integrating StoryScape into the process was relatively easy.

Artwork can be produced in any desired way for StoryScape given that a digital representation can be obtained. The only requirement is that backgrounds be JPEG or PNG images and that actors be PNG images. For example, a student can use a camera to take pictures of the school, which can be used as stages. A student can paint a watercolor image of a dog and then take a picture of the painting to now have a digital picture of the dog watercolor painting. Digital illustration tools such as Photoshop, Illustrator, Gimp, and InkScape can also be used. Students were familiar with the tools and processes to create such artwork.

While the actual use of StoryScape was found to be easy and intuitive for the class, challenges related to the concepts of art creation were significant. Students were not accustomed to considering art creation with animation, interaction, and remixing features. It made clear the need for detailed descriptions of how art works within the StoryScape platform, and proved the need for artwork creation curriculum for StoryScape. As a result of this exploration, we identified the following important pieces of information students need to know to create StoryScape artwork:

- **Story**: A story is composed of one or more scenes.
- **Scene**: A scene, or page, is composed of a single stage image and zero or more actor images.
- **Stages**: A stage, or background, is a static illustration. Stages should have open areas for placement of actors. A stage should never have foreground objects that limit placement of an actor. Such foreground objects should be considered for creation as an actor.
- **Actors**: Actors can be characters or props. An example of a character is a child or a
bird, while a prop may be a car or fork. Actors can be animated. Whether animated or not, the actor should have a transparent background and be cropped as closely to the visible pixels as possible.

- Animations: Animations are frame-by-frame and can be triggered by time or user interaction. In general subtle animations work better. An actor can have different animations associated with different interaction triggers. For example, an actor may have a jumping animation that is triggered by sound and it may have a falling down animation that is triggered by shaking.

- Interactions: Interactions include touch, multi-touches, shaking, and sound triggers.

- Remixable: All artwork can be remixed, hence more detailed artwork may prove limiting for remix purposes. Consider an actor that is a woman pushing a baby stroller. If this is created as one single image it would have limited use. Instead consider an actor that is a woman with her arms slightly raised and a separate actor that is a baby stroller. Combined you have a woman pushing a stroller, but combine the woman with a chair and now she is standing with her hands on the back of the chair. Generally, you will want your actor to be the minimum required complexity. Again, rather than a bowl of fruit, you would have a bowl and several individual fruits; these actors would be more useful.

While StoryScape does not provide tools for the actual creation of artwork, it does provide tools for the construction of the animations and association of interactions with animations. These tools were found intuitive to use and students required little instruction or help with them. During the process of creating a story art set, students would upload their stages and actors to the StoryScape platform using the artist tools. Once art sets were uploaded, students created their intended stories. In addition to the interactive digital stories that they created from their original artwork, they were able to print out each story and create the paper bound book as they normally would. Moreover, they now had an interactive digital story. In addition, they had created art sets that they or others could use again to make other stories.
4.1.3 Study 3: Immersive Story Craft

In addition to the animated and interactive features of the StoryScape platform, it is possible to create immersive stories. Immersive stories connect the digital story world to physical objects and environments. As described in the design chapter (see Chapter 3), the StoryScape platform integrates NFC and the IOIO electronics platform to allow for interaction with physical objects. To better understand challenges and opportunities associated with creating immersive stories we worked with a local school to build immersive stories.

NuVu Studio is an innovation school for neurotypical middle and high school students that focuses on art, design, and hands-on engineering skills. The NuVu Studio serves approximately 30 students per semester from local schools. All students, prior to entering or while at NuVu, have had experience with computer programming, electronics, digital fabrication tools, digital art tools, and traditional craft.

Working with school administration and staff we developed a week-long immersive story class. In total 12 students aged 11 to 17 years participated. The class was conducted as a normal studio class at NuVu with full instruction from 9am to 3pm daily. I conducted the class with two assistant teachers, provided by NuVu for support with instruction. Observational notes were collected over the course of the class related to the use of StoryScape and the process of creating immersive stories.

The goal of the immersive story class was to have students create original stories that incorporated multiple modalities of interaction across digital and physical assets. Students worked in groups of 2 to 3 persons. First, the students created storyboards to develop their stories and interactive elements. Subsequently the storyboards provided a blueprint for the development of the story, art, and interactive assets.

After developing their story ideas, groups started creating their artwork. Students used Adobe Photoshop, Adobe Illustrator, Gimp, and Autocad 3ds Max to create original artwork. Groups approached the creation of artwork in several ways. In some cases a single person produced all the artwork, as they preferred this activity or were the best "artist."
In other groups, each member created the artwork for different scenes. In another group, one student worked on stages while the other students worked on animated characters and props.

In addition to the digital artwork, students had to incorporate physical objects into their stories. The physical objects could incorporate NFC technology or the IOIO electronics platform. Incorporation of NFC characters involves first creating an actor. Once this is done, a unique identifier (UID) is created to connect the actor to any NFC tag. The UID can be written to an NFC tag. Next the corresponding NFC tag can be attached to any physical item. In this way, an animated actor of a pixie can be associated with a particular NFC tag. If the NFC tag is inserted into a “magic wand,” and that magic wand touches the StoryScape Android reader, the flying pixie will “magically” appear into the story.

Incorporation of the IOIO electronics platform allows for the building of hardware and sensors that can respond to the story. This is achieved by associating a digital input or output signal with an actor. For example, an actor which is a digital image of the sun may have a digital output signal associated with it. In this case, when the digital sun is touched a signal is sent to the IOIO board which controls a relay circuit that activates a physical light in the reader’s room.

The following section describe stories created by students.

4.1.3.1 Paris Adventure

A group of three students worked together to create a story called “Paris Adventure.” The story, about three dogs that travel to Paris, took advantage of the NFC features of the StoryScape platform for story augmentation and for story control. Using the StoryScape authoring tool and the NFC writer, the students created a number of digital assets that were connected to specific NFC tags that were embedded in plush dog dolls. In addition, tags were programmed with story controls, so that when certain tags were encountered on physical objects, like a model of the Eiffel Tower, the StoryScape mobile-reader would
load that part of the story. When a plush dog doll was brought in close proximity of the StoryScape mobile reader, the digital representation of the dog would appear in the story.

The students used a number of tools in addition to the StoryScape platform for creating their story. For artwork they used Adobe Photoshop and Adobe Illustrator. For physical story extension they sewed stuffed plush dog dolls and embedded NFC tags into the dolls. In addition, they used a laser cutter to create a model of the Eiffel Tower as an exterior story navigation control.

4.1.3.2 Batman Saves the Day

A group of two students worked together to create a story called “Batman Saves the Day.” The story is about the Joker character creating chaos in Gotham and Batman coming to save the day. In this story, the students explored the idea of story-pop-outs. To do this the students used Autocad 3ds Max to create 3D renderings of the story artwork. This resulted in every object of the story having a 3D representation that could be packaged with the story. In addition, the students used the NFC features of the StoryScape platform to create a dynamic fight sequence where the story reader would touch physical action bubbles representing “bam,” “smack,” and “pow,” the classic Batman comic book action bubbles. When this was done the fight sequence unfolded in the digital reader. In addition, they 3D printed the Batman character from their story and outfitted it with an NFC tag that was used to bring the physical Batman character into the digital story.

Because the students used Autocad 3ds Max, they were able to print their Batman character using the Makerbot 3D printer. They intended him to serve as an action figure that had an NFC tag associated with it that allowed a user to “transport” Batman into the story from the physical world.

4.1.3.3 Luckiest Day

A group of two students worked together to create a story called “Luckiest Day.” This story was a choose-your-own-adventure type of story. Each choice path had different outcomes
and interactions associated with it.

One choice path leads to the reader having robbed a bank and being chased by police. In this case, there is also a small Matchbox toy police car that if touched triggers a real strobe light. To create this effect, the students created a capacitive sensor that was connected to the IOIO board; in addition, a relay switch was implemented to control a standard 115v wall outlet (see Figure 3-11). This combination was used to detect a capacitance change when the car is physically touched, which then triggers the relay circuit turning on the strobe light. While the students had to create the sensors, the StoryScape authoring tool allowed them to connect the physical to the digital through a simple drop down menu selection which programs the story actor to send an output signal to the corresponding IOIO digital output pin.

In another choice path, the user gets to make a wish from a Genie. To do this, the user has to touch a Genie lamp on the mobile-reader screen. When this is done a confetti canon shots off, streaming confetti all over the room.

Again, the students took advantage of the relay switch and wall outlet to control the canon. Using the authoring tool, they were able to easily connect the touch event to control the relay circuit to power the canon.

The students used a number of tools in addition to the StoryScape platform for creating their story. For artwork, Adobe Photoshop and Adobe Illustrator were used. The students also built several sensor and circuits for use with the IOIO board to get input from the physical world and control physical objects.

4.1.3.4 Observations

Similar to students at Shady Hill, NuVu Studio students found the creation of artwork time consuming and required assistance in planning out how to make art to best fit their needs. Likewise, the actual time using StoryScape was minimal in comparison to the time using other tools for the production of artwork and physical assets. The activity of creating an
immersive story was seen as a strong motivator for integrating work across different domains, i.e., combining art, animation, physical props, and hardware. As a result, students worked with multiple digital tools including Adobe Photoshop, Adobe Illustrator, and Autocad 2ds Max. They also used other tools for creation of physical assets including laser cutters, 3D printers, and electronics prototyping tools. In the process of using these tools students often sought assistance from the teaching team. Such assistance created learning opportunities where the teacher would teach the student how to achieve their goal. Overall there were few problems with the StoryScape platform and students reported finding the project rewarding.

This exploration further highlights the opportunities to use StoryScape and immersive story creation as a motivator for learning. The process of creating immersive stories required students to use multiple sophisticated tools. While the class went well, it should be noted that there were three teachers, all with extensive experience in such sophisticated tools, teaching the class. In addition, the students had much more experience with such tools than most people do. It is unlikely that a typical class could create similar stories in such a short time, highlighting the need for well thought out curriculum to make such learning experiences more accessible to others.

