A COMPARATIVE ANALYSIS OF PROTOTYPING TECHNIQUES WITH YOUTHS

by

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ABSTRACT

Researchers working with young participants may use prototyping techniques as a tool for design components of the research. This research focuses on idea generation from prototyping design sessions with youths of various ages. We conducted research with two groups of youths in two different contexts. One in an open in-field session involving contextual inquiry and interviews, and the other in temporally bound, structured prototype design sessions. We performed an in-depth comparative analysis of three commonly used prototyping design techniques, Storyboarding, Paper Prototypes, and Bags of Stuff, with one group of participants. We found no strong preference for one technique over the other in the design sessions, but we did find that the physical constraints of the design space affected what crafting materials were chosen and how materials were used. Finally, we discuss how the highly structured sessions could be used in tandem with the less structured, more opportunistic field work.

LIST OF ABBREVIATIONS AND SYMBOLS USED

SB	Storyboard
PP	Paper Prototype
BoS	Bags of Stuff
CI	Contextual Inquiry
ANOVA	Analysis of Variance

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CHAPTER 1: INTRODUCTION

1.1 PROBLEM DEFINITION

1.1.1 COMPARING PROTOTYPING TECHNIQUES

This research focuses on idea generation from prototype design sessions with youths of varying ages, and how the choice of prototype design methods affects the design outcomes. I conducted two research projects, one which sought to use contextual inquiry and iterative prototyping and development with a single group of youths to develop a mobile app that had direct value to them[1], and another which focused specifically on comparing prototyping design technique strengths, weaknesses, and outcomes with different groups of participants.

While there is a lot of research with students that use prototyping design techniques, often in a participatory context, the design techniques themselves are used as a means to facilitate other research, such as studying high level approaches to collaborative work, exploring specific learning outcomes, and software creation or evaluation, for example Druin (1999), Bell and Davis (2016), Yip, Clegg, Bonsignore, Gelderblom, Rhodes, and Druin (2013), Yip, Foss, Bonsignore, Guha, Norooz, Rhodes, McNally, Papadatos, Gloub, and Druin (2013b), Ashkortab and Vitak (2016), Sheehan, Haden, & Metz (2015). A comparison between the design techniques used isn't often the focus of the research.

Selection of design techniques is an important consideration for computer science educators, since introducing students to successful learning techniques can have an influence on their future studies. While there are examples of participatory design and the use of prototyping methods with teens and youths, participatory design is often used as a medium for other research goals, for example Ashkortab and Vitak (2016), Yip et al. (2013). Additionally, the choice of design technique used to develop prototypes

[1] This project was not completed due to a combination of scheduling and budgetary issues, as discussed later in the thesis.

may impact the quality and scope of the resulting designs. While there has been some comparison between design techniques (e.g., Bell and Davis (2016)), there is little in-depth comparison of design methods used when limited to a specific design domain, such as mobile application development. Antle (2008) emphasizes the importance of and need for thorough understanding of effective lo-fidelity tangible prototyping materials and how they relate to design inquiry. Using three different prototyping techniques, this study examines the design dimension of tangibility in sessions with youths developing a mobile application and explores the impact on both designer experience and design outcomes.

1.1.2 COMPUTER SCIENCE IN THE CLASSROOM

There is an increased demand for computer scientists (Department of Computer Science Western University, n.d.). Enrollment in computer science programs at the post-secondary levels has surged over the past few years (Computing Research Association, 2017). This surge—which leads to larger class sizes—has created teaching challenges for staff (Computing Research Association, 2017). In addition, enrollment in CS related courses by non-CS majors is also on the rise (Computing Research Association, 2017). Because of this shift, it is important for younger students to learn aspects of software design at an early age.

While it may not be feasible to fully immerse all students in software design, due to costs and classroom logistics, user interface design lends itself to low-cost and quick to implement classroom activities. There are many methods of developing designs used by programmers and software engineers, such as sketches and diagrams, for example Baltes and Diehl (2014). Other common approaches may be storyboarding, wireframe prototypes, and paper prototypes.

In a classroom environment, it may be difficult or impossible to practice fundamental computer science skills, such as coding, app development, *etcetera*. This can be due to environmental restrictions, such as lack of computers or software licenses, or the teacher's lack of formal computer science training. Whatever the limitations, it is important for students and teachers to have some options for lesson plans that introduce or encourage computer science education. To accommodate lack of computer science training and experience, these lessons should be quick and easy to set up, relatable to the students, and ideally low cost by making use of available materials that would commonly be found in a classroom. Antle (2008) states how almost any physical object can be used as a tool for inquiry, and that researchers recommend incorporating many different types of arts and crafts supplies.

This research began with the organization Hope Blooms. Hope Blooms is an organization in Halifax, Nova Scotia in which youths age 5-18 learn about and participate in organic farming (“Hope Blooms About”, n.d.). With this organization, the research focus was to explore the development of a shared community greenhouse monitoring application over non-consistent work groups. One aspect of the research was to explore approaches to prototyping design sessions. This is further expanded upon in chapter 3.

During the summer months of July and August of 2017 our lab hosted several science camp groups from the organization SuperNOVA. I used this opportunity to expand the design session activities from the Hope Blooms project to study how the design sessions could be applied to consistent, temporally bound, single groups of youths instead of non-consistent workgroups.

