ARTIST: INTERACTIVE AUGMENTED REALITY FOR CURATING CHILDREN'S ARTWORKS

A Thesis

by

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ABSTRACT

Art education plays an important role in a child's education. It evokes creativity, supports self-expression, and builds confidence. In traditional art education, children's artwork has been displayed on the bulletin boards, walls, hallways, or art rooms utilizing frames, tables, or pedestals. This encourages children's communication and collaboration. However, presenting children's artworks on a physical display becomes challenging because it requires sufficient space and equipment at school. Unfortunately, in school the arts are a low-priority subject, causing lower funds to be allocated to art classes. Due to current limitations, children usually do not expect their works to be displayed at school very often. Furthermore, many schools have transitioned to virtual education because of the spread of COVID-19 which limits hands-on art activities and physical display opportunities. Thus, seeking alternative ways to present and share children's artworks is critical. Recent innovations in augmented and virtual reality technology open new opportunities to enhance the traditional art experience and connect people through children's artworks.

We developed *ARtist, a* mobile augmented reality application to meet these needs. *ARtist* aims to improve traditional art display mechanisms and presentation environments with augmented reality technology. Users can incorporate virtual art objects within their own environment using a smartphone. A formal user study with children was conducted to explore how *ARtist* supports children to curate, display, and share their artworks. Children participated via Zoom by importing photos of their artworks and placing them within their own environment using *ARtist*. The study session was recorded and collected video data was transcribed and later analyzed using qualitative analysis. Children's experiences with *ARtist* were extremely positive.

The results show that children were highly engaged while they were decorating their environment with their own artworks and, they wanted to share their AR shows with other people. This study suggests future improvements of *ARtist* in terms of the scope and functionality.

DEDICATION

This thesis is dedicated to my family who always support me with love.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. Jinsil Hwaryoung Seo for guiding and motivating me, and my committee members, Dr. Ann McNamara, and Dr. Daniel Bowen, for their guidance and support throughout the course of the research.

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CONTRIBUTORS AND FUNDING SOURCES

This work was supervised by a thesis committee consisting of Professors Jinsil Hwaryoung Seo and Ann McNamara in the Department of Visualization and Professor Daniel Bowen in the Department of Educational Administration and Human Resource Development. While all of the interaction design work was done by the author independently, the integration and development of mobile app were completed by Jack Greene of the Department of Computer Science & Engineering. 3D asset creation was supported by the Aggie Research team members from the Department of Visualization.

NOMENCLATURE

2D	Two-Dimensional
3D	Three-Dimensional
AR	Augmented Reality
UX	User Experience
UI	User Interface

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1. INTRODUCTION AND MOTIVATION

The arts are a crucial component of the K-12 curriculum. Music, theatre, visual arts, and dance are basic means of communication for children to express themselves (Young, 1973). In particular, visual arts allow children to demonstrate their feelings and knowledge (Danko-McGhee & Slutsky, 2003).

Among other key components of visual arts education, displaying and presenting children's artworks are essential stages of the art creation process (Hurwitz & Day, 1991; Boone, 2008). However, there are challenges and limitations for presenting children's artworks on a physical display. To display children's artworks a school needs sufficient space and equipment, but since the arts have often been recognized as low priority, and budgets have been assigned correspondingly (Bresler, 1992), schools have insufficient budgets to accommodate this physical environment (Hurwitz & Day, 1991). Limitations with traditional displays and the benefits of displaying children's artwork indicate that these environments need to improve, and alternative ways to present and share children's artwork need to be critically devised. Additionally, because COVID-19 has caused school closures worldwide, the need for virtual education is rising (Rosman, 2020). This limits hands-on art activities and physical display opportunities for children. Regarding these circumstances, designing a virtual art presentation should be considered the next step for art education.

One of the most recent interactive technologies, Augmented Reality (AR), has presented many advantages as a potential educational tool for children. AR seamlessly combines the real and virtual environment. It integrates 3D virtual objects into a 3D real environment in real time (Azuma, 1997). Huang et al. (2013) extended the definition of AR and Mobile Augmented Reality (MAR), noting the special implementation of AR on mobile devices. Mobile technology

improvements such as cameras, sensors, resources, and cloud computing have made AR possible on mobile devices (Chatzopoulos et al., 2017). This technology allows students to understand abstract concepts (Furió et al., 2014) and to visualize events that otherwise could not easily be explored in the real world (Chen et al., 2016). If mobile AR technology is adopted in art display, AR will enable children to present their artworks as virtual content in the real world, which allows them to view their artwork whenever they want.

We developed *ARtist* utilizing mobile augmented reality technology to support children to curate, display, and share their artworks. By using *Artist* users can incorporate virtual art objects within their own environment by using a smartphone. In this thesis, we present the design process of *ARtist* and a study that we conducted with children. Chapter 2 presents a literature review of the relevant studies. The design process of the *ARtist* application and the user study methodologies are described in Chapter 3. Chapter 4 describes the analysis of the user study. The study findings are discussed in Chapter 4. Finally, Chapter 5 concludes the study.

2. LITERATURE REVIEW

2.1. Traditional Elementary Visual Art Environments

A visual arts class is one of the art courses that is taught from kindergarten through 12th grade. The National Art Education Association (2014) recommends integrating these four standards to design a visual arts curriculum: creating, presenting, responding, and connecting. Creating includes generating, conceptualizing, developing, and refining artwork. Presenting includes analyzing, interpreting, and conveying the meaning of their artistic works. Responding is understanding and analyzing artistic works. Connecting is synthesizing and relating knowledge and personal experiences or societal, cultural, and historical contexts to make art (The National Art Education Association, 2014). In each art class, children begin to discuss a project once art materials are prepared and well organized. Then, they begin working on their artwork at their benches, desks, or tables. Teachers then evaluate and display children's artworks (Young, 1973).

Among other key components of the art education, displaying and presenting children's artworks are the final and communicative stages of the creative art process (Hurwitz & Day, 1991; Boone, 2008). Displaying children's artwork encourages children to represent, document, and connect their experiences in both home and school while contributing to creating art classroom culture (Kim et al., 2001; Burton, 2006). Research regarding the display of children's artwork demonstrates that it is an essential aspect of artistic learning (McArdle, 2001) because children consider their artwork as memorable experiences (Boone, 2008). Children also feel proud and have a strong sense of ownership when displaying their artwork to others (Boone, 2008; Short, 2007). One purpose of displaying children's artwork is the documentation of their artwork at different stages of completion, which also showcases what they have learned

(Schroeder-Yu, 2008; Seefeldt, 2002; Spodek, 1993; Twigg, 2011; Kuhnert, 2014). The documentation additionally functions as "a form of communication" between children and other people (Kuhnert, 2014; Seefeldt, 2002). Children enjoy seeing their own art and the art of others displayed at school (Boone, 2008); furthermore, they feel a sense of oneness with the group (Hurwitz & Day, 1991). Kim et al. (2001) further mentioned that "art displays can be utilized to make teachers, parents, and visitors aware of the children's potential, their developing capacities, and what goes to school" (Kim et al., 2001). Displaying children's artwork requires sufficient space (Young, 1973).

Traditionally, children's artwork has been displayed on bulletin boards, walls, hallways, or in the art room (Hurwitz & Day, 1991; Seefeldt, 2002). However, due to decreased art education funding, children have limited physical space for displaying artwork in school, and they cannot expect their works to appear frequently (Hurwitz & Day, 1991; Jefferson, 1965). Furthermore, even though children take their artworks after art shows, most of their artwork is disposed of at home because of space limitations (Kim et al., 2001). Additionally, because COVID-19 has forced school closures around the world, the need for virtual education is rising (Rosman, 2020). Regarding these circumstances, designing a virtual art show should be considered as the next step for art education.

2.2. Understanding Augmented Reality

One of the recent interactive technologies, AR has many advantages as a potential educational tool for children. According to Azuma (1997), AR is defined as a technology that combines real and virtual environments. It is interactive in real-time and is registered in three dimensions. Huang et al. (2013) extended a definition of AR and Mobile Augmented Reality (MAR) to include the special implementation of AR on mobile devices. Additionally, Milgram

and Kishino (1994) demonstrated the Miligram Reality-Virtuality Continuum, which portrays how real and virtual worlds are combined in various proportions. Utilizing the Reality-Virtuality Continuum, AR can be related to the real environment, which is enhanced through computer graphics.

