6-16-2024

AR Storybook

Priya Jain

Jessica Torres

Melody Trinh

SANTA CLARA UNIVERSITY

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

Date: June 16, 2024

I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Priya Jain
Jessica Torres
Melody Trinh

ENTITLED

AR Storybook

BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREES OF

BACHELOR OF SCIENCE IN COMPUTER SCIENCE AND ENGINEERING
BACHELOR OF SCIENCE IN WEB DESIGN AND ENGINEERING

Sharon Hsiao
Thesis Advisor

Department Chair

AR Storybook

by

Priya Jain
Jessica Torres
Melody Trinh

Submitted in partial fulfillment of the requirements
for the degrees of
Bachelor of Science in Computer Science and Engineering
Bachelor of Science in Web Design and Engineering
School of Engineering
Santa Clara University

Santa Clara, California
June 16, 2024

AR Storybook

Priya Jain
Jessica Torres
Melody Trinh

Department of Computer Science and Engineering
Santa Clara University
June 16, 2024

ABSTRACT

Parents often use technology as a digital pacifier or source of entertainment for their children. While excessive screen time for children can be harmful, a digital future seems inevitable. As technology becomes more prominent in everyday life, children should utilize their early years to engage with technology in a way that develops their growing minds. AR Storybook is an interactive storybook that strives to provide children with an active learning experience. The story teaches children computational thinking skills through augmented reality activities embedded into the plot. The activities ask the user to help a character complete a task by using a computational thinking skill. The skills taught are algorithmic thinking, pattern recognition, and decomposition. There is a physical and digital version that allows parents to be involved in the learning process to prevent excessive screen time. We used Adobe Illustrator to write and illustrate the book, Blender to create the 3D models for our augmented reality activities, and 8thWall to host the activities. Overall, we found that parents want their children to learn computational thinking skills. These children are already using technology, so our product simply redirects their focus to enrich their use of technology.

Table of Contents

List of Figures

Chapter 1

Introduction

This project aims to explore educating young children on computational thinking concepts through parent-child storytelling. Learning computational thinking at a young age has several advantages. Children are equipped with valuable tools to navigate and adapt to today's rapidly evolving digital world. They also develop systematic and logical approaches to various problems. Understanding problem decomposition and pattern recognition encourages creative solutions and innovative thinking. Computational thinking serves as a basis not only for various STEM disciplines but also for daily tasks such as organization and planning [1]. The target age range is 3 to 6 years old as the first few years of a child's life are a vital time in their growth and should be monitored, particularly when it comes to screen time. Our project was designed to include parent involvement to prevent excessive screen time.

1.1 Problem Statement

Children are increasingly exposed to technology at a young age, often through the use of mobile devices. "Parents often use media as pacifiers, giving mobile devices to their children to keep them calm... It has also been shown that parents allow the use of mobile devices to their children to keep them busy while carrying out domestic activities, to facilitate their sleep, and to keep them calm rather than simply consoling the child in times of crying" [2]. With the rapid advancement of technology, our world is becoming increasingly digitized. "...Children's use of and exposure to [media, technology, and screen time] can lead to decreases in executive functioning (ability to attend to tasks), academic performance, quality social interactions with parents and peers, and creative play" [3]. While concerns exist regarding the potential negative effects of excessive screen time for children, the progression towards a digital future seems inevitable. As technology becomes increasingly embedded in our daily lives, children should move beyond passive consumption and engage with it in ways that foster intellectual growth. One avenue for achieving this is to interact with content that promotes computational thinking.

1.2 Background or Related Work

Several applications have used AR to teach children different topics, with some being more educational than others.

Immerse is an app that aims to teach children about STEM topics [4]. There are a variety of 3D models of animals and machines that the user can interact with and learn facts about. There are also quizzes to ensure the child reads and learns from the facts listed alongside the 3D model. Although this app does have educational AR features, it lacks a storyline, creating a disconnect between activities. Furthermore, there is little room for parents to be involved since the child can navigate the app on their own. Part of what our project aims to do is have a book that parents can help read to their child to get them involved with the child's learning.

Peronio is an interactive pop-up book very similar to our project [5]. It has different puzzles for the user to complete on every page. It can be found in multiple formats, such as VR and AR. It is more interactive than most AR applications and is educational in that it aims to help children discover different career paths in a fun way. Some concepts from this app that we also applied to our project are having both a physical and digital copy of our book, having different AR features and activities for each page, and having music playing in the background.