4.2 Complex Learners

Children diagnosed with ASD present complex learning challenges. In addition to communication impairments, they often have idiosyncratic interest and behaviors which make generalized teaching materials and whole class engagement difficult. The StoryScape platform was developed with these complex needs in mind, and can be used in many different ways to accommodate the needs of different individuals and groups of learners. The following research explorations first consider the use of StoryScape for creating individualized learning materials (ILM); we then explore the use of StoryScape for teaching nouns and verbs; lastly we explore using StoryScape during story co-creation with whole classes of students.
4.2.1 Study 1: Individualized Educational Materials

Most students diagnosed with ASD have an Individual Education Plan (IEP). An IEP is a legal document created by school officials with input from a particular student's school support staff, i.e. teachers, therapists, etc. The IEP outlines learning needs and goals for the year and is used as a tool to help guide and measure progress for a student. As a result, students of similar age, or who are in the same class, may have very different learning objectives. The IEP creates a need for individual learning materials (ILM) to address the media needs of each child.

Typically, teachers and therapists who work with students that have an IEP will make custom learning materials for each student. Overwhelmingly, the materials they make are paper based, not reusable, and time consuming to craft. We were interested in how StoryScape might support teacher needs for creating ILM for students diagnosed with ASD. A study was conducted at the KiDA private school for children diagnosed with ASD to determine the use of StoryScape for the creation of ILM. Two teachers and four students participated in the study. Student participants were aged 6-9 years, were minimally verbal or non-verbal, and had limited reading ability.

Working with the teachers, we first identified learning goals to target. The following list describes learning goals and teaching approach:

- Body part labeling: from a set of images of body parts, children would be asked to select the image of an ear, etc.
- Name identification: from a field of three names, students were asked to identify their own name.
- Preposition practice: using toy figures, a teacher would ask a student “Is the dinosaur on top of the box or beside it?”
- Simple addition: using felt animals and numbers, teachers would construct an equation that would equal the number of a particular animal present. For example, the teacher would create the equation $1 + 2 = 3$ and there would be 2 felt ducks and 3 felt lions also present. The teacher would state, “1 plus 2 equals 3, are there 3 ducks or are
there 3 lions?"

- Matching: using two images a teacher would ask a student "Which one is a ball?" and the student would select an image. Images used were of common daily objects such as balls, blocks, eye glasses, milk containers, etc.

Teachers already had physical materials that they used with students to target the above learning activities. Using these physical materials, we created corresponding digital representations that could be used in the StoryScape platform to test ILMs creation. Teachers, with minimal assistance from myself, were able to create simple interactive media using StoryScape that also mimicked the teaching approach used with the physical materials (see Figure 4-5). The ILM created were not in a story format, but instead resembled simple interactive apps. The teachers would actually refer to the materials as apps, rather than stories.

Over the course of six contiguous school days, teachers used the ILM with the students at KiDA. In addition, students were allowed to take the StoryScape Android Reader home. Parents were taught how to use StoryScape at home with the children. Each student had a specific device and usage data was collected. Usage data included what materials were actively being used, length of time used, what images were touched, if there were sound events triggered (i.e., did a noise trigger an animation). This data allows us to determine if a particular goal was achieved. For instance, the page may ask a child to select their name
from a field of five names, the data would allow us to determine what name was selected, if
other names were selected first, how long it took, etc.

It quickly became evident that data collection would not reveal any user specific behavior
because of the level of help and prompting required by students to complete a task. While
children appeared to like using the interactive media, they were unable to use it in an
independent and meaningful way during the short study. Despite this, there were a number
of positive outcomes reported by teachers and parents.

Teachers found the ability to create interactive media that mimicked their typical learning
tasks and materials useful. Teachers found the sound triggered animations to have potential
value with students that needed motivation for vocalization. The fact that StoryScape made
it very easy to create interactive media that is able to react to sound was seen as a potentially
useful feature for these children and others.

Despite StoryScape’s own media library, from which materials could be used, teachers did
not feel there were the “right” types of images available for their needs. While teachers
found creating “stories” from pre-existing images on StoryScape easy, they felt creating
their own images was time consuming.

Three of the parents commented that they liked being able to do homework with their
children. Interviews with the teachers revealed that the children did not take work home,
so parents did not typically see what media a student used in class. In addition, parents
commented that they liked that they could potentially create “apps,” specifically for their
children. While the interactive media crated by teachers during this study was not an
actual “app” it did resembled many of the simple education apps these children had on
their personal tablets.

While the study revealed benefits in using StoryScape for the creation of ILM, it also revealed
that using StoryScape for story specific purposes with young children with minimal verbal
and written language abilities might not be appropriate. Furthermore, data collection
methods were not sufficient to discern when the student was interacting with the device vs.
a teacher or parent. While staff reported using StoryScape to be easy, the media library did
not contain the domain specific images required by staff for creating ILM beyond the study. Furthermore, the time investment of creating their own media from preexisting physical media was seen as an extra challenge in an already busy schedule.

An unexpected positive outcome was that teachers and parents were able to share the same media in and out of school using the StoryScape mobile-reader. Both parents and teachers found this beneficial, as homework is not typically assigned and parents do not usually see the media used by students in class.

4.2.2 Study 2: Nouns and Verbs

A pilot study was conducted over a five contiguous days with two classes of children diagnosed with ASD at a public elementary school in the Frisco School district in Dallas, Texas, to determine the feasibility of teaching nouns and verbs via StoryScape. Two special education teachers along with 10 students aged 5-8 years participated in the study. Students participating in the study were minimally verbal to verbal. All students were below their age appropriate language levels. Reading ability ranged from simple sight words to full sentences. The aim of this study was to test the feasibility of using StoryScape to teach noun and verbs.

This study was motivated by interaction with the Special Education Director and two teachers at the participating school. Teachers reported that engaging students in learning was a challenge, and teaching verbs was particularly difficult. With respect to nouns, they felt the incorporation of physical assets via NFC would be exciting and, hopefully, engaging for children. With respect to verbs, the teachers said they typically used static images meant to convey the action of a verb. They reported that the children struggled to learn verbs with this approach. They felt that the ability to show actions through animation and create stories with the verb animations in them would help children with verb acquisition.

Prior to the start of the study, teachers were consulted to inform the creation of artwork to target verbs that children were currently learning. From consultation with the teachers, we constructed two animated art sets for use during the five day study. For nouns, a set of
farm animal plush toys were outfitted with NFC and corresponding digital representations were created. The farm animals were a cow, pig, duck, and chicken (See figure of duck and reader). Two new art sets were created for the verb content, the themes were “a day at the circus” and “witches cooking stew.” The following verbs were depicted in the art sets: pouring, mixing, washing, juggling, and pealing.

During the first day of the study, observation of classroom activities and interviews with teachers and support staff were conducted to better understand how the teachers and students used stories and other media. Teachers and support staff reported that they currently used Microsoft Word or Boardmaker for creating stories or other media for teaching nouns and verbs. Teachers and support staff were asked to use the StoryScape authoring tools to test usability and acquaint them with the authoring tools. Following the StoryScape usability test, both teachers independently reported that it was “so much easier than Boardmaker.” Teachers and staff found using StoryScape to be easy and were able to create a short story after little instruction. One teacher that initially said she could not create a story because she was not creative, later reported that she had created another story at home and stayed up until midnight writing her story. Over the next three days the same teacher wrote two more stories for use with her students.

4.2.2.1 Motivating Interaction through Physical Story Characters

Tests were conducted using the NFC farm animals with students to determine if children would be motivated by the interaction. Stories were created that purposely had missing elements that required interaction with the NFC character to “transport” the animal into the story. Four students took part in this activity. I demonstrated how to touch a NFC character to the StoryScape Android reader to make the character appear. During this initial demonstration each student showed extreme surprise and was very excited to do it himself or herself. Each student was able to use the NFC characters and make them appear in the digital story. For example a story might read “The duck stood by the tree,” but there was no duck image in the visual scene. To complete the scene the NFC character would have to be used to bring the digital duck into the scene (see Figure 4-6). I worked with
Figure 4-6: Adding an NFC character to a story. In the left image the duck plush toy has an NFC chip inserted in it; notice that there is no duck in the digital scene of the mobile reader. In the right image the duck has been brought into contact with the mobile reader which triggers the appearance of the digital duck in the scene on the mobile reader.

each child individually, reading the story and prompting the child to get the appropriate animal for the scene. Sessions lasted approximately 20 minutes.

The students were excited to participate and repeatedly tried putting other objects into the story. They appeared disappointed that not all objects could be used in a similar way to the NFC characters. While the students already knew the farm animal nouns, they were highly motivated to participate and always selected the intended target character. Teachers reported that the students were very engaged by the NFC characters, and felt they could be used to motivate learning nouns. Teachers reported that the students tried multiple times to touch objects to their personal tablets after NFC sessions to see if the physical object would appear in their tablet. In addition, over the remaining days, students asked several times to play with the NFC characters.

4.2.2.2 Teaching Verbs Through Animated Stories

These teachers typically teach verbs by sitting with children and showing them flash cards of a static image meant to convey the meaning of a particular verb. Depending on the verb, the teacher may also act it out. As another means of teaching, the verbs we determined to create stories containing animated versions of target verbs, picked by the teachers, within the story. The teacher would use the stories during verb teaching time and students would also be able to read the stories during free time.
Teachers made several short stories with *StoryScape* using the circus and witch art sets. The stories were written to highlight target verbs selected by the teachers, e.g., “The clown is juggling balls,” or “The vendor is pouring lemonade.” The art set characters that demonstrated the verbs automatically played the verb animation at a fixed time interval. The verb characters also responded to touch, which would start the verb animation. Teachers using the *StoryScape* Android reader would read a story to a child in a one-on-one situation. This was repeated several times with each student using multiple stories. During reading, the teacher would ask the child to touch the character performing the verb. If the child pointed to the wrong character the teacher would correct them.

In addition, teachers recorded their voice for the narration of the story and recorded verb descriptions of the characters. The result was that if the text of the page was touched, the teacher’s narration played, while if a verb character was touched a recording would play that labeled the verb. For example, suppose there was an animated witch stirring a pot of soup, the narration for this character might be, “The witch is stirring soup.” Once the audio narrations were added children were also allowed to play with the stories on their own during free time. Several students were observed over the course of the study playing with the stories and listening to the narration.