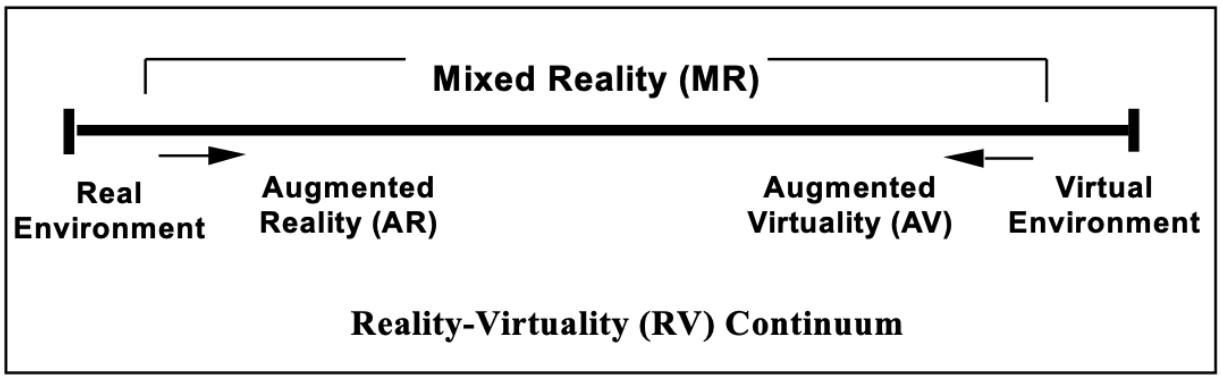

Figure 1. Reprinted from Reality-Virtuality (RV) Continuum by Milgram (Milgram and Kishino, 1994).

Additionally, AR technology offers students the potential to understand abstract concepts (Furió et al., 2014) and to visualize events that otherwise could not easily be explored in the real world (Chen et al., 2016). The technology will enable children to present their artwork as computer-generated content in the real world, which allows them to view their artwork whenever they desire. Furthermore, due to the social aspects of mobile devices, MAR applications allow children to communicate and discuss with their people about their artistic creations.

There are some approaches to incorporate MAR with art education. Disney Research has demonstrated an AR coloring book application in which children color characters in a printed coloring book and view their work utilizing a mobile device (Zünd et al., 2015). The drawing is detected, tracked, and augmented with an animated 3-D format of the character that is textured according to children's coloring. Disney Research has additionally presented a MAR application

that allows its users to modify the colors of paintings at museums through simple touch interactions (Ryffel et al., 2017). Google AR has presented the Arts & Culture application that enables users to view popular artwork and artifacts with AR (Google Arts & Culture, n.d.).

Figure 2. Created 3D characters from drawings reprinted from Disney Research (Disney Research Hub, 2015).

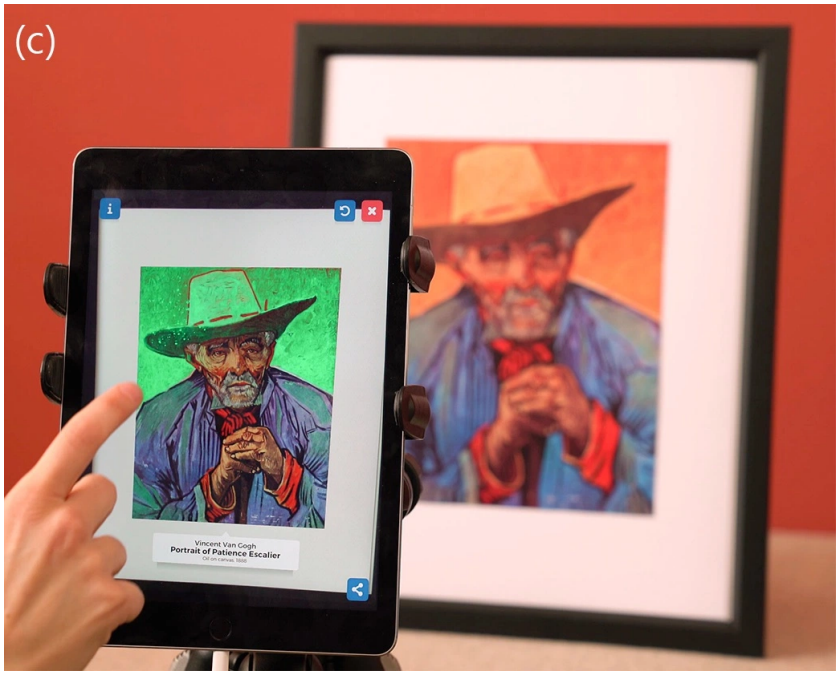

Figure 3. AR Museum reprinted from Disney Research (Ryffel et al., 2017).

2.3. User Interface for Children

Children generally prefer bright, colorful, and cheerful palettes because the color scheme is a primary visual guide for many of their activities; furthermore, these palettes attract attention and create moods (Kosa, 2018). Children prefer large, bold UIs with oversized imagery and cheerful colors (Gallavin, 2019). One children's service, Spotify Kids is using enticing and bright colors such as blue, purple, pink, and yellow (Spotify Kids, n.d.). Furthermore, it is important to utilize familiar UI patterns when users perform direct manipulations such as tapping and dragging.

Figure 4. Screenshot from Spotify Kids (Spotify, n.d.).

Another important element to consider is a visual hierarchy. Children cannot process visual information as quickly as adults (Kail, 1991, p. 492). Therefore, Shneiderman (2002) recommends utilizing a multilayer design approach to enable users to begin and learn interfaces easily, which will lead to universal usability. As Figure 4 shows, YouTube Kids has four main

menus on its main page to allow children to navigate to their contents easily (YouTube Kids, n.d.).

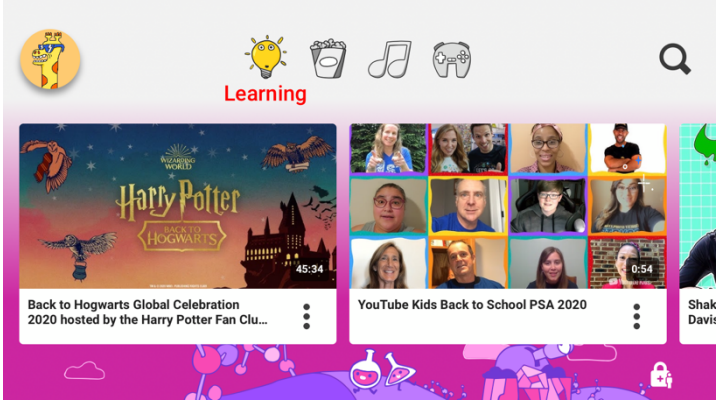

Figure 5. Screenshot from YouTube Kids (YouTube Kids, n.d.).

Icons for children's applications, furthermore, should be designed to present actions or objects recognizably so that they are easily distinguishable from each other, can be recognized as interactive and distinct from the background, and have no visual complexity (Hanna et al., 1998; Shneiderman & Plaisant, 2010). Moreover, icons should also be sized appropriately so that children can select them easily (Hourcade, 2007). In terms of the visual style for icons, the Nielsen Norman Group recommends skeuomorphic design because studies have found that this could reduce the mental efforts of children (Liu, 2018). See Figure 6.

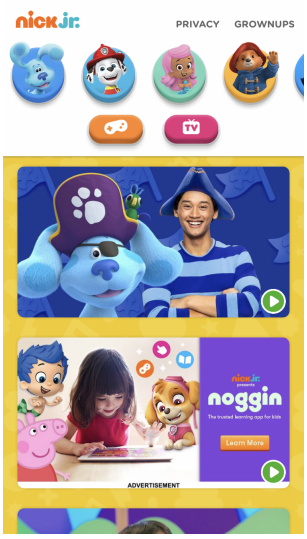

Figure 6. Screenshot from Nick Jr. (Nick Jr., n.d.).

Moreover, increasing the font size and line spacing of copy ensures that it is legible to read for children, especially on screen (Witkowski, 2019). The utilized text should be limited, particularly for children who do not know how to read or are just beginning to read (Druin et al., 2001). Simplifying copy and replacing text descriptions with imagery is one way to allow children to understand the interface (Witkowski, 2019). See Figure 7.

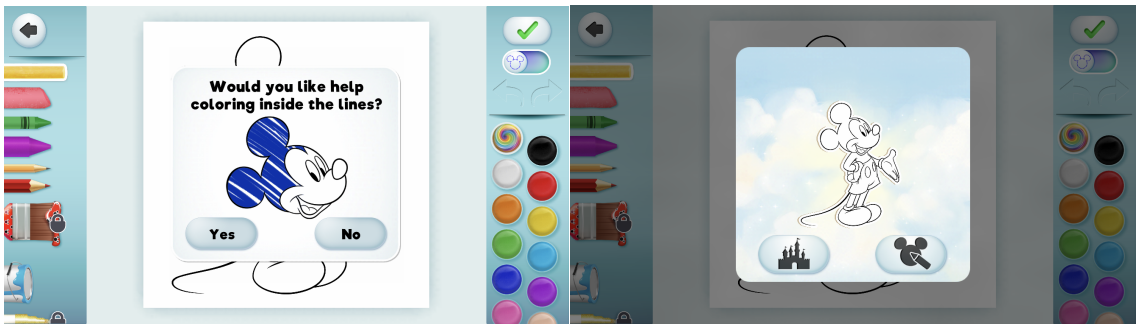

Figure 7. Screenshot from Disney Coloring Worlds application (Storytoys., n.d.).