The Case of the Missing Cleopatra comes in a physical book format with AR features as well as a VR version [6]. The user can see 3D animations of the characters and items illustrated in the physical book and can complete puzzles. The VR version is a more immersive experience since the user can explore 3D components in more depth. Similar to this application, our project has activities on every page that the user can complete.

1.3 Objectives

To explore teaching computational thinking skills to young kids using an augmented reality storybook, we set out to achieve the following objectives:

1. Build an augmented reality application with both physical and digital components
2. Write stories centered on computational thinking skills and accompany it with artwork
3. Evaluate the feasibility and usability of the design

1.4 Our approach

We used Adobe Illustrator to write and illustrate our story, and 8thWall to create our accompanying activities. 8thWall is a platform that enables developers to create augmented reality experiences directly from web browsers. Initially, we considered using AR.js to create our augmented reality component, but 8thWall offers several advantages. It provides a cloud-based editor and hosting platform, making collaboration and publishing simple. It also includes a variety of pre-built features and templates to help us get started quickly and easily. 8thWall offers better compatibility with a

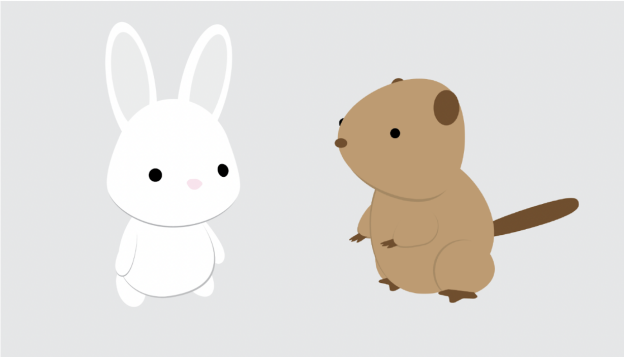

Figure 1.1: Bunny and Beaver Character Design

wider range of mobile browsers, including older versions of iOS and Android. This will make it more accessible to our intended audience. There is also detailed documentation and tutorials available for 8thWall.

In developing the plot for AR Storybook, we focused on incorporating elements and events that would be appropriate and engaging for our targeted audience. Eventually, we created a pair of characters, Bunny and Beaver, who are best friends (Figure 1.1).

One day, Beaver gets invited to Bunny's house, where the main plot follows Beaver's journey. Along the way, Beaver encounters smaller challenges, providing the opportunities to introduce CT skills.

In the following sections, we will discuss our stakeholders and their needs before diving into the design and development process of AR Storybook. This includes our system design, technologies used, functional and non-functional requirements, and a timeline of our work. Additionally, we will also address risks and constraints to our project, and any standards we followed while implementing the project. Finally, we will reflect on any societal and ethical issues that AR Storybook pertains to.

Chapter 2

User Research

2.1 Methods

To identify user needs, we brainstormed multiple potential features that the user may want when interacting with our project. This was done through empathizing with our target market and doing research on other similar products, as mentioned in the related work section. This method helped us tailor our project so that users have the best experience possible.

2.2 Stakeholder needs

Our stakeholders are children and any adults who want to use technology to introduce computational thinking skills to young children. In this case, this would be parents or educators who work with the target audience.

Children need a story that is interactive and engaging, instructions that are clear and age-appropriate, visually appealing AR elements that enhance the story, a safe and secure AR experience, and overall a fun and rewarding learning experience.

Parents and educators need a safe and controlled AR environment for children, educational value from the storybook, and an application that is easy for children to use and understand.

Our main focus is parents since we want them to be involved in the learning process by reading to their child. The other main focus is having a positive impact on children's development.

2.3 User stories

As a parent, I want my child to use technology in a safe but fun way so that it does not hinder their development.

As a parent, I want the technology to have age-appropriate content so that my child is exposed to suitable material.

As an educator, I want my students to learn computational thinking skills so that they can use these skills in other subjects.

Chapter 3

Literature Review

3.1 Introduction

Computational thinking (CT) is the process of formulating and solving problems by breaking them down into simple steps. This process can be used to support problem-solving in all disciplines and allows students to engage in experiential learning of content-related problems. The characteristics that define computational thinking are decomposition, pattern recognition, abstraction, algorithm design, and evaluation. Decomposition is the process of breaking a complex problem down into smaller problems that are more manageable. Pattern recognition is the process of identifying patterns and relationships between information. Abstraction is the process of extracting the essence of a problem. Algorithm design is the process of creating a series of ordered steps to solve a problem. Evaluation is the process of checking and revising solutions for accuracy and efficiency.