Overall, teachers felt that children responded well to the stories and the teachers liked how they could create stories that had target verbs in them. Furthermore, students enjoyed playing with the stories on their own, which increased their exposure to the target verbs. While we did not test for verb acquisition, informed observations indicate that adding verb animations to a *StoryScape* story can help increase exposure to target verbs. Students appeared to enjoy story reading more than flash card learning lessons.

### 4.2.2.3 Student Story Narration

During free play, a student was observed reading a story on *StoryScape* and recording his voice as narration for each page of the story. Interestingly, this particular student had significant speech and language impairments. Teachers reported that the student was not
a reader and had never been observed reading aloud to himself. Despite this, the child was obviously engrossed in his reading.

I video recorded the child interacting with StoryScape while also taking observational notes. The child would select the controls to record audio, start the audio recording, and proceed to use his finger to follow the words while “reading” the text. He would then end the recording and associate the recorded audio with the text of the story. Following the recording, he would select the text, which would play back his narration. While listening to his narration he would sit with an obvious smile on his face. This was repeated for 23 of 26 pages. During the “reading” of one page as his finger passed over the word “queen,” the student was clearly heard to say, “queen.” Needless to say, all present were very surprised. Teachers had never seen this behavior before from him prior to this instance.

While this was a single occurrence, it should be noted that the feature to record audio was designed into StoryScape to motivate children to use their own voice for narration and add silly sounds to the stories as they saw fit. With this feature the boy was able to enjoy recording his own narration and play it back to listen to his own voice, both of which surprised his teachers.

4.2.3 Study 3: Story Co-Creation

An exploratory study was conducted at the Lionheart private school in Atlanta, Georgia. Lionheart serves children diagnosed with ASD and other developmental challenges. While our initial intention was to determine the feasibility of StoryScape as a dyadic story creation activity between students and teachers, our study took an unforeseen and fortunate turn.

During the initial on-site consultation at Lionheart, it was discovered that StoryScape could be used as a whole class activity around story co-creation. Each class was equipped with a large interactive touchscreen display, which enables the use of the StoryScape authoring tool as a shared interface among all students. In addition, students were able to use individual iPads, if they needed, that mirrored the classroom display. The technology configuration allowed for the whole class to easily take part in story creation. This usage of StoryScape
aligns with goals of the school to facilitate and maintain whole class engagement in shared activities, while also emphasizing increased student communication, social collaboration, and creative expression.

During the initial on-site consultation, I demonstrated the use of StoryScape to each class. Over a 30-minute period, the author of this paper worked with the class to create a short story. During these demonstrations the teachers, teacher assistants, and students became acquainted with the functionality of StoryScape. This was the only training session provided. All subsequent StoryScape sessions were conducted over a thee week contiguous period by the teacher and teacher assistant as a regular classroom activity. All sessions were video recorded and follow-up interviews were conducted with the teachers and students at the end of three weeks.

Teachers and staff were consulted to determine whether the story co-creation activity should be a free-form creative writing exercise. As agreed, the teacher and assistant supported the students in the creation of “their” stories.

4.2.3.1 Participants

Two classes were chosen by school staff to take part in this exploratory study. The classes were comprised of 11 students in total. Each class was composed of a special education teacher, a teacher assistant, and students. Class 1, C1, had 6 children in total with 4 diagnosed with ASD and 2 others with cognitive delays, but no ASD. Class 2, C2, had 5 children diagnosed with ASD. Participating children ranged in age from 12 to 20 with a mean age of 14.09 years and standard deviation of 2.77 years. Teachers described all students as being below age-appropriate levels in language skills. While all students were verbal, 3 students spoke very little.

4.2.3.2 Procedure

StoryScape co-creation sessions were conducted as a class activity over a 3-week period. Sessions were conducted 2-3 times per week during their class technology time. C1 conducted 6
StoryScape sessions, while C2 conducted 3 sessions. During each session the StoryScape authoring tool was projected onto a 77” interactive touch display. An accompanying desktop computer, with keyboard and mouse, controlled the interactive display.

Story creation started with the students selecting an art set to use for story creation. When students did not unanimously select an art set the teacher would typically attempt to negotiate the differences among students. If a unanimous decision could not be reached the majority choice was used. Students typically sat in a semicircle around the display and took turns adding elements to the story. Additions may include choosing a new scene, adding actors or props to a scene or developing the dialogue of the scene. Teachers were left to their own discretion on how long each session should be. Teachers were asked to keep notes for each session indicating what about the activity worked or did not work, surprises they encountered, and whether they felt the students enjoyed the session.

The following example highlights class interactions while creating a story scene with StoryScape:

- Teacher prompts Anthony that it is his turn to select a new stage.
- Anthony stands up and walks to the interactive display. With his finger he selects the stage view window to see all backgrounds, from which he selects the circus tent stage.
- The teacher prompts Anthony to select an actor for the scene.
- Anthony selects a clown juggling balls
- While Anthony is placing the clown into the scene, other students are commenting on the scene and continuing to develop the story.
- The teacher asks, ”who wants to put another character into the story?” and two students raise their hands while saying, ”I do.” The teacher tells Sally she can put her character in first, then Chris can have a turn.
- Sally and Chris put their characters into the scene, while the teacher asks the students what they think the characters are doing.
- The students and teacher talk to each other and develop the dialogue of the scene.
- The teacher now asks Craig to type the sentences that the class has developed.
- The activity continues with a new student selecting a new stage.

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4.2.3.3 Lionheart Story Co-Creation Insights

At the end of the three week study, semi-structured interviews were conducted by me to determine the feasibility of a longer study using StoryScape as a whole class story co-creation activity. A summary of the interviews follows.

Teachers reported some minor challenges initially with the authoring tools because they were not well-acquainted with them. In this respect, they both stated that students learned how to use StoryScape faster than they did and would teach them how to use it during sessions. After the first week, teachers reported that the students would ask daily if they were going to use StoryScape. Teachers also reported that students were “more engaged,” which they described as spending more time on task and focused on the activity, requiring less support and prompting. Teachers also reported that they felt as though they were not “working as hard,” “things just seemed to go better.” Both teachers reported that students “really liked making stories,” and were surprised how creative students were. It was also reported that students spoke more, using words and concepts that surprised the teacher(s). Multiple times teachers referred to StoryScape as a “high affect” activity.

Questions presented to better understand how the StoryScape activity compared to other activities also revealed interesting details. Teachers reported that they typically have difficulty maintaining engagement of the whole class in an activity, and that whole class engagement is a goal for all classes. They reported that they usually start an activity as a whole class and will work to maintain class engagement until they are losing student focus or otherwise feel it is necessary to break the class into smaller groups. They report that it is very difficult to maintain whole class engagement for even 20 minutes. While whole class engagement is a goal, teachers often work in small groups or one-on-one with students to maintain their engagement. They reported that it was easy to maintain student interest during story co-creation with StoryScape and students were very engaged.

Review by me of the nine video recorded StoryScape sessions revealed that on average session length in minutes for C1 was $m = 30.03$, $std = 9.44$ For C2 the average session length in minutes was $m = 37.87$, $std = 8.11$. Interviews with teachers supported observations from
videos that children maintained engagement over the course of the *StoryScape* sessions. Teachers were very encouraged by the results of using *StoryScape* and story co-creation as a whole class activity. Both teachers reported that their classes would ask to use *StoryScape* daily and that the students were speaking more and exhibiting better behavior during *StoryScape* sessions. Overall results were very encouraging and warrant further exploration.
Chapter 5

Story Co-Creation Research Study

There was encouraging feedback from teachers and students during our exploratory study of using StoryScape as a whole class story co-creation activity (see Section 4.2.3). Teachers reported prolonged class engagement, class focus on activity, increased speaking, reduced teacher support, reduced teacher prompting, and that students “really liked making stories.”

From this initial exploration, we determined to more deeply study StoryScape and story co-creation as an activity to facilitate social engagement during a language based social and collaborative activity. This further study of StoryScape was also conducted with the Lionheart School (see Section 4.2.3).

5.1 Research Question

Does story co-creation using StoryScape result in increased whole class engagement?

It is worth considering why engagement is a worthy area of research with respect to StoryScape’s usage and the autism community. It is well accepted that engaging children diagnosed with ASD in educational settings is difficult, and that maintaining engagement in group activities is even more challenging. As a result, many children diagnosed with
ASD do not succeed in group activities and require extensive assistance in the form of one-on-one activities or personal class aids. Even with extra assistance, it remains difficult to engage students diagnosed with ASD in communication-oriented or social activities. These challenges are particularly concerning giving the strong empirical support for the connection between engagement, learning achievement, and school behavior across individuals diagnosed with ASD [53, 39]. There are meaningful benefits to engaging children in language-based social activities. Our challenge is engaging the most complex learners in such activities.

While there is a rich research body with respect to engagement in learning settings, there is not an agreed upon definition, measure, or method for studying engagement. Past works have at their root a common understanding that engagement reflects a person’s involvement in a task or activity across physical, cognitive, or emotional behaviors [53, 39, 16, 50, 61, 35].

Furthermore, while there has been an increased interest in technologies to facilitate social collaboration and engagement for children diagnosed with ASD, there is no standard approach or measures to research engagement in the autism technology literature [35, 51, 62, 29, 27, 26, 9].

In this study, I propose an approach and measures similar to those used by Hourcade et al. in their study of engagement of students diagnosed with ASD during story co-creation activities [35]. The measures employed by Hourcade et al. are similar to measures and methods used in the education and engagement literature [53, 39, 16, 50, 61].