Both the Hope Blooms and SuperNOVA participants were young students who were interested in working on mobile app design. One key difference between the two scenarios is that the Hope Blooms participants were going to engage in several different participatory design techniques over the course of the semester and iteratively add to the designs from the previous sessions, whereas the SuperNOVA participants engaged in one of three possible design session once and completed the app design in a single design session. It was from the planned participatory design sessions with Hope Blooms that I chose the design techniques for SuperNOVA.

1.2 THESIS CONTRIBUTION

This research focused on developing a shared community application through participatory design sessions with the organization Hope Blooms as well as comparing and evaluating three different prototyping techniques from the Hope Blooms sessions with youths of various ages from the SuperNOVA science and technology camp groups who visited our lab each week. I focused our sessions on three commonly used prototyping techniques found in the Human Computer Interaction literature and used with children and youths: *Storyboarding*, used for example by Wahid et al. (2011), *Paper Prototyping* as seen in Bertou and Shahid (2014), and Bell and Davis (2016), and *Bags of Stuff*, used by Yip et al. (2013). These design techniques were cost effective, making use of materials commonly found in elementary and secondary school classrooms, low-fidelity (requiring no programming), and easy to set up for a classroom teacher who may want to introduce their students to some basic aspects of software design.

Each week a group of 18-20 campers ages 8-15 would arrive at our lab. The group would be divided into two smaller groups, and each group would participate for 45 min in one of the three design sessions. Their goal was to use their assigned prototyping method to develop a mobile application that would help them catalog and record sea life on a vacation to the Caribbean. I provided them with several design requirements, tools for the prototyping technique, and a simple example of a pre-made prototype to motivate the design process. The sessions focused on designing a user interface that met the design requirements.

Each of the design techniques used: Storyboarding (SB), Paper Prototyping (PP) and Bags of Stuff (BoS) had different levels of tangibility: they had components that could be manipulated with your hands on the prototype. BoS was the design technique with the highest degree of tangibility and required the most crafting using art supplies. One aim was to study how the different tangible natures of Storyboarding, Paper Prototyping, and Bags of Stuff would affect the participants' design experience. Because the three design techniques that I used required different levels of fine motor control, I also studied how age affected the design experience with each of the techniques. An interesting outcome of our research was how the physical constraints and freedoms of each of the design activities affected the design outcomes. This was not something I originally intended to measure.

My research question is as follows:

> How will higher levels of tangibility in low-cost, low-fidelity prototype design sessions affect participant satisfaction with their design and the design session as a whole.

From the literature review in the chapter 2, I expected the following outcomes:

1. Older participants may find SB to be too elementary based on work by Katterfeldt, Zeising and Schelhowe, (2012).
2. Younger participants will have more trouble with the highly tangible method (BoS) based on the results of Mazzone, Iivari, Tikkanen, Read and Beal (2010).
3. BoS may produce higher satisfaction than SB and PP due to its tangible nature, based on work by Allen (2007) and Hinzman (1997) in the realm of manipulatives for math classrooms at the elementary and middle school level.

1.2.1 OUTCOMES

- There is no strong preference for one prototyping technique over another in terms of surveyed happiness, helpfulness, easiness, ownership, or frustration.
- Highly tangible techniques, such as BoS, may be more frustrating and less easy for younger participants, but still produce similar levels of happiness as other less tangible techniques, such as SB and PP.
- The physical constraints on the prototyping design space affect what materials are used in the design canvas (the physical space used to display/interact with the prototype) and how those materials are manipulated to suit the design space. Highly tangible and constrained design spaces (BoS) lean towards crafting elements from scratch, whereas less constrained design spaces use more templates.
- Different prototyping methods may lend themselves to different design stages. SB and PP may be useful for early work in non-constrained design spaces, whereas BoS may be more useful when there is limited design space, such as screen space.

1.3 THESIS OVERVIEW

Chapter 2 presents an overview of related work starting with modern user interface design techniques. We then move onto different learning styles and factors which affect outcomes in learning, such as age differences and teaching aids. We also describe how participatory design is used with young participants and focus on prototyping techniques in the participatory design process.

Chapter 3 discusses how this research project evolved from working with the organization Hope Blooms to study non-consistent work groups while designing a greenhouse monitoring application into studying design sessions with more consistent and temporally bound groups of participants.

Chapter 4 presents the methodology of our study design, including participants, the setting, materials used, data collected and plan for analysis.

Chapter 5 is the presentation of the results from the collected data in chapter 4. We start with the design artifacts from the SuperNOVA participants, exploring design requirements, and different layouts and templates used. The next section presents the results of the affinity diagram, and finally we explore the questionnaire results across different activity types and age groups.

Chapter 6 discusses the results from chapter 5 in the areas of how different prototype methods affected participants' design experiences and outcomes, such as screen and template usage, prototypes as evaluation tools, and constraints on the design space, such as persistent vs. removable design canvases. This chapter also discusses key design artifacts, teaching considerations, and recommendations for future prototyping sessions as well as study limitations.

Chapter 7 will summarize the key findings and help to situate this research in the greater HCI literature. Finally, chapter 7 will present several considerations for future work building off this research.

CHAPTER 2: RELATED WORK

2.1 MODERN USER INTERFACE DESIGN TECHNIQUES

In software development, designing the user interface is an important step since it is what the end users will interact with primarily. User interface design may be an iterative process in which multiple prototypes of different complexities are developed, and depending on the stage of the software development, may involve design requirement gathering, simple prototype development, group critiques, and prototype evaluations. My research focuses on comparing three popular prototyping techniques used in HCI. This section will give an overview of the design techniques that are often used in HCI research and development.

