Using Digital Storytelling to Improve Knowledge Acquisition of Circumscribed Interests of Children with Autism Spectrum Disorder

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Abstract. Children with Autism Spectrum Disorder face difficulties in many areas, such as academic performance and social integration. However, suppose the circumscribed interest of the children with Autism Spectrum Disorder could be adequately taken advantage of. In that case, more career opportunities could be open to them, which may facilitate their social integration. Hence, exploring how to better shape the knowledge acquisition process of the circumscribed interest areas is meaningful. Digital storytelling is considered to be an excellent pedagogical method for teaching children with autism. Therefore, this study aims to test whether digital storytelling positively influences knowledge acquisition in the CI area. Two websites with similar content but different design structures (one with digital storytelling and one without digital storytelling) are given to two children with autism between nine to twelve years old. It was predicted that a website with a digital storytelling design has a higher attraction level and thus leads to a better learning outcome. The result demonstrates that children with ASD prefer the design structure of digital storytelling and could correctly answer more questions on the website with digital storytelling. Future studies may use digital storytelling to smooth the knowledge acquisition in the CI areas.

Keywords: Digital Storytelling; Autism Spectrum Disorder; Circumscribed Interest.

1. Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder. It can be characterized by the impairment of communication difficulties, social interaction (accompanied by limited social imagination), behavior, activities, and repetitive and rigid patterns of interests [1, 2]. Autism spectrum disorder has several stages, from average to profound, which affect learning processes differently. This study only focuses on moderate syndrome [3]. Children with autism spectrum disorder face difficulties in communication deficits, social development, cognitive development, sensory and motor development, adaptive behaviors, and problem behavior [4], which could result in poor academic performance [5], social integration [6], and employment outcomes [7].

Due to many challenges, it is hard for most children with ASD to develop well as other adults later in adulthood [8]. However, children with ASD still have opportunities to further develop their skills to support their lives through circumscribed interests [9]. Circumscribed interest (CI), a subcategory of restricted, repetitive behaviors, is defined by an intensely focused interest in a narrow range of subjects [1, 10]. It differs from a typical hobby due to its higher intensity and nonsocial nature [11]. Most children with ASD have CI [11]. Previous studies show that CI has many negative consequences, such as interference in daily life [12], lower social and communicative development [12], and less involvement with other people [13]. However, there are also positive arguments in terms of CI. First, CI could bring pleasure and enjoyment to children with ASD [14]. Secondly, it is believed that CI could improve visual expertise because when seeing pictures of personalized pictures, the neurons of children with ASD are more activated compared with others [15]. Thirdly, it could be seen as a talent or unique ability exploited by children with ASD. According to [9], people with ASD could become successful in one or more of their CI areas. Therefore, the current study tries to incorporate CI in the

experiment to promote a positive learning outcome in the area of CI. Astronomy is chosen from many categories [9, 16] of CI as an example.

Coming to how to better communicate the knowledge about a particular CI area to children with ASD, this study uses digital storytelling as a method. Storytelling is defined as describing stories by memorizing them without looking at the script [17]. Storytelling telling is considered to be effective in education by improving creativity [18], promoting memorization [18], and enhancing engagement [19]. Digital storytelling combines traditional storytelling with multimedia, such as images or sound [20]. In 2008, Daigle and Sulentic-Dowell firstly used digital storytelling as a pedagogical method to promote learning outcomes and social skills of children with ASD [21]. The study shows that digital storytelling positively affects academic and social skill promotion. Another study conducted by Lindsey-Glenn and Gentry finds that digital technology is also beneficial for improving the vocabulary skills of children with ASD [22]. With the development of technology, digital storytelling is becoming a more popular pedagogical method applied in school because it helps increase interest in learning [23], promotes social skills [24], and fosters behavioral skills [25]. Hence, the current study chooses to use digital storytelling as a method to teach children with ASD.