5.2 Study

The following describes the study. First, I describe the participants. Second, I present the design of the study, followed by the procedures carried out during the study. I then present the quantitative measures, including definitions of measured features. Results are presented last, with quantitative and qualitative analysis, respectively.
Table 5.1: *Number of students and age with mean and standard deviation in years.*

<table>
<thead>
<tr>
<th>Class</th>
<th>Number Students</th>
<th>Mean Age (σ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>5</td>
<td>6.80 (0.84)</td>
</tr>
<tr>
<td>C2</td>
<td>5</td>
<td>9.40 (1.67)</td>
</tr>
<tr>
<td>C3</td>
<td>6</td>
<td>12.29 (2.43)</td>
</tr>
<tr>
<td>C4</td>
<td>5</td>
<td>15.60 (3.65)</td>
</tr>
<tr>
<td>C1-4</td>
<td>21</td>
<td>11.19 (3.92)</td>
</tr>
</tbody>
</table>

5.2.1 Participants

Four classes were chosen by school staff to take part in this study. The classes were chosen to provide a cross-section of age and ability. In total, there were 21 students, 4 teachers, and 4 teacher aids. The students ranged in age from 6 years to 20 years, with a mean age of 11.19 years (3.92 yr). Class age composition is provided in Table 5.1. Teachers described all students as below age appropriate levels in language skills, with 19 of 21 students having a diagnosis of ASD and the remaining two with cognitive delays.

5.2.2 Design

A mixed methods comparative research methodology was used to investigate increased whole class engagement using *StoryScape* as a story co-creation activity. This approach involved qualitative and quantitative analysis of multiple story co-creation activities. For comparison, we adopted story co-creation activities from Hourcade et al. [35]. The following section highlights story co-creation technologies and the approach used by Hourcade et al., while also describing our own approach.

5.2.2.1 Digital Story Drawing Activity

Hourcade et al. developed the Open Autism Software (OAS) drawing app for collaborative story creation. Their drawing app provides basic drawing through use of a mouse or finger input, as well as panning and zooming using the pinch gesture. It also includes a simple
palette of colors. The software was installed on a Dell XT2 Tablet running Windows 7. They used this app primarily for collaborative storytelling by two or more participants. During collaborative storytelling activities, children were asked to take turns drawing the next visual scene in the story. The children were asked to draw first and tell the story afterward. During this turn-taking, children would ask their peers about what they were drawing and what will happen next. Two researchers conducted their sessions with two students in a separate space from the classroom. One researcher would facilitate the activity, while the second recorded the session. In addition, a member of the school staff was always present.

Attempts were made to use the OAS drawing app in the present study, but it was not compatible with computers present in the school and replacements could not be made. In place of the OAS software, we used the ActivStudio Drawing application for Promethean interactive displays. This application is very similar to the OAS drawing app; it provides basic drawing through use of a mouse or finger input, as well as panning and zooming using the pinch gesture. It also includes a simple palette of colors and allows for drawings to be copied and pasted into the drawing area. Each class was outfitted with a 77” Promethean interactive display, which are standard technology in all the classrooms and students and staff all have access and familiarity with the ActivStudio Drawing application.

Each digital story drawing (DSD) session was conducted by the teacher as a regular classroom activity with the whole class, typically five students. The teacher conducted the sessions to facilitate the students creating stories. The teacher encouraged students to think about what they would draw, take turns drawing, and talk about resulting drawings and stories. Students typically sat in a semicircle around the display and took turns adding elements to the story.

5.2.2.2 Paper Story Drawing Activity

For the paper story drawing (PSD) activity, Hourcade et al. replaced the tablet computer with large sheets of paper, 25”X30”, together with colored markers. Apart from the replacement of the tablet computer with paper and colored markers, the activity was conducted
in the same manner as the DSD activity.

Similarly, rather than use the interactive displays, we used an easel with a pad of 25" X 30" paper together with colored markers during the PSD activity. Apart from the replacement of the interactive display for story co-creation, the activity was conducted in the same manner as the DSD activity.

5.2.2.3 StoryScape Activity

Similar to the DSD and PSD activities, the StoryScape activity was conducted by the teaching team with the whole class as an integrated classroom activity. The teaching team facilitated the activity and students were asked to take turns adding to the story creation.

5.2.3 Procedure

Prior to the start of the study we conducted a 60-minute training session with all staff taking part in the study. In addition, other interested staff participated. First all participants were instructed to create a short story with no instruction on how to use the StoryScape platform. At the end of a 20-minute period, the System Usability Scale Test was administered to participants [15]. For the remaining 30 minutes, I gave a demonstration of the StoryScape platform with explanation of functionality.

The study was conducted over seven contiguous weeks with story co-creation activities, conducted by the teaching team, integrated as a regular classroom activity. The activities were conducted as a whole class, comprising the teaching team and students. Sessions were scheduled to be conducted three days per week; each of those days a different activity would be conducted. Because there can be day and time biases that might affect student engagement the activities were randomly shuffled so that it was never the case that a particular activity always took place Monday mornings before recess, etc. Teachers were left to their own discretion on how long each session should be, though approximately the 10-minute mark, teachers were instructed to present the class with the
option to switch activities. Teachers would ask the class if they would like to continue the 
current activity or switch to one of the other two activities. Each child would vote for the 
activity they preferred to do. The class would continue the session with the activity that 
received the majority of votes. In cases of a tie, the teacher would make the final decision 
on which activity to do. Teachers would record the vote results for later analysis. Teachers 
could use their own discretion to stop an activity or modify the activity as needed to support 
the classroom goals or student needs.

For all activities, the teacher would introduce and facilitate the activity. Facilitation in-
cluded prompting children to start or end their turn, suggesting ideas, asking the child to 
explain what they were doing, etc.

Each session was video recorded for further off-line analysis. In addition, teachers were 
asked to take notes on the activity, using a prompt guide I developed. The prompt guide 
was used as a tool to facilitate the teacher taking notes on the sessions and contained the 
following prompts:

- Please note anything that surprised you (good or bad) from the session today.
- What about the activity did/didn’t work today?
- What about the activity helped or did not help support the class goals?
- Were there technological features that helped or hindered the activity?
- Why do you think the children liked or disliked the activity?
- Other comments.

In addition to the video recording and teacher notes, I conducted semi-structured interviews 
with teachers, teacher aids, and students at the end of weeks 1, 4, and 7.

5.2.4 Video Measures

Given time and cost constraints, along with staff preferences for supporting language, videos 
have only been coded for vocal expressions. The decision to code for this event was also 
supported by the work of Hourcade et al. They found statistically significant results only
for vocal interactions and physical interactions; while supportive comments, discouraging comments, atypical behavior, social missteps, and time off-task did not inform social engagement [35].

5.2.4.1 Vocal Expressions

An intentional vocalization directed at another or self, without intent for interruption, for the purpose of expressing information that may or may not elicit response. Vocal expressions may be from 1 to N vocal gestures in length, comprising indistinguishable sounds used for communication purposes or distinguishable words. Vocal expressions start with the sound of the first vocalization in the sequence. While most vocal expressions are statements, comments, or questions, they may also be interrupted or abandoned utterances.

5.3 Results

While we started the research study with four classes, class C2 withdrew from the study at the end of the second week because of challenges maintaining classroom order during the activities. Further discussion of C2 follows in section 5.3.2. While C1 attempted to perform the PSD activity, the teacher determined that the class would not be able to conduct this activity, though they did conduct DSD and StoryScape activities. Likewise, the teacher in C4 had to modify the PSD activity, as they could not perform this activity as a whole class. Only C3 was able to perform all three activities without modification. Furthermore, classes were not always able to conduct three sessions per week due to other school activities or teacher discretion. Lastly, a number of sessions were not included for analysis because of technical or procedural issues, i.e., video recording was not captured. In total, 27 activity sessions are used for analysis (see Table 5.3). The following sections present the quantitative analysis.
5.3.1 Quantitative Measures

The following is a presentation of quantitative results for the StoryScape story co-creation study. I first present results of the System Usability Scale testing. Second, I present the student activity preference results, followed by social activity preference results. The section concludes with an analysis of vocal expressions from the video data.

5.3.1.1 System Usability Scale

Prior to the start of the study we conducted a usability test with school staff. The System Usability Scale (SUS) was used for measuring the usability of StoryScape for authoring stories. The SUS is a reliable tool for measuring the usability of a wide variety of products. It consists of ten questions with five response options from respondents; from strongly agree to strongly disagree [15]. In total nine individuals with no prior use of StoryScape took part. The SUS score for StoryScape was 90.27 on a scale from 0 to 100. The StoryScape SUS score represents a system that is very easy and intuitive to use.

5.3.1.2 Student Activity Preference

During every session, teachers were instructed to ask students at the 10-minute mark if they would like to continue the current activity or switch to one of the other two activities. The activity with the majority of students votes was selected. Note that all students present would vote. In cases of a tie the teacher would make the final decision on the class activity. Preferences were not recorded for all sessions, since sometimes the activities could not be continued or results were not recorded. Over the course of the study, 17 class activity preferences were recorded across the three classes. Overall, the StoryScape activity was the majority choice of the classes 94.12% of the time, with 70.60% of those selections by unanimous vote. Of the 29.40% of StoryScape activities not chosen unanimously, 60.90% were in favor of StoryScape vs. 29.10% opposed to it. The DSD activity was selected by
Table 5.2: Each activity shown with percentage of times it was chosen, with a majority votes from students, as the preferred activity. The percentage of unanimous selections and not majority selections also presented with detail of average “yes” vs. “no” vote in majority class decisions.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Times Chosen</th>
<th>Unanimous</th>
<th>Not Unanimous: Yes vs. No</th>
<th>Overall Selected</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSD</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>DSD</td>
<td>1</td>
<td>0</td>
<td>60.00% vs. 40.00%</td>
<td>5.88%</td>
</tr>
<tr>
<td>StoryScape</td>
<td>16</td>
<td>70.60%</td>
<td>60.90% vs. 39.10%</td>
<td>94.12%</td>
</tr>
</tbody>
</table>

majority 1 of the 17 times. The PSD activity was never chosen by a majority of students. These results indicate strong preference for the the StoryScape activity.

5.3.1.3 Social Activity Preference

Over the course of the seven week study, I conducted three interviews with each participant. Of particular interest was the students’ interest in StoryScape as a social-collaborative activity. During semi-structured, informal interviews with students, probing questions were asked to determine whether the students “liked” the social-collaborative feature of story co-creation during the StoryScape activity. Questions included:

- Do you like making stories with your friends?
- What about making stories with your friends do you like?
- Would you rather do StoryScape by yourself, or do you like doing StoryScape with your friends?