Contextual inquiry, lab studies, and surveys are examples of tools used for gathering design requirements and understanding the domain of a problem (Myers et al., 2016). HCI methods can also be used to evaluate a tool or techniques (Myers et al., 2016).

Design techniques, such as rapid prototyping, heuristic evaluations, cognitive walkthrough, and think-aloud usability evaluations are useful for gathering feedback, design costs, and establishing a clear goal to the clients and developers (Myers et al., 2016).

Rapid prototyping is used to quickly iterate on the design at hand. Often the first step is the use of paper prototypes, which are created with pen and paper (Myers et al., 2016). This is used to test if the design ideas are likely to work (Myers et al., 2016).

Heuristic evaluations involve several people evaluating and commenting on a UI (Nielsen, 1990). Cognitive walkthroughs involve carefully performing tasks while using the UI and recording when a user will need new information to proceed to the next step in the interface (Myers, Ko, LaToza, & Yoon, 2016).

Think-aloud usability evaluations having the users continuously state their goals, struggles, and any other thoughts (Myers et al., 2016). This “think aloud” technique provides the experimenter with data on user performance which may help to solve a problem with usability (Myers et al., 2016).

Each of these design techniques has its advantages and disadvantages. Rapid prototyping allows for quick low-cost feedback at the expense of low-fidelity design which may limit the analysis of problems with the design (Myers et al., 2016). Heuristic evaluations are quick and require no participants, but they may be limited on which usability issues are brought to the surface (Myers et al., 2016). Cognitive walkthroughs, like heuristic evaluations, are quick, and do not require participants, but may only reveal some usability issues (Myers et al., 2016). Think-aloud usability evaluations help to reveal usability problems and the intent of the developer, but they require participants, and the setting might not be the same in the real world (Myers et al., 2016).

Using pictures to elicit designs is another technique which may help participants develop conditions in a UI design. For example, Myers et al. (2016), showed pictures of Pacman to novice programmers and non-programmers to examine how novice and non-novice programmers expressed different programming concepts, such as how developers can solve the problem about what Pacman should do when running into a wall.

Each of these design techniques have different levels of tangible approaches. Rapid prototyping, for example, could involve hand drawing with pen and paper or a mock up semi-working physical prototype (Myers et al., 2016). However, a cognitive walkthrough involves asking questions with developers working from the view of the user (Spencer, 2000, Blackmon,2004). Having multiple activities for design may be beneficial. Sluis-Thiescheffer, Bekker, & Eggen (2007) conducted a study with different groups of 10-year-old children which compared design outcomes from brainstorming and prototyping. They hypothesized that prototyping may elicit more ideas than brainstorming, since it engages more types of intelligences (Visuo-Spatial, Linguistic, Kinesthetic, etc.). In my research, I am interested in idea generation from prototype design sessions with youths of varying ages, and how the choice of prototype design methods affects the design outcomes.

2.2 DIFFERENTIATED LEARNING STYLES

This research focuses on comparing and evaluating different prototyping design techniques in the realm of mobile app design. Preference for design type may vary from participant to participant due to their individual learning style. The three prototyping design techniques that I used incorporated different levels of tangibility in an effort to explore if a tactile element would aid the design process. The following section discusses different learning styles and how they may be affected by factors, such as age, environment, and the medium of the activity.

2.2.1 DUNN AND DUNN MODEL

Learning styles among students are an important consideration when applying new teaching techniques. Dunn and Griggs (2000) describe how students need to understand physiological characteristics and their strengths in, auditory, visual, tactile, and kinesthetics to capitalize on their own learning style and how they may process information differently based on their own inherent traits according to cognitive-style theory.

A common learning style model, The Dunn and Dunn Learning-Style Model, states that it is possible for most individuals to learn and that the instructional environments, resources, and methods work for different people of diverse learning styles and different strengths (Dunn and Griggs, 2000); all students have strengths, but they may be different strengths (Dunn and Griggs, 2000); students do have preferences for individual instructions, and this can be measured (Burke, Guastello et al., 1999/2000 cited in Dunn and Griggs, 2000); students can use their own learning style to help them learn new and difficult information (Roberts, 1999; Schiering, 1999 cited in Dunn and Griggs, 2000), and that teachers can use different learning styles to aid in their instruction (Roberts, 1999; Schiering, 1999 cited in Dunn and Griggs, 2000).

2.2.2 AGE DIFFERENCES IN LEARNING STYLES

Students' age can play a role in their learning style as well, and these learning styles change as the students age (Dunn and Griggs, 1995 cited in Dunn and Griggs, 2000). These learning styles typically change between elementary and junior high, and again between junior high and high school (Dunn and Griggs, 2000). For example, Mazzone, Iivari, Tikkanen, Read, & Beale (2010) found from examining three different studies from a project to develop a mobile music making and sharing system for children, that younger aged 6-7 children required more time and explanation to gain momentum on a crafting-based design activity compared to aged 9-10 children. They suggest giving younger children shorter tasks. Mazzone et la. (2010) also note the importance of using multiple methods in design to allow children to express their ideas, such as drawing, prototyping, telling stories, etc.