Augmented reality (AR) is an interactive experience that uses the existing real-world environment and puts virtual information or a virtual world on top of it to enhance the experience. Educators can use augmented reality technology to create educational content by materializing abstract concepts, which will enable students to visualize and understand challenging subjects. There are several applications of augmented reality being used in education. This section focuses on a select few applications that have been specifically designed to teach the process of computational thinking to students.

3.2 Integrating computational thinking in education

Computational thinking allows children to gain problem-solving strategies as well as a set of non-cognitive skills for processes including critical thinking, collaboration, and communication. Making and interacting with artifacts foster a student's creativity and curiosity, and interacting with computational thinking-enabled kits encourages children to socialize and communicate with each other.

These skills are fundamental for children to develop positive learning mindsets and attitudes.

As such, CT provides great learning opportunities for students to develop their cognition and social skills that

empower them to perform well and achieve goals in the future.

However, it can be challenging to learn and teach computational thinking in an early childhood education setting for a few reasons.

1. Children do not learn computational thinking concepts at a young age.
2. Educators will need to design age-appropriate activities for young students.
3. There is a lack of valid and reliable computational thinking assessments for young children, which could be attributed to a need for consensus on computational thinking frameworks and definitions.
4. Young children find it challenging to negotiate and solve problems with their peers.
5. Robotics and programming can cause gender bias because young girls will feel demotivated by boy-dominated activities, which can lead to digital inequity in early childhood education and society [7].

3.3 Stimulating computational thinking through augmented reality

The authors in [8] developed an Android-compatible augmented reality application that tracks physical cards that then creates 3D maps for the user and gives them a character that can be programmed to walk on said map. When the application was tested by children, they had a hard time tracking the map like they wanted because devices with low processing have problems with map tracking. Despite these technical difficulties, it was still positively received by children because they enjoyed getting to use augmented reality to create their own map. This led the authors to conclude that this technology has the potential to stimulate computational thinking skills in children.

3.4 Exploring computational thinking skills through AIoT

Artificial intelligence of things (AIoT) is a combination of artificial intelligence (AI) technologies and the Internet of things (IoT) infrastructure. It aims to solve real-world problems by integrating sensing technologies with relevant algorithms. The authors in [9] conducted a study with the intent of exploring the effect of computational thinking skills. They had students use augmented reality applications to understand AIoT applications, place different AR sensors in real-life scenarios, and generalize and design algorithms. Based on the results of the experimental course, the authors concluded the following:

1. The introduction of the augmented reality AIoT application had an impact on computational thinking competency performance in terms of creativity, logical thinking, and problem-solving.
2. The augmented reality application did not improve students' programming skills or algorithmic exercises.

3. The cognitive load of science and technology had minimal impact on students.

AIoT learning had a positive impact on problem-solving and comprehension with AR technology.

3.5 Developing computational thinking skills by learning about augmented reality

The authors in [10] take a constructionist approach with ExposAR, an educational augmented reality authoring experience that enables children to engage with augmented reality concepts, practices, and perspectives by building and testing an augmented reality application. It is a Pokémon GO-inspired game with two simple game elements: gems and star vending machines. Virtual gems can be collected in the physical space and exchanged for stars at the star vending machine. ExposAR is related to the concept of computational thinking because it exposes children to the computational concepts of augmented reality, which enables them to reflect on the role of augmented reality technologies in their own lives.

3.6 Conclusion

Augmented reality can be a powerful tool in education because it can help students with complicated subjects and lets educators enhance classroom experiences and teach new skills. Unfortunately, there has been a slow adoption of augmented reality in the classroom due to the extra equipment, the quality of educational content, concerns over its academic value, and a lack of proper funding. However, if we can find the solutions to these problems while also integrating computational thinking into the activities, it will make a positive impact on a child's education because it will provide them with tools to succeed in the future. They will become more effective communicators, planners, critical thinkers, and problem solvers.

Chapter 4

Design and Rationale

4.1 Design

At a high level, the system is an interactive AR storybook with both physical and digital components. The storybook acts as a trigger for the AR experience, as explained in Figure 4.1. It contains markers in the form of QR codes. Users will need a device with a camera to scan the QR codes which will redirect them to a webpage with the corresponding AR activity. Figure 4.2 illustrates this system diagram. In total, there are 4 AR activities. The first is simply an introductory activity that allows users to become familiar with the AR space and navigation. This is followed by 3 activities, each teaching the user a different computational thinking skill. Here is a brief overview of each activity:

1. Algorithm Design: to reach a solution through a series of steps Beaver is getting ready to leave for Bunny's house. Users will be asked to place a series of steps in the correct order to help him get ready.