3. MATERIALS AND METHODOLOGY

3.1. Interaction Design Process

The project was designed through a typical interaction design process that designers to create solutions to enhance and augment the way people work, communicate, and interact (Sharp et al., 2019). The following four primary phases are considered to design interactive products. The first phase is discovering requirements. In this phase, designers discover the problem and define what they will develop. This includes understanding the target users and the support that an interactive product could usefully provide. The second phase is designing alternatives. A designer is expected to produce a conceptual model for the product to solve the problem. The third phase is prototyping, in which a designer develops a low-fidelity or high-fidelity prototype. The final phase is evaluating. In this process, users are invited to evaluate the product to enhance the product.

This project followed the interaction design process as follows.

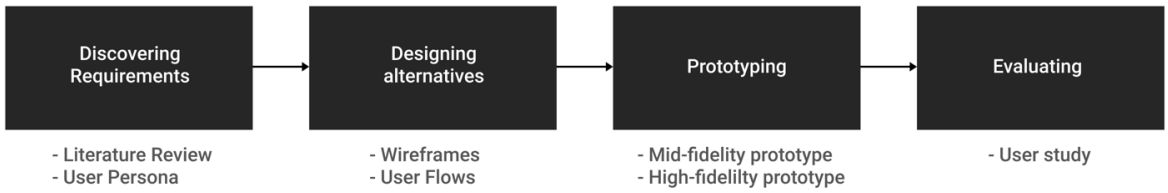

Figure 8. The design process of *ARtist*

A literature review was conducted to determine challenges in the current traditional art display system at school. After that, user personas (Babich, 2017) were developed to empathize users and understand users' requirements in the process. A user persona is a common tool that is

utilized in user interaction design. Two primary personas (male and female) were created. They are 10 years old children who are interested in making art (Figures 9 and 10). One persona is Joey who loves crafting and enjoys showing his artwork to his parents and grandparents. The second persona is Moana who enjoys drawing every day but feels quite shy in presenting her works to other people.

Figure 9. Persona workshop.

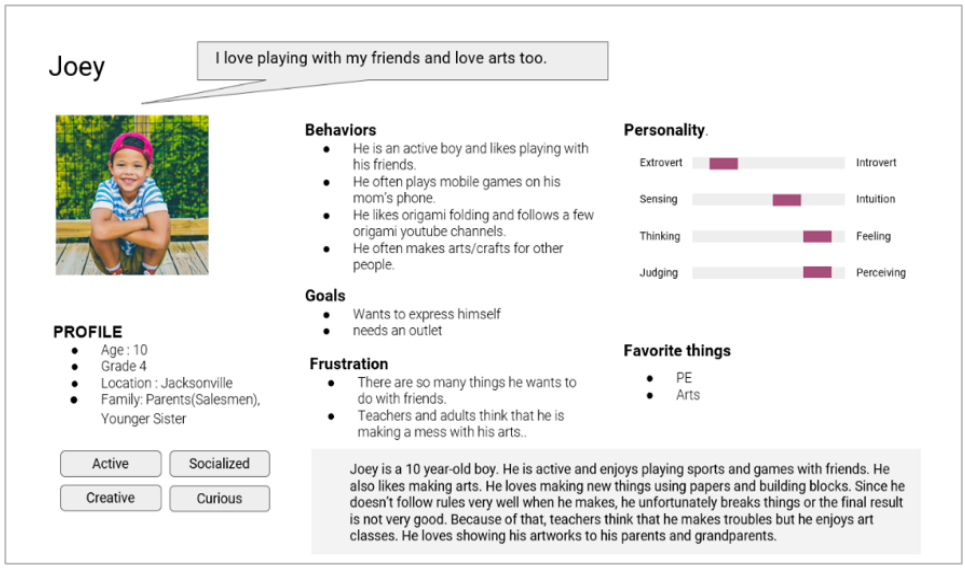

Figure 10. Personas for *ARtist*

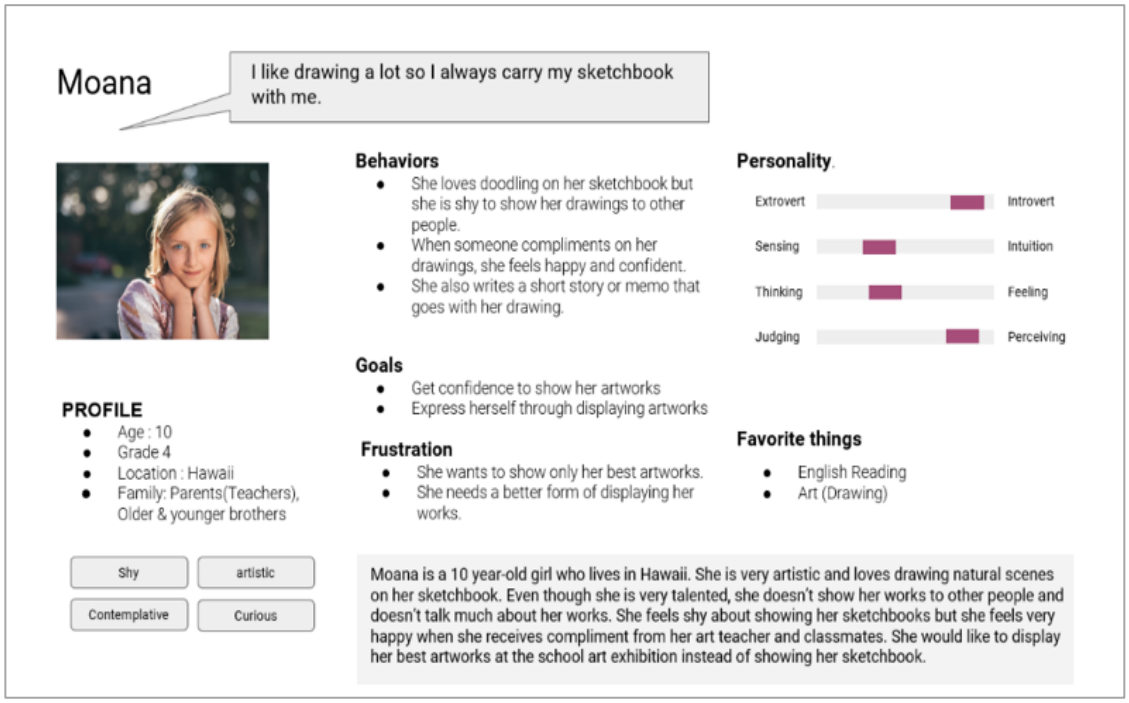

Figure 10 Continued.

Next, ideas about target users were explored, and key features and design guidelines were developed through the ideation workshop in the research team.

1. *ARtist* allows children to present their own artwork at any time they desire and to customize their artwork by utilizing the virtual space.
2. *ARtist* provides 3D assets (frames, pedestals, etc.) to decorate their artwork, encouraging children to engage with the application.
3. *ARtist* provides interactive experiences and positive feedback to encourage children to be more confident in displaying their artwork.
4. Because AR technology could be a new technology for children users, *ARtist* will teach them how to utilize the application.

Considering these design guidelines, multiple versions of wireframes and user flows were designed to visualize the ideas for the application. See Figure 11.