Teachers need to be considerate when designing instructional packages. Tactile and kinesthetic materials can be motivational for students due to their game-like nature, but they may also seem too childish to some students depending on the activity type and the age range of the students, and this can ruin motivation for the activity (Dunn & Dunn, 1978). Katterfeldt, Zeising, & Schelhowe (2012) state that childlike activities, such as acting and drawing approaches, did not work well with teens in a design context.

From the above research, we can see how children may have a preference towards different activities depending on their age range, the complexity of the activity, and how the activity is delivered. In our research I explored how age range affected the outcomes of different design activities. I did not vary the complexity or the delivery of the activity in order to keep the experimental design manageable and feasible given the uncertain number of youths who would participate. I selected a simple activity with straightforward delivery because I wanted to focus on simple, repeatable design activities that anyone, even without any computer science or design background, could perform with a large class of students.

2.2.3 INCORPORATING TACTILE ELEMENTS IN LEARNING

Tangible user interfaces involve the user manipulating objects in the real world to affect the virtual environment. TUIs are popular in recent UI design research involving children, such as the work by Leduc-Mills & Eisenberg (2011), Antle, Wise, & Nielsen (2011), Sheehan et al. (2015). Antle et al. (2011) looked at how to create tangible user interfaces (TUIs) to help support learning with children ages 7-10. They created a prototype application called Towards Utopia to help explore environmental sustainability issues. Their TUI helped the children learn about and significantly improve their understanding about environmental sustainability issues. They state that there is a need for empirical and analytical work to understand how to best use tangible user interfaces to support children's learning that may be different from other learning approaches. Children may learn better using multiple modalities, such as haptic (kinesthetic), visual, and auditory, and the use of a Tangible User Interface (TUI) allow for the presentation of information in ways that can be used with different modalities. Hands on techniques, such as TUIs allow us to present information in ways that can be used with different modalities. Derboven et al. (2015) suggest, from their co-design work with aged 9-10-year-old children creating design artifacts, that it is important to pay attention to both text and tangible outcomes.

Leduce-Mills & Eisenberg (2011) examined using 3D devices to allow for spatial exploration. Their study involved an evaluation of their prototype device, the UCube with 14 participants ages 12-14 years old. Their device, the UCube, uses 3D arrays of lights to allow users to represent shapes in 3D space. They found that their device, the UCube, ended up being a potentially useful tool for spatial cognition, and noted the importance of learning about 3 dimensions from 2 dimensional representations.

While researchers have explored the use of tangibles and tactile interfaces for the purpose of learning e.g. Antle et al. (2011), improving programming activities for kids e.g., Sheehan et al. (2015), Wang et al. (2013), or, exploring the use of a TUI for new purposes, such as spatial assessment tools e.g., Leduc-Mills & Eisenberg (2011), there appears to be a research gap exploring the tangible nature of some common low-fidelity and low-cost prototyping design techniques. For example, Paper Prototyping involves the table manipulation of a user interface, and Bags of Stuff is often implemented using basic arts and crafts tools, which open up many hands-on ways to manipulate a design, such as picking the design up off the table, and offer a unique tactile way to design a prototype, or use a designed prototype for a system evaluation.

2.2.4 MANIPULATIVES IN LEARNING

Manipulatives are a low-cost teaching tool, often used in middle-school, and high-school math classes. They serve as a tactile and visual aid for learning new math concepts and algorithms. A study by Allen (2007) examined the use of math manipulatives in a grade 5 classroom with 23 student participants. Students used pattern blocks to understand the relationship between angles and polygons. The researchers found that the use of manipulatives improved achievement, understanding, and helped to create a positive attitude around a previously struggling concept.

A study by Hinzman (1997) also confirmed the benefits of manipulatives for mathematics at the middle school level by using survey data from 27 students in a pre-algebra classroom after an 18-week period involving the use of manipulatives in the classroom to learn new algebraic concepts. They found that manipulatives helped to positively impact students' performance and attitudes towards mathematics.

Highly tactile methods, such as the use of manipulatives, have been shown to improve student achievement, attitude, and understanding in a mathematical environment for elementary aged students as evidenced by Allen, (2007)'s study and also improve performance and attitudes towards math in middle school students as evidenced by Hinzman (1997).

The use of manipulatives is common in math classrooms, and often uses low-cost and low-tech materials. This highly hands-on method might translate to computer science application exploration and development. However, computer science already has other methods of prototyping which have some degree of physical manipulation, such as Paper Prototyping.

In our research I used three different methods of prototype design with varying levels of tangibility which allowed the participants to manipulate a user interface: Storyboarding, Paper Prototypes, and Bags of Stuff. Our aim was to study if these differences in tangibility would affect the design experience. From the above research, I hypothesize that higher levels of tangibility in our prototype design sessions will lead to higher participant satisfaction with their design and the design session as a whole. I go into detail on how these prototyping techniques are commonly used in section 2.4.

2.3 PARTICIPATORY DESIGN WITH TEENS AND CHILDREN

Participatory design (PD), sometimes called co-design, is a set of methods which focus on end-users as full participants in the design process of creating software and hardware (Schuler and Namioka, 1993). My work with Hope Blooms was meant to use participatory design to develop a shared community mobile app, starting with contextual inquiry and leading into iterative prototype design sessions. The additional work with SuperNOVA focused on prototyping techniques that are often a component in the participatory design process. To help us understand how to involve youths of all ages in the design process, it is helpful to examine how children are included and what changes could be made to be more inclusive.