2. Pattern Recognition: to identify patterns and regularities in data On the way to Bunny's house, Beaver encounters some mud. Users will be asked to select the correct item that matches a key.

3. Decomposition: to break down a larger, complex problem into smaller problems Bunny is missing a chair for Beaver. Users will help assemble a chair by placing each piece in its correct spot.

4.2 Functional requirements

- The system must teach children computational thinking skills to prepare them for the education system.
- The system must get parents involved in the child's screen time to make sure they are not spending an excessive amount of time on technology.
- The system must introduce reading material to children so they can learn to read.

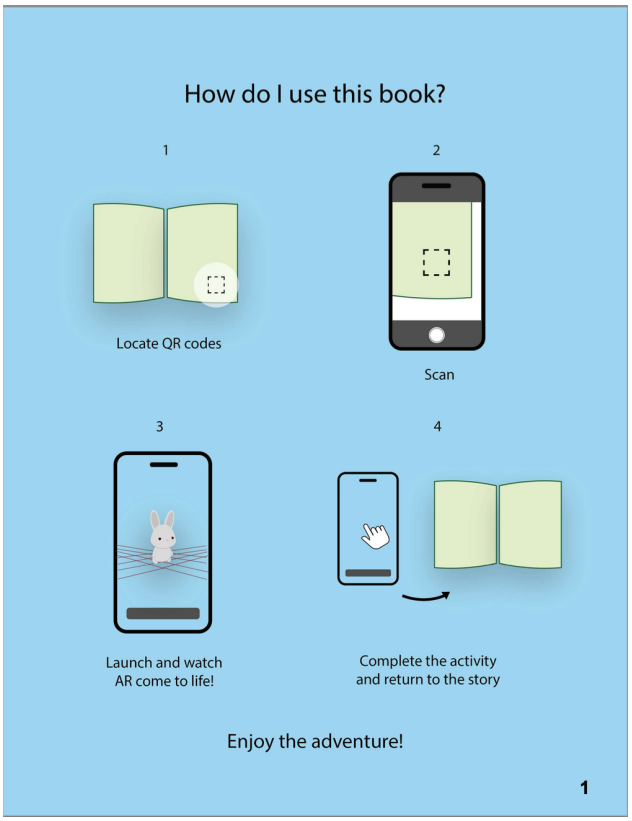

Figure 4.1: Book Instructions

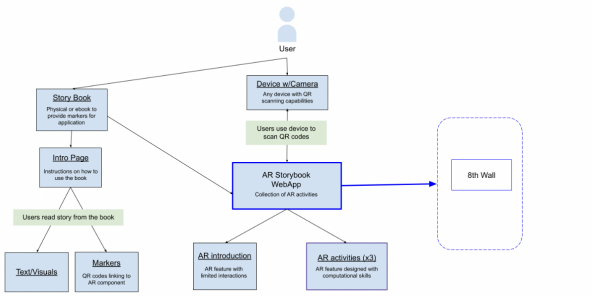

Figure 4.2: System Diagram

4.3 Non-functional requirements

- The system shall be compatible with any device and modern browser.
- The system shall be easy for children to use and navigate.
- The system shall run smoothly and without lag.
- The system shall be reliable and avoid crashes.

4.4 Rationale

We wanted the system to have a physical storybook to allow children to take a break from technology and encourage parents or guardians to engage with their child by reading to them. We also wanted the storybook to be in a digital format to make sure it is accessible to anyone regardless of their location. We wanted to include augmented reality components to help users visualize and interact with concepts in real time while still being aware of their surroundings.

Chapter 5

Technologies

5.1 System Components

The digital component of AR Storybook is built and hosted entirely on 8thWall. 8thWall, owned by Niantic, is a web-based platform that allows for AR development. It is cloud-based, which is ideal for collaborative projects. Each activity is created as a separate WebAR project and built with JavaScript. The 3D AR scenes are implemented using A-Frame, a HTML-based framework. Due to the limited availability of open-source 3D models, our team created all 3D components, including characters, interactive pieces, and other props using Blender.

Our storybook is just like any traditional storybook with text accompanied by full-page illustrations. Illustrations were created through Adobe Illustrator and modeled after our 3D models to create cohesive and consistent imagery. Illustrator was also used to create any 2D elements that can be placed in the AR environment. To connect the storybook to the AR application, we used QR codes which can be scanned to redirect users to the 8thWall website, as seen in Figure 5.1.