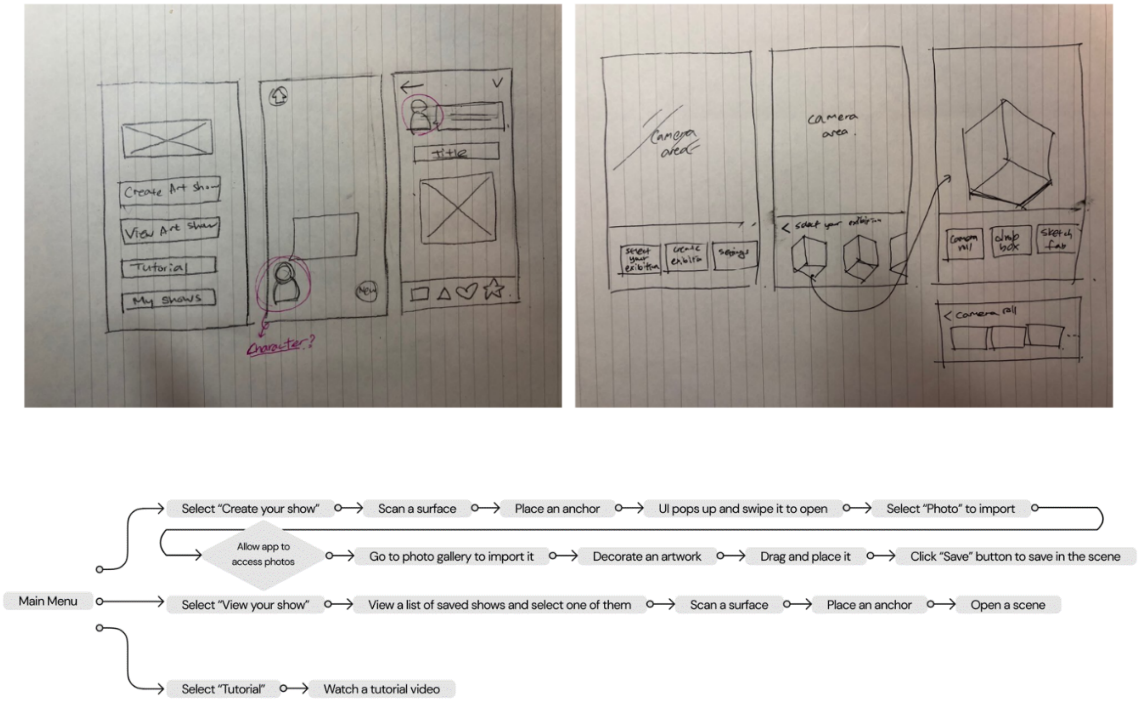

Figure 11. Wireframes and user flow.

The chosen wireframes were implemented with mid- and high-fidelity prototypes. A mid-fidelity prototype was created with the Figma tool (Figma, n.d.), which is a design program that specializes in interface design and prototyping. Once a mid-fidelity prototype was completed, it was developed as a high-fidelity prototype with Unity to incorporate AR functionalities and create an interactive prototype for users. Through iterations, a high-fidelity prototype was improved, and a final application was developed. Then, users were recruited for a user study to validate the proof of concept and to acquire user's feedback for improving designs.

3.2. *ARtist* Development

3.2.1. 3D Asset Creation

Maya 2019 (Autodesk, n.d.) and Substance Painter (Substance, n.d.) were utilized to create 3D frames and pedestals for *ARtist*. The 3D models were created with Maya and textured with Substance Painter. Each 3D asset's color schemes were designed with gender-preferences. Jonauskaite et al. (2018) stated that girls usually select pink or purple for their favorite hues. Conversely, boys select red as their favorite more often than girls. The most common favorite hue for both genders is blue. Children can decorate their artwork with provided 3D assets tailored to their preferences. See Figure 12.

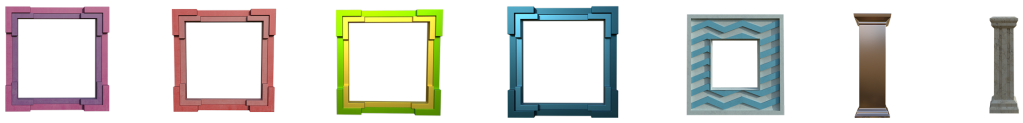

Figure 12. Examples of 3D assets in *ARtist*

3.2.2. Development

The *ARtist* application was built with Unity (Unity Technologies, n.d.) and Google ARcore (Google Developers, n.d.). Unity is a game engine platform that allows developers to create 3D and 2D games, experiences, models, and design. Google ARCore is a development kit for Android applications that utilizes three capabilities to incorporate virtual content with the user's environment through the user's phone camera: motion tracking, environmental understanding, and light estimation.

Additionally, Google provides interactions for manipulating objects, such as moving objects, rotating objects, resizing, and elevating an object through Unity. With Google ARCore functionalities, the *ARtist* application is built to detect a plane, anchor an object that a user has created, and manipulate objects with fingers in 3D space.

3.2.3. Features and User Experience Design

In the *ARtist* app, users can select photos of their artwork taken with a smartphone and load the photos in the application. Once users select the artwork, they can name it and decorate it with frames or pedestals. When they type the title of the artwork and selects a 3D frame or a pedestal for decoration, their artwork is displayed in a user's environment. Users can rotate the 3D artwork in any direction and anchor the augmented artwork to their needs. Their works are saved, and they can view them again if they desire.

The UI of the application is designed for children aged 8 to 10 years old. In this age group, children are familiar with touch screens and can easily comprehend common UI design capabilities (Falbe, 2015). Furthermore, according to Piaget's development theory (Ginsburg & Opper, 1988), children between the ages of 7 and 11 learn how to utilize logic to make inferences and reason about the world (Liu, 2018).

ARtist is designed with a simplified layout and information architecture that has a three-item menu. This menu allows children to understand the application easily from the first time they enter the application. Furthermore, tutorial videos teach them how to utilize this application. Regarding visual elements, bright colors and bold buttons have been implemented. A colorful avatar guides children through their journeys using the application. Moreover, the use of text is minimized, and the words employed ensure that children can understand. Simple control UIs are designed considering augmented reality applications. Apple and Google recommend allowing

users to utilize the entire screen in AR applications because it could reduce immersive experiences (Apple Developer, n.d.; Google, n.d.).

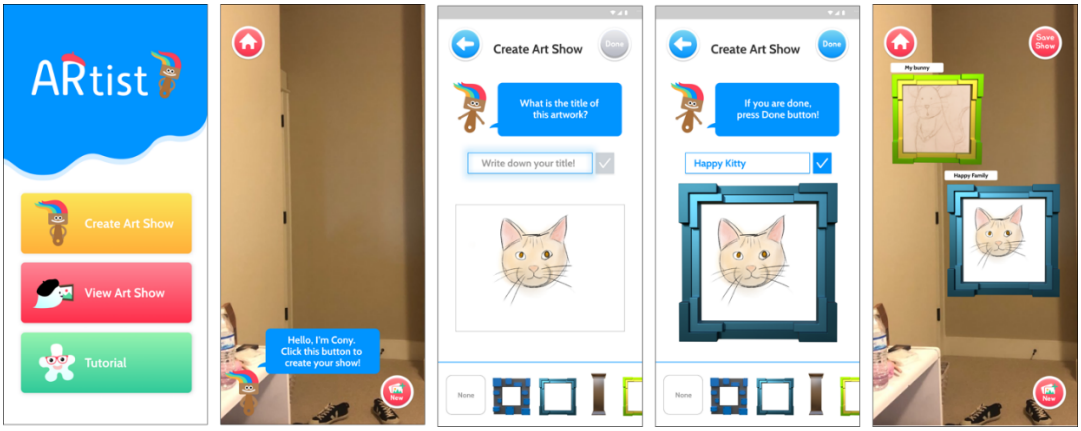

Figure 13. Start page of the *ARtist*, Scanning stage, Decoration stage, Modifying stage, Viewing stage

3.3. Methodology

A formal user study was performed to investigate and evaluate how an AR can enhance children's art display experiences.

3.3.1. Institutional Review Board Exemption

The appropriate institutional review board (IRB) approval was applied for, and an exemption status has been applied to the study. The study number was: IRB2019-1509D. All participants were asked for informed consent before they participated.

3.3.2. Recruitment of participants

Children who are interested in making arts were eligible for the user study. Furthermore, children aged 8 to 10 years were recruited because this age group is comfortable using mobile

interfaces (Falbe, 2015) and thinking logically about the world (Ginsburg & Opper, 1988; Liu, 2018).

Bulk email via the Texas A&M University System was delivered to recruit eligible users on September 1, 2020. Potential participants were asked to provide their availability and select a time slot to participate. The day before they participated in the study, participants were sent an email reminder regarding their chosen time to participate in the user study the following day. At the day and time of their user study participation time slot, users were asked to provide informed consent and assent forms before beginning their participation in their user study.

3.3.3 User study description

The user study was conducted from September 7 to 20 in 2020. It is occurred via Zoom video to reduce the risk of spreading COVID-19. All participants were given approximately 60 minutes maximum to complete the activities in the user study. The parents of each participant received the application APK file with detailed instructions through email, and they were asked to install the APK file to their phones one day before the study. Participants were additionally asked to collect their children's artworks and take photos of them. On the day of the study, participants entered the Zoom meeting, which the researcher provided.