Yarosh et al. (2011) suggests, after a systematic review of IDC papers over 9 years, that IDC researchers design for a wider age range since most research targets children between the ages of 6-12 for example, Derboven et al. (2015). Yarosh et al. (2011) mentions how there were few IDC papers that focused on teenagers. In my research, I had the opportunity to work with a mix of older and younger participants.

When teens are involved in design it is usually as testers instead of partners. This is noted in literature surveyed by Fitton et al. (2013). Yarosh et al. (2011) did a content analysis of Interactive Design for Children papers between 2002 and 2010 examining contributions and the role of children in creating designs. They found that the level in which children are involved in the design process has a lot of variance in different studies. From their analysis, 59% of the published systems had children as testers, with 7% discussing children being used to inform the design, and only 5% involved children being used as testers and also as design informants. They note how the data reveals a decreasing trend in papers where children are design partners, and an increasing trend in papers where children are used as testers. Also, few of the reviewed papers targeted teenagers.

2.3.1 BENEFITS OF PD WITH TEENS AND CHILDREN

Scheperes et al. (2018) mention from their literature survey how children are not usually asked what they have gained from the PD process, and in their work they explored fun as a user gain. In their case study “Making things!” they focused on how children of various ages engage in different games or crafting activities and looked for instances of fun in their data analysis to be measured as user gains. One important result from their interviews was that children developed confidence and self-esteem from working through challenging activities.

Ashkortab and Vitak (2016) worked with high school students to develop solutions to cyberbullying through the use of participatory design. The students participated in prototype design sessions to create solutions to common problems on different social media platforms. The students also mentioned how PD allowed them to work with adults as equals and how involving participants who have a stake in the research, in this case preventing cyberbullying, may provide new and important solutions.

Participatory design can be a medium for creating a rich learning environment that may benefit youth (Bell and Davis, 2016). According to the work done by Bell and Davis (2016), in which high school students participated in six Participatory Design sessions to design a digital badge system, PD techniques help youth develop or support:

- an appreciation of their community of practice
- a sense of ownership over their learning
- awareness of their learning
- their academic and professional identities
- ownership and investment in learning experienced outside of school
- help to create a platform for science discussion

2.3.2 EXAMPLES OF PARTICIPATORY DESIGN STUDIES

There are many ways to use participatory design, such as end product creation, pedagogical uses, or improving communication between designers and stakeholders. Below are some examples of participatory design used in different contexts.

Katterfeldt et al. (2012), used various design methods to involve teenagers aged 16-20 in a vocational learning web app as part of a larger project called expertAzubi. Through several different workshops, participants used several different design methods used with children and adults, such as paper prototyping, dot voting, drawing, and acting to create a final product (Katterfeldt et al., 2012). Of the various activities used in the workshops, two paper prototyping sessions were used to help design the look and feel of the website. The first session used blank browser templates and colored pencils only, which produced poor results of only scribbles with no color. The second was a more structured approach using website element templates, scissors, and glue. The students had much better and happier design and idea outcomes with the second, more template driven, paper prototype approach. The authors also mention how the design techniques that were often used with children, such as drawing and acting games, were unpopular among the participants. From these results we can see how minor changes to the structure of the activity can affect the satisfaction of the participant, such as using different templates or different art supplies, and how a seemingly fun activity, such as acting games, can be unpopular among young participants. For my own research, this suggests that a subtle change in the design constraints or materials used may have a significant effect on the satisfaction of the design sessions, and subsequently the design artifacts.

Bell and Davis (2016) looked at PD with teens in designing a Digital Badge system, which is a tool to help recognize and reward science achievements outside of the classroom. They performed six PD sessions with students between the ages of 15 and 18. These design sessions used activities, such as sticky notes, spreadsheets of skills to be turned into science badges, and iteratively developed paper prototypes which helped the students to visualize different ways to get to an end goal. Their research explores the use of multiple design techniques for the purpose of developing an end product as well as how these techniques associate with specific learning outcomes, such as creating a platform for science discussion, and ownership and investment in their learning. One limitation to this study is that the outcomes measured were very high level, and the researchers did not do a rigorous comparison of the features of different design techniques, such as what the participants did or did not enjoy.

In a case study “Digital Natives”, Iverse and Smith (2012) worked with teenagers to design museum exhibitions. The study used Scandinavian PD to involve the teenagers in the design process with the teenagers carrying out and participating in the research. In the study, PD was used as a mediator between the teenagers, the designers, and programmers which allowed the teenagers to participate on the same level as the designers. They discuss how engaging the students from the early stages of the design process was helpful in giving the students ownership over the project.

Druin (1999) states how prototyping offers a way for children to communicate their ideas to adults and claims that there is never any need to teach people how to prototype when using design elements, such as art supplies, since using these basic supplies should be natural to both young and older participants. Druin (1999), created cooperative inquiry which is a method to create new technology designed for and created by children. It involves partnering with children to understand what is needed to develop new technology. Druin (1999) explains that cooperative inquiry takes the form of three stages, contextual inquiry, participatory design which involves low-tech prototyping, and finally technology immersion where children are given access to different kinds of technology to see how children use different types of technology. Druin (1999) cites their 1998 research notes to discuss learning outcomes related to the cooperative inquiry process, which they call *design-centered learning.* From these notes, which surveyed an intergenerational team over a period of time, Druin noted several areas of self-reported learning, such as “I learned about the design process”, “I learned to communicate and collaborate in a team”, “I learned new technology skills and knowledge”, “I learned new content knowledge”. My research focuses on the outcomes, such as ownership, design satisfaction, and quality and depth of design, of different prototyping techniques. However, through the process of using the prototyping techniques, I expected my participants would also learn about designing prototypes, although this is not the focus of the research.