Once users scan the QR codes, they can launch the 8thWall application and interact with the AR space as shown in Figure 5.2. The user can perform the activity while simultaneously seeing their surroundings. In every activity, there is audio and visual feedback to inform the user of their performance. The audio feedback is in the form of positive or

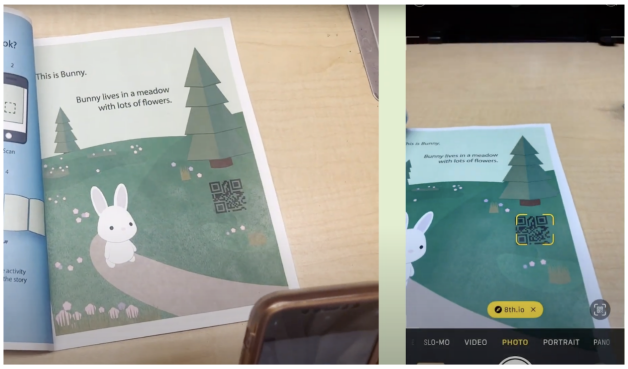

Figure 5.1: QR Code Scanning

Figure 5.2: User interacting with AR activity

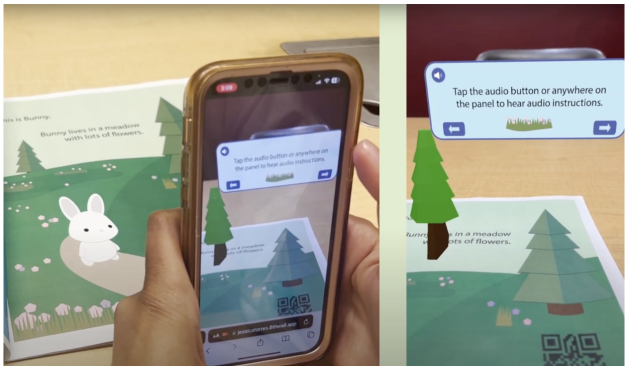

Figure 5.3: Audio Feedback

negative sound effects that indicate whether the user completed the correct step. There is also an audio button that the user can press to trigger audio instructions, as shown in Figure 5.3. This is especially useful for our young audience who may not know how to read yet.

The visual feedback is in the form of instruction panels and a visual cue at the end of every activity informing the user that the activity is completed. The instruction panels have text that can be read aloud by the parent or child that informs users how to complete the activity. The visual feedback at the end allows the users to know when to place their device down and continue reading the book.

Chapter 6

System Evaluation

6.1 Internal Testing

Thanks to 8thWall's easy preview feature, our team is able to constantly test the application through the development process. We are able to quickly upload and interact with the project in an AR space, without publishing any changes. Internal testing was primarily limited to functional design requirements. We could easily test to see if each element worked as expected. This includes the mobility of objects and accurate sound effects and user feedback. While internal testing was useful in evaluating the functionality of each activity, it was hard to gauge the overall usability of the product, since we were already familiar with the UI as well as the expectation from each activity.

6.2 External Testing

External testing began when we had a working prototype in the form of user testing. Currently, usability testing is issued in the form of a survey, remotely and unmoderated. Users are given a pdf version of the storybook and asked to fill out the survey upon completion of the book. Survey questions focus on whether AR Storybook successfully engages with the target audience and to gauge overall interest and usability of this product. Additionally, users are asked about their overall understanding of using technology, AR, and computational thinking skills to help improve the usability of the project. Many responses indicated that AR navigation was unclear, thus we included an additional introductory activity in a later iteration of the project. This not only allows users to become acquainted with interacting with AR, but also the overall structure of subsequent activities.

We hope to expand the scope of our usability testing to provide more thorough feedback for the product. Having moderated user testing will provide more accurate and detailed responses regarding some of our non-functional requirements including usability and performance. Additionally, collecting quantitative data as to how and where users interact with their screen could help determine if the UI is intuitive.

Chapter 7

Implementation Plan

7.1 Timeline

Our project can be broken down into four generalized steps: researching, planning, AR development, and storybook development.

The fall quarter was dedicated to researching available technologies that could be used for this project and initial planning for the storybook. Since AR is relatively new, there are limited open-source webAR libraries available, which would limit the scope of our project and the complexity of each activity. Likewise, we quickly realized quality 3D models were scarce, so we pivoted to seeking out AI model generators, before deciding on creating our own models.