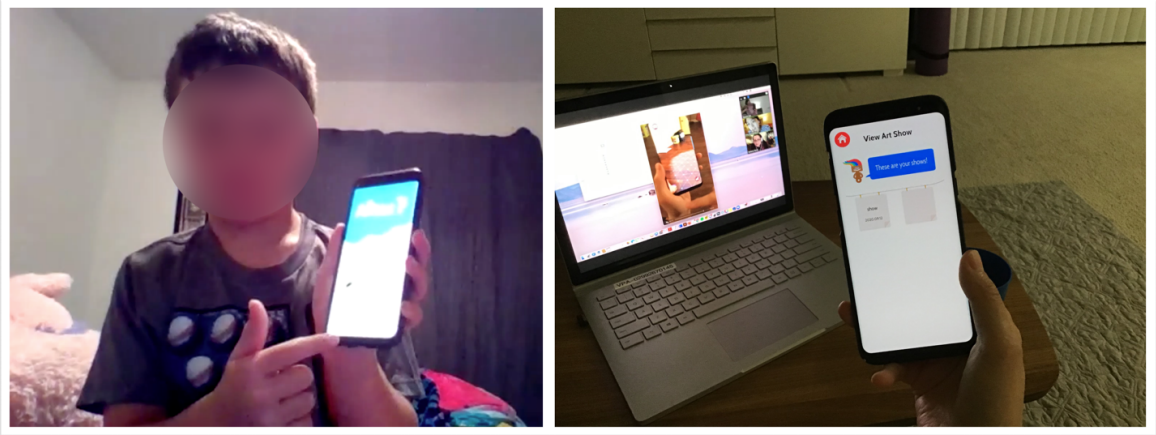

Figure 14. User study via Zoom (Zoom, n.d.)

The researcher explained the overview of this project and asked a few questions about participants' art experiences at school. Then, the researcher played a tutorial video of the application. After watching a tutorial video, a participant performed each task. Table 2 includes 7 steps to finish a task in *ARtist*. Each participant was asked to create a minimum of two artworks for one art show.

Table 1. *Steps of User Task*

1	Scan their environment and find a surface to anchor
2	Load a photo from a gallery of their phone
3	Title a piece of artwork and decorate it with 3D assets.
4	Place a decorated piece by moving, rotating, and changing its size.
5	Add another piece of artwork in a participant's environment
6	Title the art show and save it.
7	View a saved art show and present it to their parents.

After completing their interactions with *ARtist*, participants were interviewed by the researcher regarding their experiences and thoughts concerning the application. After that,

participants were asked to send a screenshot of their art show; this completed their participation in the study.

4. STUDY RESULTS AND DISCUSSION

4.1. Participant Information

In total, 10 volunteers participated in the user study for the *ARtist* application. Participants were children aged 8 to 10 years old who had interests in creating their own art. Five of the participants were male and five were female, see Table 2 for more detailed demographics. Six participants were currently enrolled in online classes due to COVID-19 and four participants were attending school in person. When they were asked whether they had art show experiences at school, seven participants responded affirmatively. However, because most schools are currently online, children mentioned that school art shows could not be held this year.

Table 2. *Participant Demographics*

Participant ID	Gender	Age
P01	Female	9
P02	Male	10
P03	Female	8
P04	Male	8
P05	Female	8
P06	Female	9
P07	Female	10
P08	Male	10
P09	Male	10
P10	Male	10

Regarding their favorite art activity, most respondents (7 participants), answered that their favorite activities were drawing and painting. Two participants answered that their favorite activities were crafting and one participant responded that he liked sculpting.

4.2. Data Collection and Analysis

Study data that was collected was both qualitative and quantitative in nature. Quantitative data included children's artworks. Qualitative data was collected via video recording and included interviews with the children and their parent and observations of the study session. Qualitative data was transcribed and further synthesized and analyzed into groups with common themes and relationships through affinity diagramming. Affinity diagraming is an inductive method that divides qualitative data from user research or design activities into smaller chunks and then organizes those chunks into groups of related information highlighting particular themes (Wilson, 2012). See Figure 15.

Figure 15. Affinity diagramming in the data analysis process

4.3. Research Findings

4.3.1. Participants' Creations within *ARtist*

4.3.1.1. Participant's artworks

The following images (Figure 16) are selected artworks that participants used in the creation of their AR art shows. The majority of the artworks were two dimensional such as paintings and drawings. This could be because the participants were more accustomed to creating 2D artworks at school, and they have displayed 2D artworks in the previous art shows. Some participants chose a specific artwork that held a unique meaning to them. For example, ID 02 mentioned how he chose his picture because it was the first time that he had appreciated his own artwork (Figure 16. A). ID 10 chose his artwork because he had drawn his pet (Figure 16. E). While there were participants who selected artwork they had already created, some participants created new pictures to display new works in this user study (Figure 16. D). In addition to drawings and paintings, ID 09 chose his family photo because it was taken with his siblings on the first day of school (Figure 16. C). ID 10 additionally displayed his sculpture because he likes sculpting in his art class (Figure 16. F).

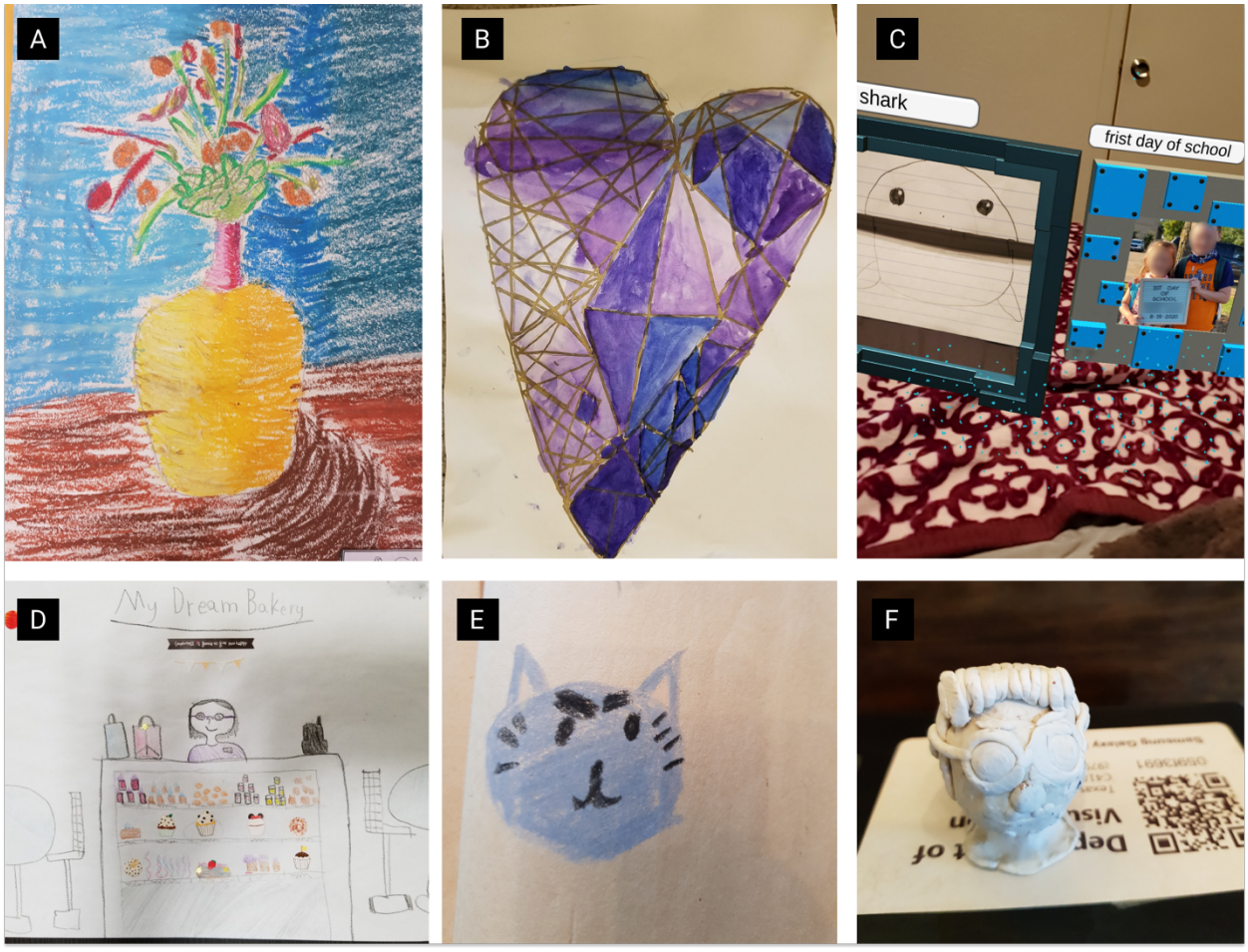

Figure 16. Examples of participants' artworks

4.3.1.2. Participant's choices of 3D digital assets

The majority of participants selected 3D digital frames to display their artwork. It is assumed that they chose frames because most of the artworks participants prepared were two dimensional and people were generally familiar with an artwork displayed in a picture frame. However, they loved employing a pedestal when they were suggested to do so to display their artworks. One interesting finding was that female participants frequently chose pink and purple frames to decorate their artworks, which can be seen in Figure 17.