Druin (1999) demonstrated the use of cooperative inquiry with two projects, the KidPad: a collaborative storytelling tool developed with a team of educators, programmers, and aged 8-10 children, and PETS: a personal electronic story teller which allows children to create robot animals to act out stories. We can see that cooperative inquiry uses participatory design as a major component in the creation of new technology with kids. It adds contextual inquiry, which may be necessary in any design process where the design requirements are not known, and technology immersion to explore what technology is currently being used.

Ashkortab and Vitak (2016) used PD to help create solutions to cyberbullying. They worked with teenagers from local high schools aged 14-18 and performed five sessions with each of the two groups of students to iteratively develop solutions to cyber bullying. Different participatory design techniques were used, such as Focus Groups, Scenarios, Bags of Stuff, and Prototype Evaluations. Prototypes that helped to mitigate cyberbullying were some of the results of the sessions. For example, one prototype helped to report bullies. In the study, participants were asked to reflect on their PD experience. One of the findings from this reflection was that the teens appreciated the inclusion of their ideas and enjoyed collaborating with adults. This study's focus was on the development of cyberbullying mitigation tools, but they also explored the PD experience. The specific techniques used in the study, such as Bags of Stuff, were not rigorously evaluated for their effectiveness in the design process.

In 2013, Yip et al. examined two cases of children as design partners, in which they were design experts and subject experts, with the goal of developing a mobile science app. Yip et al. (2013) looked at constraints of designing learning technologies when working with children who were experts in the subject area, and also with children who were design experts, and finally how to combine the process of designing with the two groups to help inform design practices In the study, the design experts were students who participated in Kidsteam, an extracurricular program focused on co-designing technology designed for children by children. The design experts had several meetings after school, and the group also included adult researchers. Over the school year, this team would work on several projects which included developing and evaluations. The students were regularly exposed to co-design techniques. The subject experts were students and adults participating in a program called Kitchen Chemistry. With the adult researchers, the students explored science through cooking by participating in semi-structured activities. In the study, design sessions consisting of Bags of Stuff, Stickies, and Layered Elaboration were used. They found that the subject expert kids who designed low-fidelity prototypes using crafting materials were able to identify a high degree of needs for an application and suggest presenting these needs to the design expert group.

Yip et al. (2013) found that cooperative inquiry works well with kids who are subject experts for co-design, and, from their case studies, have several suggestions for using cooperative inquiry with subject expert children:

- Choose the co-design technique carefully: arts and crafts ideas, such as Bags of stuff may be easier to use than more complex techniques like Layered Elaboration.
- It can be difficult to get the co-designers to criticize and give negative feedback.
- Designing with children who are subject experts may mean that designers have few opportunities to design with them: There are a lot of constraints when working with children, such as how tired the children are, what days they can plan for design work, and how much interaction there is in the learning environment between researcher and subjects.

Assigning different groups of children different design session tasks may be more helpful than giving each group the same requirement, such as identifying design needs, and then developing usability. The above examples of PD and IDC explore topics regarding designing with children for the purpose of creating new software, evaluating software or an interface, or exploring how to use software or interfaces to support learning of new ideas. However, there is less work exploring what techniques are the most appropriate when designing a new piece of software, and how these design techniques may vary from one age group to another.

Participatory design is used with participants of all ages, and there is some PD work with teens for example, Ashktorab and Vitak (2016), Iversen and Smith (2012), Katterfeldt et al. (2012), Bell and Davis (2016). Prototyping is a component of the PD process, used for evaluating user designs, exploring design requirements, or as a medium for exploring learning outcomes in the context of the PD activity. However, there is little work with young participants that compares attributes of the prototyping techniques, as the primary focus of the research.

My research focuses on the design aspect of PD, specifically comparing different attributes of low-cost and easy to implement prototype design methods which would function well in a classroom environment. I wanted to focus on cost effective, easy to use tools that would work well in a classroom environment to give teachers a tool to engage students in app design.

2.3.3 LOW-COST AND RAPID PROTOTYPING METHODS

Walsh, Foss, Yip, & Druin (2013) describe common HCI techniques for working with children and adults in the realm of Participatory Design. In their paper, they describe the following techniques used from other researchers:

1) Bags of Stuff from Druin (1999) involves bags filled with different arts and craft supplies;
2) Storyboarding from Truong, Hayes, & Abowd (2006) involves describing a system on sheets of paper using a timeline;
3) Paper Prototyping from Kelly, Mazzone, Horton, & Read, J. C. (2006) uses letter paper is used to create designs;
4) Stickies from Druin (1999), which uses sticky notes to help identify what works and doesn't work with a design;
5) KidReporter from Bekker, Beusmans, Keyson, &Lloyd (2003) is when the designers, who are children, are responsible for recording the design of a system using video cameras or notepads;
6) Mixing Ideas from Guha et al. (2004) involves group discussions of design ideas and an eventual disassemble of the designs to be used in new designs;
7) Comicboarding from Moraveji, Li, Ding, O'Kelley, & Woolf (2007) uses an artist to draw stories created by children about the technology they want to design;

8) Mission from Mars from Dindler, Eriksson, Iversen, Lykke-Olesen, & Ludvigsen (2005) involves children talking to an alien, who doesn't understand Earth, about their ideas;
9) Layered Elaboration from Walsh et al. (2010) uses transparent layers which are iteratively added to a design;
10) Obstructed Theatre from Read, Fitton, & Mazzone (2010) uses performance sketches to describe a mobile device without showing the device.