Once we had decided on these technologies, we began planning the plot, with the center of focus being how could we shape the storyline so that each conflict can be resolved with a computational thinking skill. We also began working on modeling the 3D elements.

During the winter quarter, we completed all implementations for the AR components and began illustrating the storybook. By spring quarter, we were wrapping up the development for the prototype and implementing user feedback. Figure 7.1 depicts the timeline of our progress during the development process.

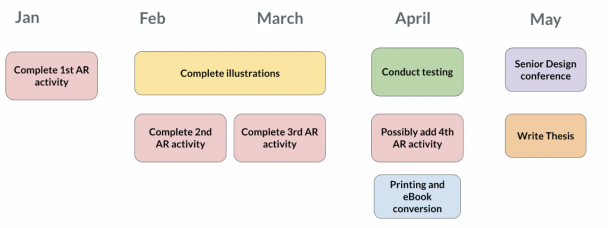

Figure 7.1: Timeline

7.2 Agile software development

Throughout this project, we used agile software development methodologies. In each sprint, we focused on one user story at a time. Each user story typically dealt with a unique computational thinking skill, or one activity. In each sprint, we divided up each activity into 3 main parts: the overall logic design, implementing visual feedback, and sound effects.

7.3 Project Risks

The main risk for this project was being careful not to overscale the project. Given we were working with fairly new technologies, we needed to plan accordingly given the time we had to still deliver a working product that meets our objectives. Ideally, the combined digital and traditional storytelling methods work to enhance user experience. However, there is also a risk that it adds a complexity factor, steering users away from the product. This would need to be evaluated through further user testing.

Chapter 8

Constraints and Standards

8.1 Constraints

The main constraints were budget, 3D modeling, and limited documentation. With our budget of $350, we could only purchase Adobe Illustrator and pay for the 8thWall subscription. While doing research for 3D models, we encountered premade models as well as software that could generate 3D models from images. The models that were of better quality and more advanced 3D model generators were out of our budget, so we resorted to using Blender, a free 3D modeling application. Another problem that arose from our limited budget is hosting our project long term on 8thWall. When our paid subscription ends, our project will no longer be accessible.

As a result of our limited budget, our second challenge was learning 3D modeling. All members had little to no experience with 3D modeling, so we had to learn and adapt as we progressed. Our last constraint was having limited documentation on AR libraries. Initially, we considered libraries such as AR.js. However, because of the limited documentation, this in turn also limited our ability to maximize the library's features or functionalities. For more efficiency, we decided to use 8thWall since it provided us with a cloud editor, an AR engine, and built-in hosting.

8.2 Standards

This project complies with the following standards: HTML Living Standard, ECMAScript, and WCAG. When using HTML, proper semantics were used such as having a header and body tag as required by the HTML Living Standard [11]. For the JavaScript code, we referenced ECMAScript [12]. There is correct use of 'let' and 'const' declarations, as well as arrow functions and 'addEventListener'. To ensure accessibility, we referenced the Web Content Accessibility Content Guidelines [13]. We followed the 1.1 Text Alternatives Guideline by providing a text description along with an audio description of the instructions for each of our AR activities. This allows users with auditory and visual disabilities to interact with our content.

Chapter 9

Societal Issues

9.1 Ethical

The digital component of our product and a relatively young target audience may bring up some ethical considerations regarding the negative effects of exposure to technology at an early age. We are aware that excessive exposure to technology can be detrimental to children's health. To prevent this, we designed AR Storybook in a way that requires parental involvement. Most children ages 3-6 cannot read on their own, so having a book component makes it necessary for a parent to be involved in the learning process. We did not want to create a game that the user could complete on their own with no parental supervision.

AR Storybook is also meant to be educational, not purely for entertainment. Although there are fun activities, they are meant to teach children computational skills and help them better understand these concepts. Another consideration is the accessibility of AR Storybook, considering that some users may not have access to a smartphone or device. In order to complete the activities, a device is needed, but the user is still able to learn the computational thinking skills through the explanation pages found in the book. Explanation pages provide a thorough summary regarding how its corresponding activity and plot relate to a computational thinking skill. Figure 9.1 shows an example explanation page for algorithm design. Though the AR activities are definitely a feature of this product, the goal of educating users on CT skills can still be achieved by reading the book. The activities are meant to supplement the book, but the knowledge is still attainable by just reading the book.

9.2 Economic

AR Storybook can be accessed in multiple ways, including a physical and digital format of the book. The digital format is available through Amazon at a low cost. This low cost was selected to make it more accessible to everyone. Our project also doesn't require additional hardware such as a headset, which reduces the cost of purchasing the storybook. Price should not be a limiting factor for children to learn CT skills.