Over the course of the three interviews, reliable responses were gathered from 11 of 16 students. The five students that were not included had behavioral and communication challenges that limited their participation. Of the 11 students, consistent responses were gathered indicating 9 students “liked” the social aspect while 2 students did not. These responses aligned with teacher reports that the students “really liked” working together.
Table 5.3: *For each activity the number of times it was conducted by each participating class.*

<table>
<thead>
<tr>
<th>Activity</th>
<th>C1</th>
<th>C3</th>
<th>C4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSD</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>DSD</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>StoryScape</td>
<td>2</td>
<td>9</td>
<td>7</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
<td>15</td>
<td>9</td>
<td>27</td>
</tr>
</tbody>
</table>

5.3.1.4 Video Analysis

As noted above, there were 27 activity sessions used for analysis. Table 5.3 represents the number of activities included for analysis for each class. A 5-minute section of video, randomly segmented from the entire session, was selected for each of the 27 activity sessions. Human coders have coded the 5-minute segments for vocal expressions (see Section 5.2.4). To ensure inter-coder reliability, 20% of the video segments have been coded by multiple coders, achieving agreement of 80% or greater for vocal expressions. The vCode video annotation tool was used by all coders [31]. The following present the results of vocal expression analysis.

5.3.1.4.1 Vocal Expressions

The total number of vocal expressions were coded for students and teachers, all results were normalized by the number of students or teachers, respectively, taking part in the activity, and by the total time of the coded video segment. We first considered teacher vocal expressions across activities and found no statistically significant differences between activities. This follows expectations that teachers would exhibit the same vocal expression behavior across activities. It is important that the teachers are approaching the different activities in a similar manner.\(^1\)

Next we considered differences between students and teachers across activities (see Figure

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\(^1\)Note that the Kolmogorov-Smirnov test was conducted on all data samples prior to further analysis to determine that the samples were from a normal distribution.
A one-way ANOVA showed a statistically significant difference between students and teachers across activities, $F(5, 36) = 26.92, p < 0.01$. Tukey’s HSD test revealed that the student’s PSD activity was statistically significantly different than all teacher activities, that the DSD activity for students was statistically significantly different than all teacher activities, and that the StoryScape activity for students was statistically significantly different than all teachers (see Figure 5-1). Again, this follows expectations for the studied populations. One would expect children diagnosed with ASD, a condition resulting in communication impairments, to exhibit significantly different vocal expression behavior than adults with sophisticated communication skills. Furthermore, since teachers are leading the class and interacting with each student they will naturally be speaking more than students.

Similar to the analysis between students and teachers, we considered student-only vocal expression behavior between activities. A one-way ANOVA showed that the differences between the PSD activity group ($N = 3, M = 1.84, SD = 0.46$), the DSD activity ($N = 6, M = 2.08, SD = 0.14$), and StoryScape ($N = 18, M = 2.79, SD = 0.66$) were statistically significant, $F(2, 18) = 7.5002, p = 0.0043$. Tukey’s HSD tests showed that StoryScape was
Figure 5-2: Student only vocal expression behavior comparison across all activities. Mean vocal expressions per student per minute with standard error of the mean bars.

statistically significantly different then both PSD and DSD, while there was no statistically significant difference between PSD and DSD activities. Given these results, we performed the following t-test analysis.

Analysis of PSD and StoryScape among only students revealed a statistically significant difference in vocal expressions between the two activities (p < 0.01). For PSD, the mean and standard deviation for vocal expressions was $m_{psd} = 1.84$ with $std_{psd} = 0.46$. For the StoryScape activity the mean and standard deviation for vocal expressions were $m_{storyscape} = 2.79$ with $std_{storyscape} = 0.66$ (see Figure 5-2).

Consideration of DSD vs. StoryScape also revealed a statistically significant difference in vocal expressions between the two activities. (p < 0.01). For DSD the mean and standard deviation expressions were $m_{storyscape} = 2.79$ with $std_{storyscape} = 0.66$ (see Figure 5-2).
5.3.2 Qualitative Measures

The richness of this study goes beyond the quantitative analysis provided. To better understand the effects observed during PSD, DSD, and StoryScape activities, we collected observational notes from sessions, had teachers take session notes, conducted semi-structured interviews with teachers and students, and reviewed hours of session video recordings for qualitative analysis. I spent a total of 10 days on site over the course of the 7-week study. These 10 days were split over the 1st week of the study, 4 days; the 4th week of the study, 4 days; and the 7th week of the study, 2 days. During these visits the researcher spent full days observing classes and taking notes. In addition, semi-structured interviews were conducted with teachers and students. Teachers were also asked to take notes during, or right after, a study activity. Video observations were conducted post study.

Our analysis led to further insights into the study. We present our qualitative analysis as a series of case studies representing the study: Classroom Characteristics; PSD Activity; DSD Activity; StoryScape, Me, Myself, & Characters; Affect-Driven Motivation; So Says the Teacher; The Case of Adam; The Case of Eve; The Case of Val and Craig; and The Teacher’s Thoughts. Note that all participant names have been changed for privacy purposes.

5.3.2.1 Classroom Characteristics

Each class is a unique social environment and presents its own challenges and opportunities. To better understand the composition of the classes, we first provide an overview of the different classes. The resulting snapshot of the classes is drawn from direct observation, teacher interviews, student interviews, and analysis of video.

5.3.2.1.1 Class 1

Class 1 (C1) had five students, all male, a primary special-education teacher, and teacher assistant. In addition, the SLP often is part of the teaching team in C1, as several students require extra assistance. The students in C1 represent the youngest of the students in
this study, between 7-9 years. The teacher described the students as smart and “wanting to be social, but they struggle so much with regulating themselves.” While several of the students have been in the class together for more than a year, there are no obvious friendship behaviors between students. All of the students have trouble regulating themselves and can be easily over-stimulated. Maintaining whole class engagement is difficult. In addition, several students needed extensive 1-on-1 assistance, at least one student will attempt to strike members of the teaching team when he becomes dysregulated. There is often yelling and or banging on surfaces that forces several students to wear sound canceling headphones at times for self-regulation. Students can be obsessive-compulsive, and generally require significant help throughout the day. While the teaching team is highly skilled, keeping the class on track and working together is a major undertaking. Maintaining group discussion is very hard, and they are usually only able to have 1-on-1 discussions between teacher and student.

5.3.2.1.2 Class 2

Class 2 (C2) had five students, two female and three male, a primary special-education teacher, and teacher assistant. The students in C2 were between 9-12 years of age. The teacher and staff described C2 as the most challenging class at the school. Student challenges included obsessions with technology, walking out of the class if not attended, two students who were minimal verbal, and general disruptive behaviors. Making these challenges even more difficult, the teaching team was new to the class and was still working to establish a routine and relationships with the students. The teacher reported that working in groups was very difficult and they typically worked with pairs of students or in 1-on-1 situations. Typically the only activities that would hold the students attention as a whole class involved watching videos; video content could vary. While attempts by the teaching team were made to conduct the activities of this study they were not suited for this class. As a result, they were withdrawn from the study.
5.3.2.1.3 Class 3

Class 3 (C3) had six students, three female and three male, a primary special-education teacher, and teacher assistant. The students in C3 were between 12-14 years of age. Two of the students speak very little, despite having the ability, while a third student required an alternative augmentative communication device for speech. All students have reading and spelling ability, though these skills are 3 or more grades below “age appropriate” levels. Two students often appear lethargic and required significant prompting and assistance from the teaching team to engage them in activities. The teaching team described one of these students as “one of the hardest students in the school to engage with.” The teacher described another student as socially rigid, and noted that this student had a hard time working in groups when compromise was required, “being flexible is hard for her.” A fourth student is very quiet and had a shy demeanor, while the final two students could be talkative and had a strong interest in technology.

While there were disruptive student behaviors present in C3, occurrences were less frequent than in C1 or C2. One of the biggest challenges in C3 was engaging, and sustaining, students in learning activities, especially as a whole class activity.

5.3.2.1.4 Class 4

Class 4 (C4) had five students, one female and four male, a primary special-education teacher, and teacher assistant. The students in C4 were between 11-20 years of age. One of the students spoke very little and was typically very quiet and difficult to engage. The youngest student, 11, demonstrated a sophisticated vocabulary and could easily carry on conversations. The teaching team described this student as being very opinionated and rigid with respect to his perspective. This student was observed multiple times pointing out other peoples inconsistencies or logical problems within stories being created by the group. A third student also exhibited rigid opinions and would often get emotionally upset if he did not get his way. The final two students had affable personalities and were eager to communicate, despite obvious difficulties in communicating ideas with others. Both
students were observed struggling to relate their ideas and would often require assistance from others to help them complete their expressions.

While there were disruptive student behaviors present in C4, occurrences are less frequent than in C1 or C2. One of the biggest challenges in C4 is engaging, and sustaining, students in learning activities, especially as whole class activity.

5.3.2.2 Paper Story Drawing Activity

While the PSD activity was the least successful of the three activities, it is worth understanding what did and did not work about the activity. Of the three classes that participated in the whole study only C3 was able to conduct the PSD activity as a whole class. While on most occasions the teacher for C3 noted that the children were “not really into the activity” it did have positive moments. In particular the teacher noted, “Amanda and Brittney’s two way communication about [local aquarium] was amazing.” During this particular session the two students chose to draw famous fish from a local aquarium that they both enjoyed. This led to the girls talking back and forth about how they liked the aquarium shows. Despite some successes, it was more common that the activity “wasn’t very high affect, although they were semi-interested” as a class.

Unfortunately, both C1 and C4 were not able to carry out the PSD activity as intended in the study. At the start of the study the teacher for C1 determined the PSD activity would be challenging for her students. The teacher felt that the students would be too attached to their drawings and that they would become upset if another student changed their drawing. The class already had a lot of challenges around self-regulation and our concern was foremost for the students; as a result, we determined with the teacher that it was best not to conduct this activity as part of the study in C1. Unlike C1, C4 was able to conduct the PSD activity, but they were not able to conduct it as a whole class. As the teacher stated, “I tried it as a (whole) class activity and it just didn’t work.”