Despite the widespread use of digital storytelling, most studies focus on developing social skills, communication skills, academic performance, and adaptation behaviors of children with autism. Few studies explore whether digital storytelling could be used to correctly and appropriately shape and improve their knowledge in CI areas. This could be a result of two reasons. First, since the social deficit is one of the most conspicuous features of children [4], it is commonsensical to put effort into the social part. Secondly, CI is a controversial and understudied area due to its large variety of effects on children [26]. Also, in many cases, digital storytelling is used in the school environment by teachers. Instead, the current study excludes the social factors such as teachers and classmates for children with ASD and allows them to focus on the digital storytelling themselves purely.

In summary, the current study aims to use digital storytelling to appropriately improve the knowledge of children with ASD about a particular CI area, astronomy. Two web pages with the same content but different styles (one with storytelling design and one without storytelling design) are delivered to participants. Responses of participants to the web page would be recorded for comparison. It is hypothesized that children with ASD prefer the website style with digital storytelling and learn the content better on the web page with storytelling design.

2. Methodology

2.1 Overview

The experiment involved two participants with autism symptoms. Both participants were male, 11 years old, and attending a special education school in the U.S. The experiment involved two main stages. In the first stage, participants were asked to go through an existing Astronomy website, *NASA Science for Kids*. Then, participants' parents would observe the participants' behavior and record them in a questionnaire. The questionnaire asked about the website's overall structure, text content, and visual effect. The feedback from an existing website allowed the researchers to evaluate users' needs and frustrations. Based on an extensive literature review and feedback from end users, the researchers found that customization and multimedia function were the two main features preferred by the participants. According to the findings, the researchers hypothesized that digital storytelling could be an effective way to assist autistic children's learning, in this case, astronomy. The researchers then redesigned the website by employing the strategy of digital storytelling.

In the second stage, the redesigned website was delivered to the participants. The questionnaire asks the same questions regarding the website's overall structure, text content, and visual effect. Four multiple-choice questions with different difficulty levels examine participants' comprehension of text content. Participants' parents record the corresponding responses. By comparing the feedback from two questionnaires, the researchers would then conclude the effectiveness of customized digital storytelling.

2.2 NASA Science for Kids: Questionnaire and Feedback

The objective of the questionnaire is to help researchers understand features in website design that disadvantages autistic children from learning. Participants' parents were given the questionnaire to report the children's feedback. The questionnaire contained multiple choices, ratings from one to five, short-answer questions, and long-answer questions. The questionnaire asked participants to go through the webpage *All about Mercury* at *NASA Science for Kids,* an astronomy website designed for children.

While our group found several Astronomy websites designed for children, such as *Planets for Kids*, *ESA Kids,* and *NASA Science for Kids,* no Astronomy website was specifically designed for children with disabilities. We selected *NASA Science for Kids* as the website for the experiment because it was built by the National Aeronautics and Space Administration, one of the best space agencies in the world. Even though *NASA* Science *for Kids* was not designed for autistic children, autistic children who were interested in astronomy may still choose this website due to its reputation and credibility. The questionnaire examined *NASA Science for Kids* through its visual appearance, clearness of structure, and text content. The answers from participants are displayed below.

Participant	Structure	visual effect	text content
A	diverse topics are prefered	• prefer cartoon face • prefer colorful appearance, interactive functions, diverse topics	• clustered text • get overwhelmed by information
B	"clicked around haphazardly"	• prefer cartoon face • prefer colorful appearance, pictures, games	• "Did not read information, too much information, moved on quickly" • prefer audio function

Figure 1. Feedback on NASA Science for Kids

Figure 1 shows the feedback on *NASA Science for Kids*. Both participants showed a positive attitude toward the visual appearance of *NASA Science for Kids.* The participants preferred cartoon representations of planets compared to realistic images. In addition, when researchers showed a cartoon representation of Earth, one with facial expressions and the other with not, both participants preferred the cartoon image with facial expressions. The participants also preferred a colorful appearance compared to the black-white layout. Besides, interactive functions, images, and diverse topics were also desired features.