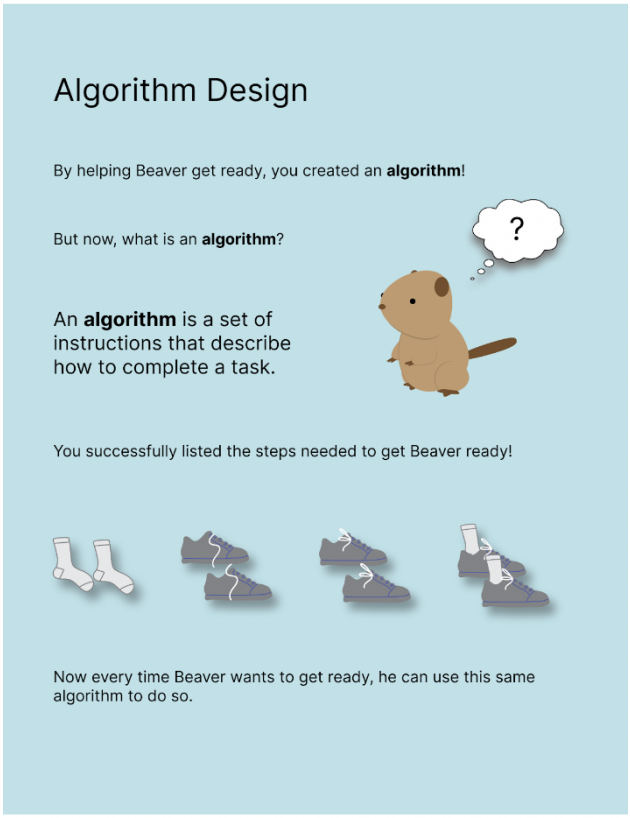

Figure 9.1: Algorithm Design Explanation Page

9.3 Health and Safety

As previously mentioned, excessive exposure to technology can be detrimental to children's health. It can affect their executive functioning skills and impact their social skills. For this reason, we decided to organize AR Storybook in a way that encourages parent involvement. The goal is to have the parent read the book to their child and have the child complete the activity with their help. By having a parent involved in the process, they will be able to monitor their child's screen time as well as the content they are watching.

AR aims to combine the user's physical world with a digital world, which allows the user to interact with both simultaneously. AR does not require the use of a headset as VR does, so it is generally safer since the user is aware of their surroundings.

9.4 Sustainability

Our project can continue to be hosted and expanded. Since we developed and hosted our application on 8thWall, other members can easily collaborate and publish new changes to the AR activities. Some problems that may arise are the cost of maintaining the 8thWall subscription and having a team take over our project. We need to continue to pay the subscription in order to keep our application hosted on the web. A new team is also needed to continue to develop and expand this project.

9.5 Usability

Our project comes in multiple formats, which makes it usable anywhere. The user can read both the ebook and the physical book anywhere they go. This is especially helpful for children who don't have a CT curriculum at their school to learn these skills at home. The AR activities are also user-friendly in that we have an introduction activity that teaches users how to navigate the AR space. Every activity also has instruction panels with audio descriptions that tell the user how to complete the activity.

9.6 Lifelong learning

This project emphasized the importance of lifelong learning. All of our members were unfamiliar with 3D modeling and A-Frame, so we had to learn these new skills as we developed this project. We researched many online resources and learned the skills needed to make this project come to life. Users of AR Storybook can also practice lifelong learning. We designed the storyline to make it easy for us to add new activities and expand the storyline. By doing this, users would be able to learn new CT skills.

9.7 Other Considerations

Some categories of societal issues do not apply to our project. These include social, political, manufacturability, environmental impact, and compassion.

Chapter 10

Conclusion

10.1 Summary

Overall, we created an AR storybook aimed at teaching children computational thinking skills. There are two components to the project. There is a book, available in an ebook or physical version, as well as accompanying AR activities. The plot of the story is about Bunny and Beaver who are friends. Beaver must travel to Bunny's house for dinner but encounters some obstacles along the way, so the user is asked to help Beaver overcome the obstacles through problem-solving. The AR activities ask the user to help Beaver complete a task and utilize a computational thinking skill as they do so. The CT skills taught are algorithmic thinking, pattern recognition, and decomposition.