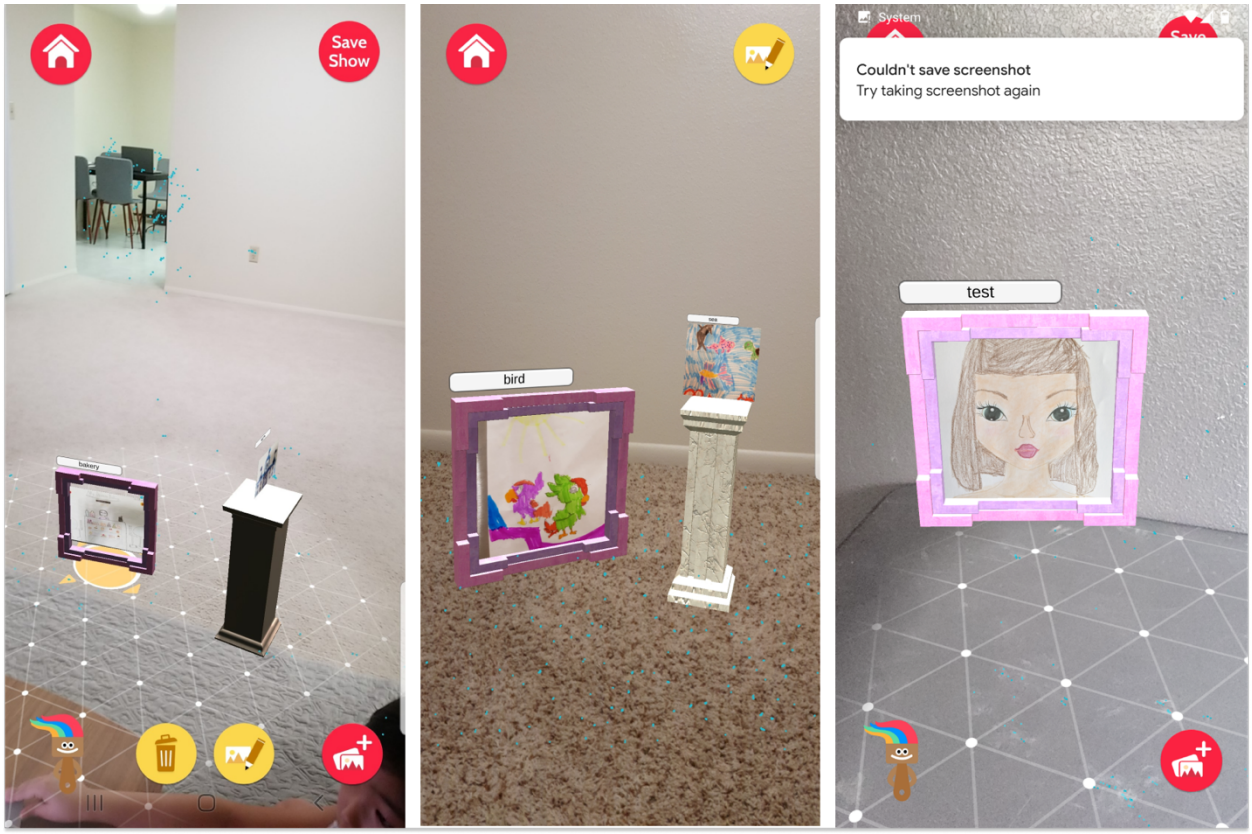

Figure 17. Selected AR art shows created by female participants

However, male participants' choices were diverse. Some of them chose blueish colors, and some of them chose red colors (Figure 18).

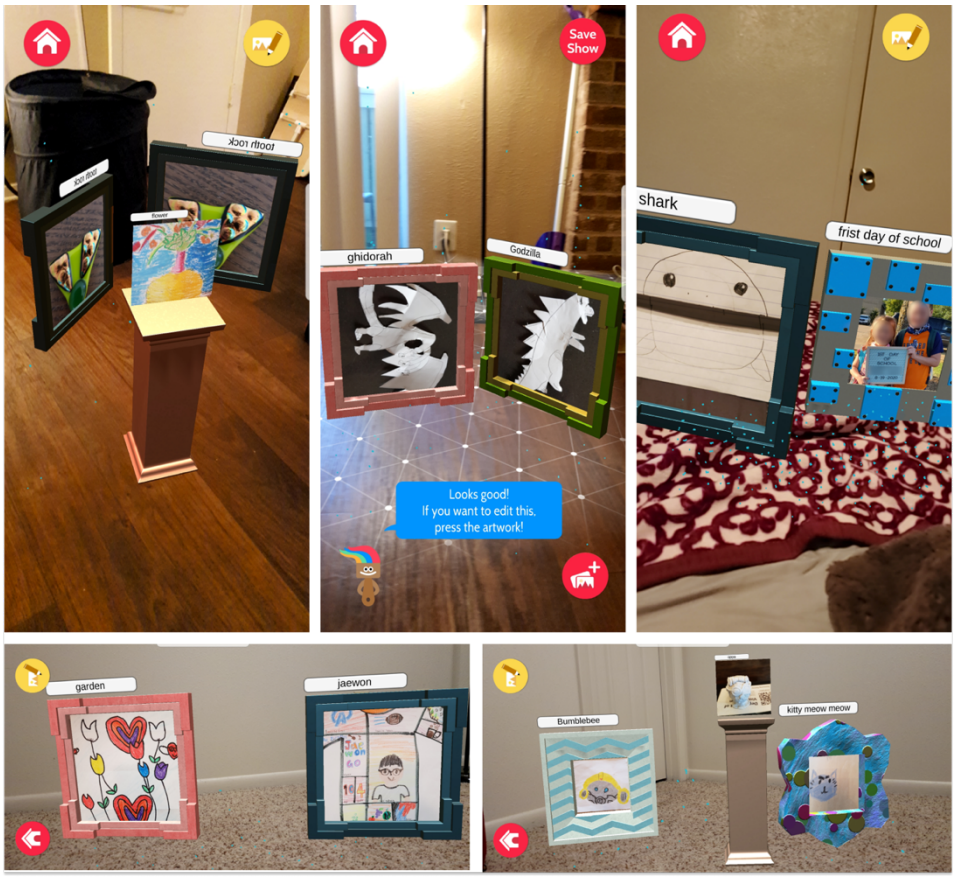

Figure 18. Selected AR art shows created by male participants

4.3.2. Qualitative Analysis

By using affinity diagramming main themes emerged and were categorized into the three following areas: 1) extended art experience; 2) integration of physical and digital components; and 3) encouragement of interaction & communication. Sub-themes were categorized under main themes, and they are listed and discussed in the sections below.

4.3.2.1. Extended Art Experience

a. Digitization of artwork

Children noted that one of the *Artist* application's positive qualities was that it preserves their art shows digitally. Participants' parents responded that they usually store children's

artworks in a box, a folder, on a shelf, or on a refrigerator door at home. They also mentioned that they would take pictures of their child's artworks and keep them digitally due to space limitation. Furthermore, some schools do not allow children to take their works home. Therefore, children mentioned how they want to keep their artworks in a digital format, and AR art shows in *ARtist* will allow them to save their artwork digitally and to view them whenever they want. These are participants' responses.

"If you have too many artworks, you should throw it. But you can see again with this app." (ID 08)

"It's cool to have work digitally." (ID 09)

"Mom would love to have this app because we don't have to keep all." (ID 10 - parent)

b. Additional decorations

Children mentioned wanting to have more 3D assets in the app to decorate their artwork and their space. For example, they wanted to decorate floors or walls with 3D assets and wished to match a background with the artwork. By utilizing their physical spaces and 3D assets, children can build and customize their own art gallery with a thematic concept of exhibition and augment their space. Below are some responses from the participants on wanting more decorations.

"I want to have more frames and pedestals." (ID 03)

'I think you could add like more parts to it. Like more things you can add, maybe like a place, like you can make the floor, like wood, you could make like your own little room, or you can put your artwork in and like, yeah. I mean, it's already good right now. So not much that like maybe some more things that you can put in to decorate your own gallery." (ID 02)

"I wanted to organize them." (ID 05)

"It would probably be cool if I used it in a curtain, like next to curtains so it could be like a backdrop. So that way the frame could look super cool." (ID 06)

4.3.2.2. Integration of Physical & Digital Components

a. 3D Artworks in the physical environment

Throughout the user study process one behavior observed from the children stood out the most. Once the participant's artwork was uploaded into the virtual space they felt excited and laughed loudly when they saw their AR artwork in their real time environment. Since AR was new technology to them, children were surprised that their artworks appeared in the application in a 3D form. This finding aligns with Huang et al. (2015), who said that kindergarten children's reactions to AR images were positive, and their acceptance of the activity was high, which implies that children of all ages can engage with AR content.