The main complaint of the website was about the text content. While the purpose of an educational website was to educate the audience, the report showed both participants were unable to understand the text content. One participant "did not read the information" at all. As described by his parents, he "clicked around haphazardly". The other was frustrated by the amount of clustered information. The participants' parents suggest bolding the keywords, simplifying the sentences, and decluttering the text would help children to understand. Additionally, an audio function was preferred for children who have difficulty following the text. Meanwhile, the text comprehension level often differs case by case. Thus, as participants' parents suggested, offering different levels of text for children to select as desired.

2.3 Literature Review for Website Design for Autistic Kids

Our group also did a literature review to deepen our understanding of ASD children's needs. Past research shows children with Autism prefer multimedia learning and customization of technology [27, 28]. The study by Azahari, Ahmad, Jamaludin, and Hashim shows that multimedia learning, which combines verbal and audio-visual materials, assists autistic children's learning. Autistic

children, who "are known for their visual strength", favor visualization of information, including "pictures, videos, and other visual items" [28]. However, excessive stimuli may also lead to detraction and confusion. As the research conducted by Froba, Nieto-Riveiro, Canosa, Concheiro-Moscoso, Miranda-Duro, and Pereira discusses in their research, the feature of adding or removing information according to children's preferred sensory style may be helpful [27].

Customization is also preferred by Autistic children [27, 29]. While the child has different sensory preferences, all elements including contents, letters, colors, and audio elements should be adjustable according to children's preferences [27]. Meanwhile, due to "a detail-focused information processing style", ASD children may be easily distracted by overwhelming information [27]. Thus, reducing the visual complexity is crucial for design. Information should be displaced in large size, with a clear organization [27].

3. Result

3.1 Design and Customized Digital Storytelling

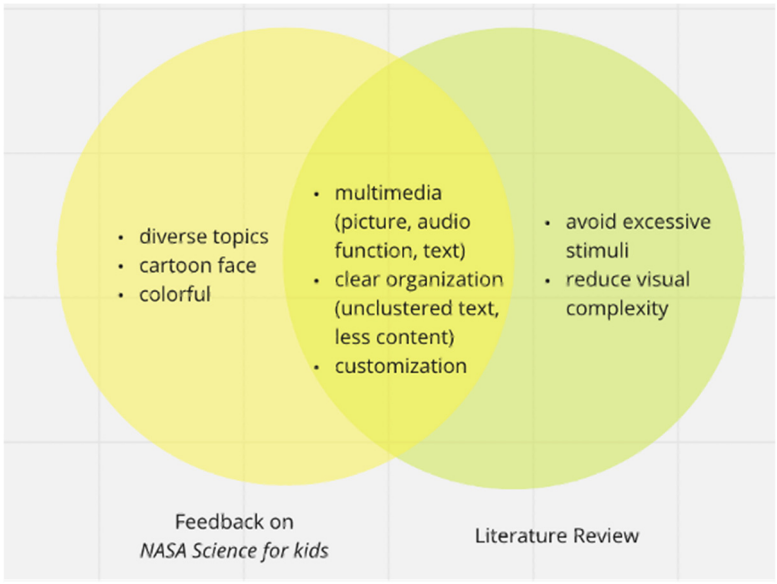


Figure 2. Autistic Children's Needs

Figure 2 shows the Venn diagram of the main features preferred by autistic children, which is based on the feedback from the questionnaire and the literature review. The intersection of the Venn diagram shows participants' preferences are consistent with the past research findings. In this case, the researchers hypothesize that customized digital storytelling would be an effective way for text content development. Thus, our group addresses the following features in the strategy of digital storytelling from the perspective of structure, visual effect, and text content.