Throughout the development of this project, we learned about children's development and the impact of technology in education. In excess, technology can cause harm to children's development, but if used correctly and in moderation, technology can be a great learning tool. We exploited the positive aspects of technology, such as AR and its teaching capabilities, while being cautious and mindful about excessive screen time. We highly encouraged and required parent involvement in the learning process to prevent excessive exposure. The book component encourages parents to read to their child and monitor the completion of the activities.

Through our user study, we learned that parents want their children to learn about AR and CT. We also learned that most children were already using technology and were supervised by their parents. Our project isn't an introduction to technology – its goal is to redirect children's use of technology so that it is more educational. We also hope that there is high parent involvement while using AR Storybook.

10.2 Limitations

Something we would like to improve on is the screen time component. Although the number of parents that would be involved in their children's use of our project is anticipated to be high, we still need to incorporate a feature embedded into our project to prevent excessive screen time. This can be in the way of a timer that informs the user if they exceed a certain time and then have the user exit the activities page. This would help prevent excessive exposure if parents

aren't supervising their child.

10.3 Future Work

Our next steps for this project are incorporating a screen limit timer, expanding the storyline, and adding new activities. By adding a screen limit timer, we will prevent the negative side effects of technology from affecting our users. Adding new activities will allow users to continue to learn new CT skills and will make our AR Storybook more engaging since they'll be able to complete new activities. We also hope to expand our user study to understand our target audience better and make changes according to our users' needs.

Chapter 11

Acknowledgments

We extend our gratitude to Santa Clara University and our advisor Dr. Sharon Hsiao for their support in the development of this project.

Chapter 12

References

[1] Mohaghegh, M. & McCauley, M. (2016). Computational thinking: The skill set of the 21st century. International Journal of Computer Science and Information Technologies (IJCSIT), 7(3), 1524-1530.

[2] Covolo, Loredana, et al. "Parents and Mobile Devices, from Theory to Practice: Comparison between Perception and Attitudes to 0–5 Year Old Children's Use." *International journal of environmental research and public health* 18.7 (2021): 3440.

[3] Sharkins, K.A., Newton, A.B., Albaiz, N.E.A. *et al.* Preschool Children's Exposure to Media, Technology, and Screen Time: Perspectives of Caregivers from Three Early Childcare Settings. *Early Childhood Educ J* 44, 437–444 (2016). https://doi.org/10.1007/s10643-015-0732-3https://doi.org/10.1007/s10643-015-0732-3

[4] "Immerse," *Hartrxr*. https://hartrxr.com/immerse/https://hartrxr.com/immerse/

[5] "Peronio," *Renato Klieger*. https://www.renatokg.com/peroniopopuphttps://www.renatokg.com/peroniopopup

[6] "The Case of the Missing Cleopatra," *Lucia Di Giammarino.* https://www.luciadigiammarino.com/blog/the-case-of-the-missing-cleopatrahttps://www.luciadigiammarino.com/blog/the-case-of-the-missing-cleopatra

[7] Su, J., & Yang, W. (2023, January 4). A Systematic Review of Integrating Computational Thinking in Early Childhood Education. *Computers and Education Open*, 100122.

[8] da Silva Esteves, A. M., Santana, A. L. M., & Lyra, R. (2019, October). Use of augmented reality for computational thinking stimulation through virtual. In *2019 21st Symposium on Virtual and Augmented Reality (SVR)* (pp. 102-106). IEEE.

[9] Lin, Y. S., Chen, S. Y., Tsai, C. W., & Lai, Y. H. (2021, February 23). Exploring computational thinking skills training through augmented reality and AIoT learning. *Frontiers in psychology*, *12*, 640115.

[10] Lunding, M. S., Grønbæk, J. E., Bilstrup, K. K., Sørensen, M. S., & Petersen, M. G. (2022, April 01). Exposar: Bringing augmented reality to the computational thinking agenda through a collaborative authoring tool: Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems. Retrieved February 26, 2023, from https://dl.acm.org/doi/10.1145/3491102.3517636https://dl.acm.org/doi/10.1145/3491102.3517636

[11] WHATWG. (n.d.). HTML Living Standard. Retrieved June 16, 2024, from https://html.spec.whatwg.org/

[12] Ecma International. (n.d.). ECMA-262: ECMAScript® 2023 Language Specification. Retrieved June 16, 2024, from https://ecma-international.org/publications-and-standards/standards/ecma-262/

[13] World Wide Web Consortium (W3C). (2018). Web Content Accessibility Guidelines (WCAG) 2.2. Retrieved June 16, 2024, from https://www.w3.org/TR/WCAG/