These techniques may be modified depending on the design or research required, such as different materials or slightly different activity approaches (Walsh et al., 2013). For my research, I wanted low-cost, and easy to implement prototype design techniques that could be used in classrooms. The techniques should also be simple enough that an instructor or teacher without a background in computer science could organize as a classroom activity.

Druin (1999) discusses how low-tech prototypes are intuitive for children and adults since everyone knows how to use basic art supplies. They mention from previous work (Druin, 1998), that children ages 7-10 are the best subjects for prototyping since they don't have pre-conceptions of how things should be.

2.3.3.1 STORYBOARDING

Storyboarding (SB) involves the creation and use of visuals to express, communicate and share ideas (Wahid et al., 2011; Buxton, 2007), and it is considered to be a low-fidelity prototyping method (Wahid et al.2011). Sketches and diagrams are an important tool for software developers (Baltes and Diehl, 2014). Sketches are used to show actors performing actions to convey a meaning to the reader (Wahid et al., 2011). This is often used to show a scenario where the product is being used (Wahid et al., 2011). Storyboarding is very similar to creating a commercial for a product, where the most interesting and important features are highlighted at some point in the sketch, sometimes by zooming in on a particular frame. There are a variety of academic tools to support storyboarding (Wahid et al., 2011), but one simple method is to use a pre-printed template with 4-6 frames and have the participants use pencils, crayons, etc. to create sketches. Above or below each sketch there is often a written description of what is occurring in each frame.

Storyboarding is a method of prototyping where the use and intent of a product are conveyed to the audience through sketches. Comparing it to other low-fidelity prototyping methods, such as Bags of Stuff or Paper Prototyping, it is relatively a low tactile method since it often only uses sketching, coloring, and writing.

Storyboarding is often used with children as a means to an end, such as acting as a low-fidelity prototype to express an idea, such as a game, eg. Alvarado (2012), or a construction kit, eg. Sherrif et al. (2017). There is little research studying attitudes towards storyboarding as a tool, especially across different age ranges.

2.3.3.2 PAPER PROTOTYPING

Paper prototyping (PP) has been used in the design of digital systems and application (Bell and Davis, 2016; Yip et al., 2013). Paper prototyping is a more tactile method of low or medium fidelity prototyping than storyboarding. It involves the use of paper objects to represent how an application might function. There are a variety of ways to approach this method, such as using sticky notes on a large poster to organize ideas e.g. Bell and Davis (2016), to having moving parts which respond to user actions to help understand how the UI will function.

Paper prototyping is often used as an evaluation tool for an already existing design. Bertou and Shahid (2014) examined the use of three different paper prototyping methods in the evaluation of mockup iPad apps with children between the ages of 7 and 8. The researchers created two games for the children to evaluate using low-fidelity paper prototype approaches. The different paper prototyping approaches in the study consisted of Background, in which the interface elements sit on a cardboard background and are free to be moved. If the interface elements fall outside of the view, they are hidden by folding the paper over. The second type of paper prototype used in the study was Blinder, in which used layers of cardboard to help mimic navigation by limiting the viewpoint, and in the third approach, Paper in Screen, photos of different interface states were set up in a photo managing app on an iPad. They used post evaluation interviews and ratings to assess attitudes towards how fun, easy, and how realistic the evaluation of the app felt. The researchers expected to find problems with all three methods, however the Background approach had problems with the researchers having to continually rebuild the interface which caused children to lose focus, and participants were afraid of making a mistake by moving the wrong piece of paper. The blinder approach had less issues, and the researchers did not need to spend time rebuilding the interface, which led to a better prototype evaluation, such as discussions about navigational flow. The researchers mention how Paper in Screen was difficult due to the photo interface, and how handling the tablet distracted from the evaluation, and this method on the tablet was found to not be considered more realistic. The researchers also found that with the Blinder method participants had more ideas about navigational and other conceptual changes, and they suggest that using multiple layers in the prototype was useful to show the constraints of the screen.

Researchers have developed interactive tools to augment paper prototype design. Ha, Park, & Lee (2014) developed a tool to draw interactive wireframe mobile paper prototypes. They performed a preliminary study to understand how to support designers via a tool. They worked with six 27-30-year-old designers from four different companies. The designers in the study had at least one year of prior design experience. They had the participants create an interactive paper prototype. They found that the designers focused on UI flow and transitions instead of the UI layout and details. From these results, they created an interactive pen which allows transitional wireframe paper prototypes to be drawn. They performed an evaluation of the tool with experienced designers. While they report the tool as being successful, there were concerns with screen transitions and whether the tool would be useful for collaborative designs.