The text content of our redesigned website is based on the original text from the webpage *All about Mercury* at *NASA Science for Kids*. The original page contains 338 words without counting the description of images. The researchers extract the main points of the original text and divide them into five sections: composition, position in the solar system, size of the Mercury, self-spin, and revolution, with 113 words in total. The content of the redesigned website is told from a first-person perspective: Mercury with a cartoon facial expression says: "Hi, I am Mercury". The text in each section is concise, with the main points highlighted in orange. Meanwhile, all text is inside of different speech bubbles to further create a narrative perspective. The title of each section is also written in a narrative way. For example, in Figure 3, instead of naming a section "self-spin", the researchers use "whose day is longer?".

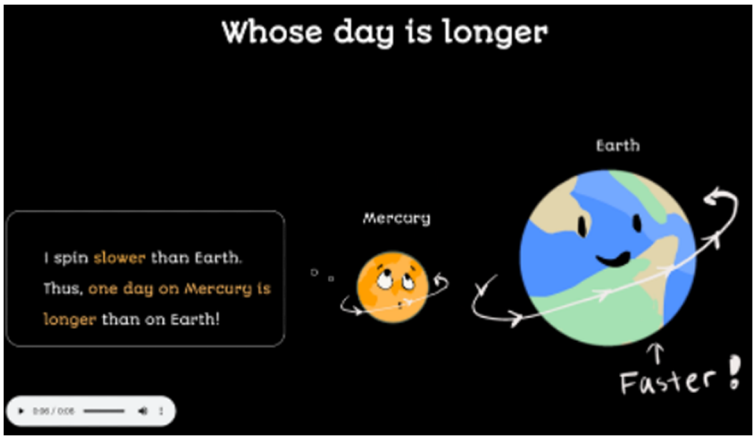


Figure 3. Example of the Redesigned Webpage

In addition to the oral narration, the researchers also customize the features of digital storytelling according to the needs of the end users. In this case, each section contains an audio function (bottom-left corner of Figure 4); the overall layout is colorful; cartoon planets contain facial expressions. To avoid potential visual complexity, only images that serve the reading purpose are included. Unmentioned stimuli, such as video, are also not included in the design as avoidance of excessive stimuli.

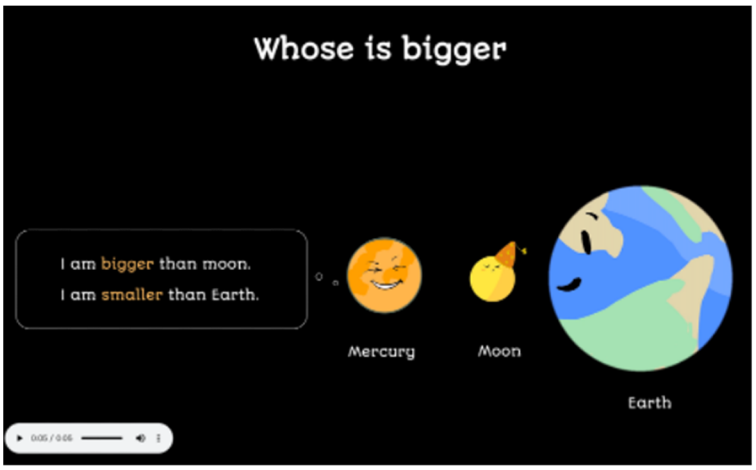


Figure 4. Example of the Redesigned Webpage

3.2 Redesigned Website: Questionnaire and Feedback

To examine the redesigned website and the effectiveness of digital storytelling, another questionnaire was delivered to the participants with a prototype webpage written in HTML. The same questions about the website's overall structure, text content, and visual effect were included. Participants' comprehension of text content was examined by four multiple-choice questions. The answer to the first two questions could be found directly from the webpage content, the last two questions required a one-step deduction. For each question, participants' parents were asked to observe if the child look at the text content of the website when he/she answered the corresponding question.

According to the feedback, customized digital storytelling is helpful to autistic children's understanding. The participant's parents asked four questions given in the questionnaire to their children. With the text content being given, one participant answered questions 1 and 2 correctly. The other participant answered question 2 correctly. Participants' parents reflected that shortened text content, images, narration with speech bubbles, and audio functions were helpful to children's reading comprehension. Overall, the feedback reflected an increased preference for the website and a better understanding of the text.