"It was fun especially drawings became in 3D. I think it gets like into cubes, spheres .. that's you make it and play with it." (ID 03)

"It made my artwork cooler." (ID 02)

"Picture things on the floor are really cool." (ID10)

"It's like another type of experience." (ID 07)

Children were also engaged with placing their 3D artworks in the virtual environment. The *ARtist* application allows children to move, rotate, elevate, and resize the 3D artwork with gesture interaction. In terms of proficiency with 3D manipulations, most participants were comfortable with utilizing gestural interaction after they watched a tutorial video. Some children figured it out by themselves but some other children had difficulty with rotating gestures. Generally, mobile AR applications require different gesture interactions to interact with 3D

objects. It is suggested that developers for AR applications for children have to consider children's fine motor skills and intuitive interface design.

"I thought it was super cool that you can move it around and that you can make it smaller or bigger, and you can put it anywhere in the room." (ID 06)

"It makes art fun. Instead of just making art, just sitting on your shelf, doing nothing, you can put it and just look at it while it's on like a pedestal in a frame. And it's just like a virtual art museum." (ID02)

"I liked dragging the picture and moving around." (ID 04)

Additionally, when 3D artwork appeared in the environment, children walked around in a circle to view their artwork from all directions. This behavior frequently caused them to lose the environment and 3D artwork. Google recommends utilizing visual or audio cues to encourage offscreen exploration (Google, n.d.) when a user loses 3D contents in the environment. Considering that children move frequently, this UX consideration is needed for AR applications. Furthermore, one participant suggested teaching users to situate themselves in spacious environments beforehand.

"Regarding the rotation, my daughter could not spin her thumb easily while holding the index finger." (ID 03 - parent)

"It's tricky to use it." (ID 06)

"Just when you make the tutorials, make sure to tell them that they need a big space so they can see it without scooting back. Because I did it on my blanket, and I had to scoot back a whole bunch to see it." (ID 09)

b. Holding AR art shows everywhere

During the interview children were asked whether they had a specific place to utilize this application and responded with diverse answers. Some participants replied that they would like to utilize the AR application in their bedrooms. Other participants responded that they would like to utilize the application outdoors, such as in a public space, a beautiful environment, around their pets, or at the beach. These responses indicate that AR technology can expand children's art activities to the outdoors. To make this possible, some environmental limitations should be improved. Currently, ARCore's limitations may hinder an accurate understanding of surfaces such as bright environments, blades of grass, or ripples in water (Google Developers, n.d.).

"If you have a painting, or you're, at the beach, you can put your pictures, sitting on the water." (ID 09)

"Everywhere is a good place to add. There's no. Well, like you could go outside, and you could just get on the floor and see some artwork or you're just sitting outside if you're bored. So, I feel like there's no specific place and making it better." (ID 02)

"I want to use this app around my cat." (ID 04)

4.3.2.3. Encouragement of Interaction & Communication

a. Sharing memories related to their artworks

During the interview sessions, children loved to tell their stories about their artworks and brought their physical artworks to researchers. For example, they explained what their artwork meant to them as they were creating it and how they created their pieces. This finding aligns with studies that state that children's experiences with their artwork are memorable for them (Boone, 2008). Kim et al. (2001) further posited that children's artwork is not merely just outcomes, and all processes of art creation could be regarded as an artwork.

"Can I show you my spin art?" (ID 01)

"Well, my rock, um, it all, that was the time I really started enjoying class. That was when I moved to that DM school. And that was my first art class. And it was so fun. So that's when I started enjoying art and the other one, my flower. That was the first time I appreciated my own artwork. I thought it was actually kind of good." (ID 02)

"I drew a superhero, and I laminated it, and I colored it, and they took it to the fair, my school did, and I won first place in my class." (ID 06)

Figure 19. One of the participants showing her work via Zoom

b. Sharing AR art shows virtually

Children also envisioned sharing their AR shows with friends and family virtually. The majority of participants responded that they would like to share their art shows with their friends

and relatives. This implies that *ARtist* encourages children to interact and communicate with others through their arts.

> *"When I saw the artwork in my app, I was pretty happy because when I need to show my friends it, they'll probably be able to see a show from virtual land, and it would be easier. And my family that's far away, like in Michigan. My Aunt Meg in Michigan 'cause she's gonna have a baby shower, and maybe that could be a present." (ID 01)*
>
> *"Just show to your friends now without, you know, all this coronavirus stuff, you can show it to them." (ID 02)*
>
> *"I want to share with my grandpa since he is an artist." (ID 03)*
>
> *"It would be cool if I could send it to my aunts because they live in Texas, and I would really like them to see my artwork." (ID 06)*

4.4. Challenges in the current *ARtist* design

4.4.1. Text entering system in *ARtist*

ARtist requires users to enter their titles for artwork and each art show. However, many participants asked their parents to type because many children do not have personal smartphones, and, therefore, they are neither accustomed to utilizing keyboards in a mobile device nor do they know how to spell. One participant attempted to utilize a voice assistant to type. This UX could be improved by utilizing speech-to-text technology or recording functionalities.

4.4.2. Flexible screen orientation

Some participants tilted the smartphones to use the application in a landscape mode, but the current application only provides a portrait mode. Future improvements should consider button placements for both orientations. Additionally, several participants took photos of their artworks in landscape orientation and attempted to rotate the photos in the decorating process.

Because the current application only allows users to adjust the size of their photos to fit in the frames or on the pedestals, some participants suggested adding this functionality.

4.4.4. Tutorial for onboarding

In this user study, participants watched a tutorial video for each task protocol and then performed each task by themselves. After watching the tutorial, participants were able to understand how to use this application. However, many children did not follow the instruction, and they wanted to attempt to manipulate the application by themselves initially. To allow child users to learn the AR interaction quickly, integrating an interactive tutorial for each task will be appropriate so that users are not overwhelmed by a long video tutorial.

4.5. Discussion

These research findings show future possibilities in formal and informal art education. Children can broaden their art experiences by virtually sharing art shows and art-related memories with others. One of the goals of traditional art displays is communicating through artworks. While chatting about their artwork, artists can learn from other works. (Seefeldt, 2002). Hurwitz and Day (1991) contended that this process is educational for children because this allows them to observe reactions from others, and they may gain insights from others. As a result of COVID-19, children have a difficult time to meeting and communicating with friends. They cannot access to typical art display experience because of online schooling and social distancing. We believe that *ARtist* encourages children to create artworks and communicate with others about their artworks virtually. This provides a broader perspective on the children's art. As Roland (2005) stated, displaying students' work in public is a way to motivate students. In addition, through placing 3D artworks in a virtual environment, children can examine artworks from different directions and learn how to arrange their artworks with a physical environment.

5. CONCLUSION

The goal of this project was to create an AR application for children to create their own art shows outside of the school environment. We investigated how AR technology can allow children to display and curate their artworks. In the project, the *ARtist* application was designed through an interaction design process to focus on design guidelines and usability for children. Next, a user study was conducted with a total of 10 participants. By analyzing and synthesizing data through affinity diagramming, main themes emerged from the data. We organized them in three categories: 1) extended art experience; 2) integration of physical & digital component; and 3) encouragement of interaction & communication. The majority of the participants' feedback was highly positive. These findings indicate that AR can offer a new way of presenting and sharing artworks in formal and informal art education.

During the user study, current UX and UI issues were discovered, and they need to be updated to improve the user experience. The typing interface for children, supporting landscape mode, and developing an effective tutorial inside of the app should be considered for future UX and UI development. Participants also responded that they wanted to have social communication components, such as collaborating and sharing in real time. These new functionalities will be newly developed for better user experiences in the near future. In addition, design considerations for safety should be handled for AR because users cannot easily be aware of their physical environments when they are immersed in an AR screen.

In this project, we explored how children can use AR for their art display and curation in an informal setting, focusing on children's organization. ARtist can be incorporated in the formal education setting such as, art classes at school. An art instructor can organize the class art show

within ARtist and share it with students and parents. Students also can be invited into the curation activities. Through this process, school art activities will be positively appreciated and teachers, students, and parents will share the common educational vision and belief. Furthermore, even though this research focused on visual art education, other subjects such as science, or history can also be considered for improving the educational environment using AR technology.

REFERENCES

Apple Developer. (n.d.).

Human Interface Guidelines. Retrieved September 26, 2020, from https://developer.apple.com/design/human-interface-guidelines/ios/system-capabilities/augmented-reality/

Autodesk. (n.d.). Maya Software. Retrieved September 26,2020, from https://www.autodesk.com

Azuma, R. T. (1997). A survey of augmented reality. Presence: Teleoperators & Virtual Environments, 6(4), 355-385.

Babich, N. (2017, September 29). Putting Personas to Work in UX Design: What They Are and Why They are Important. Adobe Blog. https://blog.adobe.com/en/publish/2017/09/29/putting-personas-to-work-in-ux-design-what-they-are-and-why-theyre-important.html

Boone, D. J. (2008). From the refrigerator door to the art gallery floor: young children's experiences with the display of their own visual artwork (Doctoral dissertation, Queensland University of Technology).