While the PSD activity did not work as a whole class activity for C4 the teacher did use it as a morning activity between two students. The teacher, on her own, found that the
activity worked well when just two students worked together. In fact, for one student he preferred the activity over the other two activities. The teacher stated, “It worked great with two students. William loved it and tended to want to control, but also opened up to Val’s ideas.” William later reported, “I liked drawing pictures, it’s easier to do the drawing activity because there is not as much going on. StoryScape is hard because it's everyone.” It is worth noting that William was the most articulate in C4 and he would often get annoyed or be sarcastic towards other students during the StoryScape activity. Overall the teacher felt that the PSD activity was too slow and required to much effort to draw the characters and create the story for it to work as a whole class activity.

Similarly, even though C3 was able to conduct the PSD activity as a whole class, the teacher noted a number of issues that prevented it from working well. The activity may be too challenging; unlike the StoryScape activity, there is no structure. They have to think of something to draw, think of a story, and then coordinate with the other students to put it all together. As a result the teacher had to scaffold the activity more by giving students ideas of what to draw and what the story should be about. She also noticed that the students tended to draw the same characters each time. Another problem was the size of the display, the 25”x30” paper was easily blocked by a student when they were drawing. Drawing a character or setting took a long time; as a result, the other students would lose interest in the activity while they waited to participate.

While the PSD activity did not work as a whole class activity, it may be better suited as a paired activity. C4 reported success with PSD as a paired activity, and one student reported preferring the activity to others. In addition, there were positives reported in C3 at the individual and pair level.

5.3.2.3 Digital Story Drawing Activity

Even though there was no statistically significant difference between the PSD and DSD activities, there was a significant qualitative difference between the two activities. The DSD activity was able to be integrated as a whole-class activity by all participating classes,
Unlike the PSD activity. This difference appears to have been driven by the display and digital affordance of the interface, since the activities were identical in all other ways.

Unlike the PSD activity, DSD used a 77" touch display with a simple drawing application. The size of the display allowed two students to work simultaneously, while the other students could still observe their drawing. In addition, corrections and modifications could be applied to a drawing very easily. It was also possible to resize and move drawn characters. These digital affordances allowed the scene to be modified, in a fashion similar to StoryScape, to more easily construct artwork and build a collaborative scene.

The DSD activity “held their attention, but they were ready to switch” whenever given a choice. While the PSD activity was never chosen as a preferred activity, the DSD activity was chosen once – at the start of the study. As a teacher noted, “each child draws their own idea, but it is hard to bring the ideas together.” Their individual ideas were often unrelated, while the StoryScape activity used artwork that was interrelated and by doing so perhaps helped facilitate collaboration of a shared story. Because of this challenge integrating the students different ideas teachers noted that they, “had to push collaboration much more.” Another issue that appeared with some students, similar to the PSD activity, is that they would only want to draw one character. This may have been because of limitations in drawing ability or because of a particular affinity for a character; similar issues were not reported with the StoryScape activity.

While both the PSD and DSD activities were not as engaging as the StoryScape activity, they did allow for a degree of creative expression that was not possible with StoryScape. Children could be very expressive and come up with their own artwork, which was motivating for some students. In fact, while the DSD activity was only chosen by the group once as a preferred activity it did consistently receive a minority of votes by students.

5.3.2.4 StoryScape Activity

The qualitative data was overwhelmingly in favor of the StoryScape activity. The remainder of this chapter focuses on the StoryScape activity.
“StoryScape is a huge success, the kids ask to do it every day!” said Sally during an interview. While Sally’s class had the most enthusiastic responses, all three classes reported surprises and overall success using StoryScape. Given the importance of social interaction and language, and the well-known difficulty facilitating these skills for individuals diagnosed with ASD, it is no small finding that the students “wanted” to do the StoryScape activity. The activity is, at its core, a social-collaborative activity centered around language.

Prior to the start of the study, Pam the teacher of C1, was concerned that StoryScape may be too challenging for her class and felt she should make accommodations for the students. She printed the characters and backgrounds onto paper to give each student. This allowed them to pick a background and character without any time pressures and reduce the need to learn a new software interface at the same time. She would then take turns asking each student what background and character they had chosen and she would select the background and place the characters for them. By the end of the first session, students were coming up to the display to move their character to where they wanted it. After the second session, they did not need to use the printed characters and Pam felt she did not have to provide students with as much support for generating story ideas and dialog. Pam’s session notes state, “surprised at how excited all were to create a story from a blank slate and work to connect their ideas,” and “they are using the story-making very creatively for their developmental level, but most of all it provides a GREAT tool for working on sharing ideas, working through emotions and so much more!” She stated, the students have “such high affect, they wanted to do it so badly they were willing to be flexible.”

While Pam’s class experienced some amazing learning moments (see Section 5.3.2.5) while using StoryScape there were also challenges. Two students had a strong interest in the animations, and could get distracted by them. These same students were frustrated at times because not all characters had animations.

In class observations, semi-structured interviews with teachers and students, teacher notes, and session video recordings support Pam’s experience. The following sections further explore specific characteristics of the activity that emerged from the data.
5.3.2.5 Me, Myself, & Characters

 Typically during the StoryScape activity a student would select a background image as the scene for that page of the story, while the same student and one or more students may then add characters to the scene. Students would often comment, “I want to be the unicorn,” or “Can I be the girl on tricycle?” Often they would then provide dialogue to the story relative to the perspective of their character. Multiple teachers observed students using their characters as a medium to interact with one another. It also happened that because two characters interacted in the story the students that identified with the characters would interact with each other during the StoryScape.

During interviews with Sally, a teacher, she commented on how her students Amanda and Brittany have been “having their characters do things together in the stories.” This came to Sally’s attention because Brittany is new to the class and she and Amanda do not interact with each other. Sally felt that they were starting to form more of a friendship and she was seeing this develop first through the characters during story creation. I also observed them “playing together” through characters in the story. During one StoryScape Brittany would remind Amanda which unicorn she was and which unicorn Amanda was and stated “my unicorn and Amanda’s walked down to the beach together.” A number of similar events took place with these students.

In another instance Pam, a teacher, excitedly reported how Tom demonstrated amazing consideration for his fellow student, Tony, during a session of StoryScape. Tony had selected a “pig” to be his character and had placed the character into a scene of a forest with a bridge over a river. The pig was placed before the bridge, as if it was going to cross over the bridge. Next it was Tom’s turn, he was using the same background as Tony, and Tom selected a “mean troll” to be his character and placed it under the bridge. Pam then asked Tom what his character was doing and he stated, “He’s very angry so nobody can cross his bridge.” Since Tony had used the same background and placed his pig character before the bridge, Pam asked Tony who he thought was going to try to cross the bridge. Tony responded “Maybe my little pig.” Pam then asked Tony to put his character into the scene, but Tony
responded, “I don’t want to, I don’t want anyone to do it.” Tony was noticeably upset and said that he was afraid of trolls. In response, Tom asked Tony if he wanted to get rid of the troll. When Tony said “yes” Tom agreed to delete the troll character. This was no small consideration for Tom, he was almost crying and struggled to make the change – but he did. Tom then selected a billy goat as his character and added it and the pig to the scene, both characters crossing over the bridge.

The teaching team was excited how Tom was “taking into consideration how someone else felt and putting their feelings before his own.” In two years of working with Tom this is the first time they had seen him do this. Later in the same session Tom placed his billy goat next to the pig in a different scene. During subsequent interviews with Pam she reported that she felt Tom and Tony were becoming friends and that this was “huge” since “no one has a true friend, we are seeing friendships start and children considering others.”

Based on observations and interviews with teachers we have concluded that some students would use characters from the artwork as proxies for themselves, allowing them to engage in dialogue or interaction with others in a way that they would not normally do. This was an unexpected result and warrants further investigation.

5.3.2.6 Affect-Driven Motivation

Across all of the observational data, the topic of “high affect” came up repeatedly. During interviews with the teachers I would ask the teachers to explain what they meant by “high affect” when describing the StoryScape activity. They related that it means “activities the students really like or love to do.” These are “activities that relate to their life (interest) and they are more engaged with them.” Teachers responded that you can tell when there is high affect because “they (the students) sit up a little straighter and pay attention, they get a glisten in their eyes and really tune in to the activity.” Interestingly, both coders of the session videos noticed a difference between the StoryScape activity and other activities in terms of affect. The students seemed to “light up” when they started the StoryScape activity. A child that was not looking at the class display, and seemed totally tuned out,
would turn bright eyed to the display and start interacting with the class when they started using *StoryScape*.

This affect-driven motivation also seemed to help students overcome challenges. When interviewing a teacher about a particular student that struggled with social interactions and accepting other people's perspectives the teacher reported, “because she likes *StoryScape* so much I have seen her push herself way past where she would normally get upset and stop an activity.” This was observed multiple times with this student. Similarly, other students also surprised the teachers.

During a *StoryScape* session, C4 was using an artset with vampires in it to create a Halloween story. Alan, a student in the class, immediately started saying how he did not like the story and did not want to do it. The whole time he was saying this he was becoming more and more upset. Tina, the teacher, went to him and started to help him calm down while asking if he could be flexible and work with the other students. After a few moments, Alan became even more upset and moved into a corner of the room while saying how the story was spooky and that he did not like vampires. He was noticeably shaking and nearly crying while the teaching team worked to soothe him.

Tina suggested to Alan that he ask the other students if they could use a different art set. Alan asked, “Do you want to pick another story, like the jungle?” Unfortunately, the other students were determined to use the vampire artwork and suggested, “Why doesn’t he go into the little room (an attached quiet room used for students to help regulate themselves) and calm down while we do this?” Tina responded, “*StoryScape* is one of his favorite things” and asked the class to be good friends and understand how this was upsetting Alan. Unfortunately, the other students were so focused on the current story they did not want to change artwork for Alan. Over the next several minutes, Tina continued talking with the class, trying to help them understand how Alan felt and why she felt their response to his needs could have been better. During this time, Alan turned back to the display. While he still looked frightened, he suddenly decided, “I want to pick a character” and walked up to the display and chose a character to put into the scene. Tina asked, “Alan are you feeling better about this art?” He responded, “just a little bit” and continued making the story.
While Alan was able to get past his fear of vampires, the class remained dysregulated and they stopped the session several minutes later. Even though this session ended prematurely Alan pushed through a major personal obstacle. “Normally Alan would become disruptive, or leave the class when he gets upset or does not get his way, it was a big deal that he was flexible and persevered.”