However, the participants' parents pointed out a clearer indication of the audio function was needed. For example, instead of providing a bottom, an audio function that activates when hovering over might be more helpful. Additionally, an animation showing the movement of planets represented text information better. For instance, an animation of slow rotating mercury and fast rotating earth would better represent the self-spin speed difference. Thus, further improvements are needed.

4. Discussion

The purpose of the current study is to explore whether digital storytelling could be used to improve learning outcomes in a particular CI area for children with ASD. It was hypothesized that children with ASD prefer the design style of the website with digital storytelling and that children with ASD could correctly answer more questions with digital story storytelling. Overall, compared with the website without digital storytelling, the result shows that children with ASD prefer the design style of the website with digital storytelling and have a better learning outcome.

In general, our study's learning outcome is congruent with Daigle's study [30]. In the study of Daigle, a High-Functioning Autism student in grade six was selected to receive the intervention four days a week in the library near her school. The invention mainly includes creating a digital story by the participant herself with the help of the researcher. The whole experiment lasts four to nine weeks. The study by Daigle shows that digital storytelling is beneficial to academic performance, which is generally consistent with the result of the current study that digital storytelling contributes to better learning results. However, the present study differs from Daigle's study in terms of the experiment period and the role of digital storytelling. As to the period, the whole experiment lasts several weeks in Daigle's study, while the invention lasts less than two weeks in our study. The difference in the period may result from the different roles and functions of digital storytelling in the two studies. As to the role of digital storytelling, in Daigle's study, digital storytelling is used to activate the interest and passion of children with ASD to take the initiative to engage in story creation. It is during the process of story creation that children with ASD improve their learning ability.

In contrast, in the current study, the focus is on whether the design result, not the design process, of digital storytelling, could improve participants' preference for learning material and thus leads to a better learning outcome. Hence, that might be why the former study focusing on the design process needs a longer time than the current study focusing on the design result. Despite the different roles digital storytelling plays in two studies, both studies show that digital storytelling positively influences the learning outcome.

In terms of the attraction level of the website or children's preference for the website, although the result generally indicates that a website with digital storytelling attracts the children more, there is still the phenomenon that one child is distracted from the website learning process and is unable to devote his mind to complete the questionnaire. That might result from two reasons. Firstly, one of the features of children with ASD is that they are easily distracted and thus find it hard to focus on one thing for a long time due to additional sensory input [31, 32]. Secondly, the questionnaire part is not included in the website with digital storytelling, which may lead to a decrease in interest when participants try to answer the question.

There are some limitations to the study. First of all, the sample size is small. Future studies could better collect more extensive sample data to explore digital storytelling's influence on learning outcomes. What is more, the study is conducted with the assistance of the parents of children with ASD and without the in-person help of the researcher. Hence, something unexpected may happen without being noticed, which may affect the credibility of the data collected. Future studies could be conducted with the observation and assistance of the researcher in person. Thirdly, this study explores one of the many areas of circumscribed interests. Although the result shows that digital storytelling could improve the learning outcome of CI, due to the large categories of circumscribed interests, it is hard for the result to represent the influence of digital storytelling on the whole CI area. Future studies

could explore more CI areas to determine whether digital storytelling could better smooth the knowledge acquisition and development in CI areas.

5. Conclusion

In conclusion, the study finds that digital storytelling positively influences the knowledge acquired in a particular CI area, which means that digital storytelling might be used to properly smooth the learning process of children with ASD in the CI areas. The CI areas may serve as an opportunity for children with ASD to better integrate into and adapt to society. Therefore, it is essential to better shape their knowledge acquisition process in CI areas. We would focus more on how digital storytelling improves the knowledge acquisition process in CI in the future. For instance, whether improved knowledge acquisition results from an interaction between sensory input and neuro reaction to the stimuli or results from the storytelling is a good topic to explore. Future studies could also explore whether digital storytelling could affect other CI areas' knowledge acquisition.

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