Bresler, L. (1992). Visual art in primary grades: A portrait and analysis. Early Childhood Research Quarterly, 7(3), 397-414.

Burton, D. (2006). Exhibiting student art: The essential guide for teachers. Teachers College Press.

Burton, D. (2006). Exhibiting student art: The essential guide for teachers. Teachers College Press.

Burton, D. (2010). Web-based student art galleries. Art Education, 63(1), 47-52.

Chatzopoulos, D., Bermejo, C., Huang, Z., & Hui, P. (2017). Mobile augmented reality survey: From where we are to where we go. Ieee Access, 5, 6917-6950.

Chen, P., Liu, X., Cheng, W., & Huang, R. (2016). A review of using Augmented Reality in Education from 2011 to 2016. Innovations in Smart Learning, 13–18.

Danko-McGhee, K., & Slutsky, R. (2003). Preparing Early Childhood to Use Art in Teachers the Classroom. Art Education, 56(4), 12-18.

DisneyResearchHub. (2015, Oct 2). Live Texturing of Augmented Reality Characters from Colored Drawings [Video]. YouTube. Retrieved from https://youtu.be/SWzurBQ81CM

Druin, A., Bederson, B. B., Hourcade, J. P., Sherman, L., Revelle, G., Platner, M., & Weng, S. (2001, January). Designing a digital library for young children. In Proceedings of the 1st ACM/IEEE-CS joint conference on Digital libraries (pp. 398-405).

Eisner, E. W. (2004). The Arts and the Creation of Mind (New edition). Yale University Press.

Falbe, T. (2015, August 10). Designing Web Interfaces For Kids. Smashing Magazine. https://www.smashingmagazine.com/2015/08/designing-web-interfaces-for-kids/

Figma. (n.d.). Figma. Retrieved September 26, 2020, from https://www.figma.com

Furió, D., Juan, M.-C., Seguí, I., & Vivó, R. (2014). Mobile learning vs. traditional classroom lessons: a comparative study. Journal of Computer Assisted Learning, 31(3), 189–201.

Gadsden, V. L. (2008). The arts and education: Knowledge generation, pedagogy, and the discourse of learning. Review of research in education, 32(1), 29-61.

Gallavin, G. (2019, April 29). UX for Kids' Products: Designing for the Youngest of Users | UserTesting Blog. UserTesting. https://www.usertesting.com/blog/ux-for-kids

Ginsburg, H. P., & Opper, S. (1988). Piaget's theory of intellectual development. Prentice-Hall, Inc.

Google Arts&Culture. (n.d.). Google Arts & Culture. Retrieved September 26, 2020, from https://artsandculture.google.com/project/ar/art

Google Developers. (n.d.). ARCore. Retrieved September 26, 2020, from https://developers.google.com/ar

Google. (n.d.). Augmented Reality Guidelines. Retrieved September 26, 2020, from https://designguidelines.withgoogle.com/ar-design/augmented-reality-design-guidelines/introduction.html

Hanna, L., Risden, K., Czerwinski, M., & Alexander, K. J. (1998). The role of usability research in designing children's computer products. In The design of children's technology (pp. 3-26).

Hourcade, J. P. (2007). Interaction Design and Children. Foundations and Trends® in Human-Computer Interaction, 1(4), 277–392.

Huang, Y., Li, H., & Fong, R. (2016). Using Augmented Reality in early art education: a case study in Hong Kong kindergarten. Early Child Development and Care, 186(6), 879-894.

Huang, Z., Hui, P., Peylo, C., & Chatzopoulos, D. (2013). Mobile augmented reality survey: a bottom-up approach. arXiv preprint arXiv:1309.4413.

Hurwitz, A., & Day, M. (1991). Children and Their Art (5th ed.). Harcourt College Pub.

Jefferson, B. (1965). TEACHING ART TO CHILDREN: The Values of Creative Expression. Allyn and Bacon, Boston, MA.

Jonauskaite, D., Dael, N., Chèvre, L., Althaus, B., Tremea, A., Charalambides, L., & Mohr, C. (2019). Pink for girls, red for boys, and blue for both genders: Colour preferences in children and adults. Sex Roles, 80(9-10), 630-642.

Kail, R. (1991). Developmental change in speed of processing during childhood and adolescence. Psychological Bulletin, 109(3), 490–501.

Kim, H., Park, E., & Lee, J. (2001). “All done! Take it home.” Then into a Trashcan?: Displaying and Using Children's Art Projects. Early Childhood Education Journal, 29(1), 41-50.

Kosa, M. (2018, July 2). Children-first design: why UX for kids is a responsible matter. Medium. https://uxdesign.cc/ux-for-kids-responsible-matter-802bd12fe28c

Kuhnert, M. (2014). Displaying children's artwork (Doctoral dissertation).

Liu, F. (2018, December 16). Designing for Kids: Cognitive Considerations. Nielsen Norman Group. https://www.nngroup.com/articles/kids-cognition/

McArdle, F. (2001). Art in early childhood: the discourse of'proper'teaching (Doctoral dissertation, Queensland University of Technology).

Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays. IEICE TRANSACTIONS on Information and Systems, 77(12), 1321-1329.

Nick Jr. (n.d.). Nick Jr. Retrieved September 29, 2020, from http://www.nickjr.com/

Roland, C. (2005). The art teacher's guide to the Internet. Davis Publications.

Rosman, K. (2020, September 25). Home Schooling and Remote Learning: How to Teach Now. Https://Www.Nytimes.Com/#publisher. https://www.nytimes.com/2020/09/23/style/wild-and-free-home-school.html

Ryffel, M., Zünd, F., Aksoy, Y., Marra, A., Nitti, M., Aydın, T. O., & Sumner, B. (2017). AR Museum: a mobile augmented reality application for interactive painting recoloring. ACM Transactions on Graphics (TOG), 36(2), 19.

Schroeder-Yu, G. (2008). Documentation: Ideas and Applications from the Reggio Emilia Approach. Teaching Artist Journal, 6(2), 126–134.

Seefeldt, C. (2002). Creating Rooms of Wonder: Valuing and Displaying Children's Work to Enhance the Learning Process. Gryphon House.

Sharp, H., Preece, J., & Rogers, Y. (2019). Interaction Design: Beyond Human-Computer Interaction (5th ed.). Wiley.

Shneiderman, B. (2002). Promoting universal usability with multi-layer interface design. ACM SIGCAPH Computers and the Physically Handicapped, (73-74), 1-8.

Shneiderman, B., & Plaisant, C. (2010). Designing the user interface: strategies for effective human-computer interaction. Pearson Education India.

Short, B. (2007). Guiding the Future: How Art Enhances a Montessori Child's Life. Montessori Life, 19(2), 20.

Spodek, B. (1993). Selecting Activities in the Arts for Early Childhood Education. Arts Education Policy Review, 94(6), 11–17. https://doi.org/10.1080/10632913.1993.9936936

Spotify Kids. (n.d.). Spotify. Retrieved September 26, 2020, from https://www.spotify.com/us/kids/

Storytoys. (n.d.). Disney Coloring Worlds. Retreved September 29, 2020, from https://storytoys.com/app/disney-coloring-world/

Strauss, V. (2014, September 29). Why the kids who most need arts education aren't getting it. Washington Post. https://www.washingtonpost.com/gdpr-consent/?next_url=https%3a%2f%2fwww.washingtonpost.com%2fnews%2fanswer-sheet%2fwp%2f2014%2f09%2f29%2fwhy-the-kids-who-most-need-arts-education-arent-getting-it%2f

Substance. (n.d.). Substance 3D. Retrieved September 26, 2020, from https://www.substance3d.com/

The National Art Education Association. (n.d.). National Core Arts Standards. Retrieved September 26, 2020, from https://www.nationalartsstandards.org/

Twigg, D. (2011). Look Out below (and Above)! Challenging Adult Understandings of Displaying Young Children's Artwork. Contemporary Issues in Early Childhood, 12(3), 262–273.

Unity Technologies, U. (n.d.). Unity. Retrieved September 26, 2020, from https://unity.com/unity/features/ar

Wilson, C. (2012). Method 22 of 100: Affinity Diagramming.

Witkowski, J. (2019, March 26). Lullabot. Lullabot. https://www.lullabot.com/

Young, M. (1973). Elementary Art Guide, 1972-1973.

YouTube Kids. (n.d.). YouTube Kids. Retrieved September 26, 2020, from https://youtube.com/kids/

Zoom. (n.d.). Zoom Video. Retrieved October 19, 2020, from https://zoom.us/

Zünd, F., Ryffel, M., Magnenat, S., Marra, A., Nitti, M., Kapadia, M., ... & Sumner, R. W. (2015). Augmented creativity: Bridging the real and virtual worlds to enhance creative play. In SIGGRAPH Asia 2015 Mobile Graphics and Interactive Applications (pp. 1-7).