Interestingly, there were two other incidents similar to Alan’s fear of a character. In each case, the students pushed pass their personal challenges and the teachers reported their surprise and joy in the meaningful action the students demonstrated. The teachers’ reports, video observations and interviews with the students suggest that the students experienced a strong, positive affective motivation for StoryScape.

5.3.2.7 So Says the Teacher

As mentioned previously, during story co-creation activities teachers were asked to take session notes, and were provided a prompt guide. One of the prompts was, “Please note anything that surprised you (good or bad) from the session today and which activity it was during.” In addition to the following sample of teacher notes, with their emphasis, we provide a visual representation of all of the teacher comments with respect to surprise during the StoryScape activity (see Figure 5-3).

- Rich loved StoryScape
- Amanda’s excitement to create in StoryScape after hard a.m. hiding in bathroom.
- Amanda telling Brittany “You don’t have to yell at me” and Brittany apologizing. VERY COOL!”
- Students engaged and communicative the entire session.
- Adam helping Mike to spell and giving ideas.
- Teamwork, socially engaged and communicative.
- Adam very engaged.
- Only activity Mike doesn’t require multiple prompts to complete.
- Difference of engagement between DSD and StoryScape was noticeably different.
Mike asking to type for everyone.

Amanda and Brittany’s two-way communication about a local museum! AMAZING!

Amanda’s immediate joy and communication with others (after switch to StoryScape).

Lisa didn’t put the nose guy in for Amanda (she was afraid of that character).

Using more affect in their voice when reading.

Brittany remembering all the characters names, AMAZING as short term memory is a challenge for her.

Tom was willing to take his scary character out of the story for his friend Tony! This was HUGE for him to put someone else first!

How quickly they were able to move away from heavy scaffolding and support.

Increased eye contact during StoryScape.

We also wanted to better understand why the teacher felt the activity worked to engage the students. Teachers often responded to the session note prompts “What about the activity did/didn’t work today” and “Why do you think the children liked or disliked the activity?”
with great insight into what worked for the activity. Again, we focus on the StoryScape activity and provide a sample of the teacher notes, with their emphasis, and we provide a visual representation of all of the teacher comments with respect to what worked during the StoryScape activity (see Figure 5-4).

- Having the images helps the class work together with less support (from teaching team), which allows them to move up the developmental ladder.
- The text box helped support getting out ideas.
- Visually stimulating, cool characters, fun setting.
- Funny food in the alien artwork as well as all the characters.
- Funny, impressive artwork.
- Fun, creative, no wrongs.
- The salience of the stories.
- Artwork and textbox.
- New art was a huge hit.
- Interesting art.
- (Teacher) able to scaffold to make it funny.
- Characters VERY high affect.
- Liked artwork and starting their ideas.
- I think they loved the artwork.
- Having the images to pick from quickens the pace of the story making, they are able to get more story created (focus on language and story).

5.3.2.8 Students

To better understand the actual experience of the students using StoryScape during the story co-creation activity I provide individual case examples. These examples provide more insight into the particular challenges of individual students and the effects of the StoryScape story co-creation study.

5.3.2.8.1 The Case of Adam

“Adam is a smart kid, but getting him to be active and present is our biggest challenge,” Sally, the teacher, comments. Sally and her aide Samantha spend the day working through different activities as a whole class, in small groups, and in 1-on-1 situations with the students. Most of the students in C3 have been in this class for 2 years. Sally and Samantha know the students’ strengths and weaknesses, and are constantly working to help the students along their developmental paths.

Adam sits with his back to the class with an expressionless look on his face. “Adam I need you to tune-in,” says Sally working to get him to engage with the class and the learning activity. The class is reading from the book Stuart Little. “Adam it’s your turn to read ... Adam can you read your part ... Adam I need you to be present ... Adam it’s your turn” the words seem like a natural pattern of interaction with Adam. Samantha moves into the chair next to Adam and prompts him “right here” as she points to the start of a sentence. There is a long pause, then Adam starts reading the sentence in a muffled, monotone voice.
Having done what was asked of him he appears to tune-out again as the class moves on with the activity.

“Today was amazing, Adam was so engaged. He was helping Mike spell and giving ideas,” during story co-creation with StoryScape Sally relates. It is easy to see the difference between PSD, DSD, and StoryScape with Adam. The PSD and DSD activities are like most activities for Adam, they require the teacher working hard to engage him in the activity and help him along. With StoryScape he is a different kid. Typically he is slow to respond verbally, hypotonic (low muscle tone), and appears disconnected from the world around him. Ask him if he wants to do StoryScape and he responds right away “StoryScape.” A minute later he is asking if he can read the story! “This is the most I have heard him laugh, in three years!” Sally states. Something powerful about StoryScape and the activity resonates with Adam, the result is he is tuned-in, turned-on, and fully engaged. He laughs, responds to others, helps create the story, helps others spell (he is a good speller), and as the teachers say, you can see a sparkle in his eyes.

Because of the strong difference in Adam’s behavior, I decided to return to the videos and code his verbal response latency to teacher prompting and his total speaking time across activities. During the two non-StoryScape activities his average response latency was 10.24 seconds, while during the StoryScape activity the average response latency was 948 milliseconds. During the two non-StoryScape activities he spoke on average 2.54 seconds over a 5 minute video segment, while during the StoryScape activity he spoke 29.63 seconds. This represents an order of magnitude change, and further helps us understand why the teacher was so happy in the changes she saw with Adam.

5.3.2.8.2 The Case of Eve

Eve is full of energy and seeks physical activity. She can often be found sitting and bouncing on an exercise ball, an activity that helps calm her. Sally describes her as, “socially rigid, she does not always like to do group activities and can have a hard time compromising.” Like all of the classes, working as a group is a goal for C3. Unfortunately, Eve is not a fan
of group activities, she will sometimes walk away from the group and pace about the edge of the class, slide under her desk, or otherwise try to elude the activity. She oscillates back and forth from the edge of class to the center, and when she does participate, the teacher has to work hard to keep her involved.

Things change during StoryScape; like the other students, Eve gets excited to make stories with her classmates. She moves from the edge of the class to the group, and often to the center of the group. “Today’s session with the farm art was awesome! I didn’t even know Eve had all these ideas to share in her head,” Sally notes. Eve is noticeably excited; she stands near the display hopping up and down commenting on the developing story. When the touch display stops working during the session and Rich is unable to move his character, Eve says, “Let me, I’ll help” as she takes the mouse and moves Rich’s character to where he wanted it. As Eve continues to excitedly help her classmates, Sally comments, “Eve, I have a feeling you are really liking this.” It was not just her excitement that stood out to Sally. Eve was much more flexible, being able to stay regulated when she would normally have gotten upset.

5.3.2.8.3 The Case of Val and Craig

Val and Craig share a lot of similarities, both are friendly, amicable people. They are quick to have a conversation with you about baseball or ask you questions about yourself. Similar to lots of individuals diagnosed with ASD, if the conversation strays from their personal interest, they struggle to keep the conversation going. While they are both creative, they really struggle with expressing themselves. Both require extra time to gather themselves, and if they are not ready they will stammer along trying to express their thoughts. Sometimes they appear to abandon a thought mid-sentence, then continue it several minutes later.

Val and Craig appeared to enjoy using StoryScape during story co-creation; they were both eager to add their opinions and shape the story with their classmates. During interviews with the teacher she commented, “I really think they like StoryScape a lot.” During visits
to the school Val and Craig were eager to speak with me about the stories they had made with *StoryScape*, and ask questions about the artwork. They always appeared excited when the conversation involved *StoryScape*.

During semi-structured interviews with Val and Craig, they provided a deeper insight into why they liked *StoryScape* so much. When Val was asked if she likes using *StoryScape* with her friends to make stories, she approached the interviewer excitedly to tell him “Yes!” Val stated, “I liked it because I want to be an author someday and it helped me get my thoughts out.” This was particularly meaningful because often Val appears to struggle getting those thoughts out.

Craig is more loquacious than Val and when the teacher’s aide asked him to tell the interviewer if he liked making stories with his friends, Craig delivered an insightful answer. Craig started “I like the pictures, they help me get the big picture of the story then I know what I am typing. Once I am in the zone, then I know what to do next. You get the picture then the words come and you get good connections.” There is an inherent structure in *StoryScape* and visual narratives, and the images appeared provide a salient artifact to structure ideas and story around. Craig continued, “I like the animations because you can type what the character is doing.” The animations extend the visual vocabulary beyond nouns to include verbs. Craig finished, “I liked making stories with others because I get their opinion on what they think. You get more interaction with your friends.” Craig is a friendly person, he enjoys interacting with his friends, it is just hard for him to do so. *StoryScape* provides him an opportunity to enjoy being creative with his friends.

### 5.3.2.9 Teacher’s Thoughts

Early in the study it appeared that the children had a much stronger positive reaction to *StoryScape*. As a result, I would probe the teachers during semi-structured interviews to help understand why *StoryScape* was motivating their students. The following represents the topics that emerged from these interviews:
• It provides a visually binding experience for the class that establishes joint attention, shared attention, and engagement for all children involved
• The visual nature of StoryScape scaffolds the ability to hold the story theme.
• It scaffolds them to share ideas and collaborate together.
• The art set provided allows for shared ideas and creativity between our students.
• The scenes with movement provides the opportunity to use more abstract language, such as verbs.
• The open-ended nature of the pictures promotes more spontaneous and creative language.
• It sustained attention for longer periods of time and within a bigger group.

5.4 Challenges and Considerations

While results show strong support of StoryScape to facilitate engagement and vocal expressions during a whole class language-based social activity there were also challenges. Teachers reported that coming up with a story was difficult for the class and typically required support from the teacher. Unfortunately, even the teacher found story topic creation difficult. It was suggested by a teacher that even a simple story prompt would help with creating a story by providing initial direction. In addition, teachers commented that art sets that contained abstract and disjoint backgrounds made it difficult to make a cohesive story. Teachers also reported that the classes struggled to create cohesive stories. This may be a drawback of working as a group, or more fundamental issues related to ASD. It was also the case that some students became frustrated at times because not all actors in an art set were animated.

In addition, it is worth highlighting that StoryScape was not preferred by all children. The DSD activity accounted for 15% of the activity preference votes and 18% of the students preferred PSD and DSD activities to StoryScape. Furthermore, using StoryScape as a whole class activity was not possible with one of the four classes. The inability to use it with a class highlights the fact that it will not work for all classes.
Chapter 6

Conclusion

Over the last two decades, through many efforts, public awareness of ASD has become widespread. While many people may not understand the complexities faced by those diagnosed with ASD, it is understood that we need to do something to help those diagnosed with ASD. In response to the need for help, there has been a significant increase in research and development of assistive and learning technologies for those diagnosed with ASD. This thesis is a response to that need, an attempt by myself and those that have contributed to do our best to help.

Even with public awareness, the ASD community still struggles to find the needed resources and technologies to help them. While cutting edge learning technologies are focused on engaging typical children as creators through the principles of constructionism, those diagnosed with ASD are given technologies that force rote behaviors. Generally speaking, those diagnosed with ASD are not treated as creators. Rather, I have simply assumed those diagnosed with ASD are creators, because I have seen them pick up technology and be creative with it. I have worked to enable that behavior, and too encourage their expression.

As I have learned alongside the ASD community, my understanding of ASD has changed significantly. I no longer only see the “social impairment” of those diagnosed with autism, but see the “social support” of those that work so hard to help those diagnosed with ASD. I
began to understand that the only way to support those diagnosed with ASD is to consider deeply their support network. Furthermore, I found that the use of illustrations and story is a common thread among activities and individuals in the support network. It also became evident that there was a real need for tools for creating media and for media that could be customized. The principles of ABA did not inform me in the creation of technologies to meet these needs. I was required to move outside the typical boundaries of the ASD community and adopt the principles of constructionism and participatory cultures, principles that I think are better suited to the needs of the ASD community. These realizations and influences have shaped the StoryScape platform.

The work described in this dissertation suggests that StoryScape has the capability to support a community of users around the story process. Different users have shown successfully that there are many different ways to use the StoryScape platform to support the needs of the autism community around communication and social engagement. We have found that the consumption of StoryScape media and creation of StoryScape media is engaging. Furthermore, we have shown that StoryScape facilitates vocal expressions and social collaboration during story co-creation. This finding is particularly important, as it is very difficult to engage groups of children diagnosed with ASD in language-based activities and to facilitate social collaboration.

6.1 Limitations

The development of the StoryScape platform has been ambitious. StoryScape is a board platform, with tools for creating interactive stories across digital and physical assets, that integrates web, mobile, and physical technologies. As such, there are many aspects of StoryScape that have not been well tested. This is particularly true with understanding how StoryScape can be used across stakeholders and to the benefit of the ASD community.
6.1.1 Limitations of Artwork

During the process of developing StoryScape it was necessary to work with many potential users to understand usability from the prospective of what StoryScape can be used for and how it supports those use cases. Perhaps the greatest limitation of the StoryScape platform is the actual art needed.

We found that the creation of artwork, whether by professional or novice, was a time-intensive task. This creates a significant bottleneck and limits the creation of stories from pre-existing artwork. Furthermore, during earlier iterations of StoryScape it was found that art sets that were structured in a thematic, visually cohesive manner enabled story creation. As a result, subsequent versions of StoryScape required that any art be submitted as a thematic set. While this made story creation easier, it made contributing art more difficult. An art contributor is expected to contribute much more than one image. While these issues around art are significant they also present opportunities for learning activities focused on art creation.

Another significant challenge related to art is the story content itself. When conducting our exploratory work looking at using StoryScape and animated content for teaching target verbs, we quickly ran into issues with a lack of content. Despite significant effort to create two art sets with target examples of verbs provided by the teachers, we ultimately needed many more examples and artwork to create useful media for learning materials.

Similar issues existed during our work exploring the creation of individualized learning materials. While the teachers found StoryScape easy to use, and expressed a need for tools to create individualized learning materials, they felt that StoryScape’s actual usefulness was hampered by a lack of domain-specific images that would be useful to them. It is evident from this work that StoryScape will require significantly more artwork to become truly useful. The work of Boujarwah et al. provides insight to the benefits of crowdsourcing, which may be the best method to develop a large media library of domain-specific images across many domains [14].

In addition to limitations associated with art content, the research explorations were not
structured in a way to provide deep insight into the usability of StoryScape. Instead, they were used to guide development of the platform and to highlight potential uses of StoryScape. While we feel that all of the explorations have provided value in the development of StoryScape and have pointed at a number of significant potential uses, we also recognize that much more work must be done to better understand its actual usefulness.

It should also be mentioned that my own involvement in the data analysis rises question and requires that further analysis is conducted to support the findings in these thesis. Ideally, independent analysis and further evaluation of the system is needed.

6.1.2 Limitations of Story Co-Creation

The findings from the story co-creation study are most exciting, but by no means definitive. For one, the number of participants is low. Even more concerning is that the data was unbalanced and the sample size small, and there were far too few examples of the PSD activity. While we were prudent in our statistical approach to the data, a larger sample size that is balanced across activities may provide stronger support, or not, for StoryScape.

In addition, we are left wondering why StoryScape worked. Why did the StoryScape activity result in increased vocal expressions? What about StoryScape made the children prefer it to the other activities? Does the quality of art matter? Does the modular nature of the art matter? How do animations affect engagement? When is group story co-creation better than dyadic story co-creation? Does the touch interface make a difference?

While I have intuitive answers to these questions, we lack evidence to support our understanding of what about StoryScape works and why. Further research is warranted to understand these questions and provide stronger support for the usefulness of StoryScape.

6.2 Future Work

Our explorations and research study have indicated a number of future research directions. The following section highlights areas we feel warrant further investigation.
6.2.1 Physical Story Assets

During initial tests to determine if NFC characters would engage children diagnosed with ASD and could be used for teaching nouns, we had promising interactions with children. Children were excited by the physical NFC characters “magically” appearing into the digital story. We feel that a set of such characters could be developed and corresponding stories created to test whether noun acquisition is increased though such interactions.

6.2.2 Social Interactive Stories

While not formally tested, we did explore the use of StoryScape for creating what I have termed Social Interactive Stories. The premise of a Social Interactive Story is that visual elements of the story are missing. For example, the text of the story may state, “Adam was happy to see the bears at the zoo,” while the corresponding visual scene will purposely be missing Adam. The goal is to have a child diagnosed with ASD complete the story by engaging socially with someone to be “Adam” and act “happy.” The idea is that completion and interaction with the story requires actual social interaction with other people. We have seen that children will often interact with others when mediated through technology. Here StoryScape and the story both scaffold the interaction and mediate it through use of the technology.

6.2.3 Artwork

During the story co-creation study a number of questions arose with respect to the artwork. Does the quality of artwork matter? Does the modular recombinable artwork make a difference? How do animated characters influence engagement?

To test the first question we could compare current StoryScape artwork with Boardmaker artwork and with other commonly available artwork for children. Likewise, the second question could be tested by providing artwork that is static and cannot be constructed by the users. The last question could be tested by removing or disabling animations.
6.2.4 Dyadic vs. Group

While we discovered that StoryScape can be used to engage a whole class of students (6-8 students) we have not investigated how it supports dyadic story co-creation. While it is very encouraging that it can support larger groups, the dyadic situation is at least equally important. It would be great to know that a parent and child can sit together and use StoryScape as a means of engagement. Such a test could be carried out with parents and their children using the current StoryScape platform.

6.2.5 Story Coherency

Over the course of the story co-creation study, teachers found the students struggled to create coherent stories. The teachers reported that during the first several weeks of the study they did not emphasize story coherency, since the children were so engaged in language expression and social interaction. Near the end of the study teachers reported that they put more emphasis on story coherency and helped the students connect their ideas from one page to the next. A question is whether incoherent stories are a result of collaboration or a characteristic of individuals diagnosed with ASD.

A study could be conducted comparing story coherency between individually-created stories and group-created stories. The study should be conducted over a number of weeks with all participants creating stories individually and as a group. For example, if a whole class was participating the individuals of the class would have time to create stories by themselves and would also work together as a whole class to create stories. In this way, we could look at the effects of individual vs. group story creation.

6.2.6 Longitudinal Story Creation Study

During the StoryScape co-creation study students expressed more language. Teachers also reported surprise at students using words and concepts that the teacher did not know they
knew or understood. Furthermore, teachers reported students being motivated to spell words and that the students were interested in creating stories. Does the use of StoryScape for story creation result in increased spelling and grammar skills? This and many other academic progress indicators can now be tested.

A longitudinal study between students using StoryScape and not using StoryScape could reveal if StoryScape supports increased learning of spelling and grammar skills. Participants would be age and skill matched and receive similar learning task, with one group also using StoryScape. Since learning often takes longer with children diagnosed with ASD, it would be necessary to conduct this experiment over the course of a semester or year.

6.2.7 Platform Extension

The StoryScape platform is an extensive media and technology platform that has been built to allow for extension. The addition of features such as facial expressions, voice analysis, and physiological recording are all exciting potential extensions of the StoryScape platform. Furthermore, the integration of StoryScape into robotics and other immersive story characters and settings presents exciting future works.

6.3 Concluding Remarks

The StoryScape platform is an extensive technology that bridges web, mobile, and physical technologies in an integrated manner through interactive stories. The platform has been deployed, with more than 500 registered users and 200 stories created from the small repository of artwork. StoryScape can be used by anyone and has the potential to support many users. Not only have we explored its many uses with many different users, we have shown significant value in engaging children diagnosed with ASD.

Perhaps one of the most difficult tasks for a teacher is to engage a class of children diagnosed with ASD in a language-based activity that requires social collaboration. It is no small feat
that we have demonstrated that StoryScape can facilitate such engagement. Even more rewarding are the smiles and fun had by such wonderful story creators, and the smiles and surprise of the teachers.

I am profoundly proud to have had teachers tell me, “I have never heard him laugh so hard,” and “I never knew how creative she is.” I feel that StoryScape has the potential to be a useful platform for the ASD community and beyond, and it is my hope that such usefulness is realized.
Bibliography