2.3.3.3 BAGS OF STUFF

Bags of Stuff (BoS) is another method of low-fidelity prototyping in which designers create models using bags of pre-determined materials, and these materials are often art supplies (Yip et al., 2013). Depending on what materials are used for the models, the process can be very 2D, like storyboarding, or paper prototyping. Crafting materials can also be used to make the design experience more 3D tangible, if the right materials are used, such as creating a Cartesian grid from drinking straws for example, McGookin et al. (2010).

Bags of Stuff has been used with children for the purpose of developing mobile apps (Yip et al., 2013). However, an evaluation of participants attitudes towards BoS as an activity, especially between age groups, seems to be a research gap. Yip et al. (2013) conducted BoS design sessions using household items like construction paper and glue that lend themselves better to a planar type of design. They concluded that BoS might be easier than other design activities because of its focus on arts and crafts. Similar to many other studies in this field, the results of this study focused on what kids would want in an app, rather than on the quality of experience for the design participants.

From our review of the literature in the realm of prototype evaluations, prototype methods, design for and with children, the Bags of Stuff method of prototyping is used and discussed less often than Paper Prototyping or Storyboarding, and to the best of my knowledge a study comparing Storyboarding, Paper Prototyping, and Bags of Stuff as methods for quick mobile app design does not exist. This is important since these three design activities are used often in HCI research with young participants, and researchers and teachers can benefit from knowing preferences for and in which context to use a specific design activity.

2.4 CHOOSING PROTOTYPING METHODS

Walsh et al. (2013) developed a multidimensional framework to compare different prototyping methods across 8 dimensions:

- Partner Experience
- Need for Accommodation
- Design Space Dimension
- Maturity of Design
- Cost

- Portability
- Technology
- Physical Interaction

For example, they reported Bags of Stuff as a useful tool for non-specific design spaces for unspecified problems, and easy to use for early designs. Paper Prototyping was classified as a low-cost, low-tech method (Walsh et al. 2013). Walsh et al (2013) did not do an exhaustive classification of each design method, instead they focused on developing their 8-dimensional framework. Figures 1-4 below, taken from Walsh et al., (2013), show examples of their framework being applied to different design techniques.

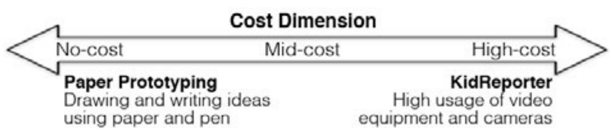

FIGURE 1 COST DIMENSION

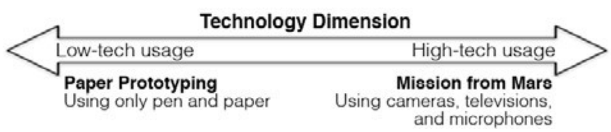

FIGURE 2 TECHNOLOGY DIMENSION

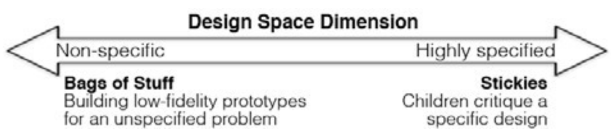

FIGURE 3 DESIGN SPACE DIMENSION

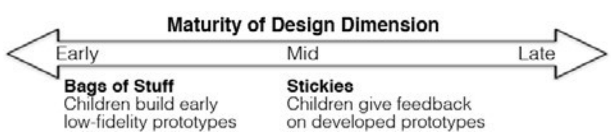

FIGURE 4 MATURITY OF DESIGN DIMENSION

Tangibility, or the tactile nature of design methods was not explored in the 8 dimensions of Walsh et al. (2013). The tactile nature may be a dimension worth exploring for Participatory Design techniques in HCI.

From Walsh et al.(2013)'s dimensional framework, my aim was to operate on the low to no Cost dimension to allow for an affordable classroom activity with a large amount of students , for early designs in the *Mature Dimension* because I wanted to explore design development, and not evaluation, to teach students about how the mobile application development process may start from a specific problem, midway on the *Design Space Dimension* in that participants were designing for a specific problem, but were free to implement the design any way they chose, and in the low-tech area of the *Technology Dimension* to make this activity usable by teachers who may not have a background in computer science or UI development. I also wanted to extend Walsh et al. (2013)'s framework to accommodate the *Tangible Dimension* and to study how this tangible dimension affects different aspects of the user-design experience. An outcome of our research was how the constraints of the design space affected the design outcomes. This could be considered a design *dimension* as well. This is discussed later in our research. Figure 5 below shows the *Tangible Dimension* and how three low-cost, low-fidelity, prototyping techniques fit on this spectrum.

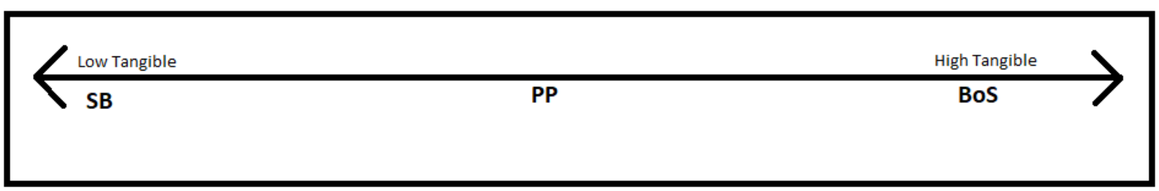

FIGURE 5 TANGIBLE DIMENSION

Guha, Druin, & Fails (2010) states the importance of ensuring that the design process is positive for the participants involved. I also wanted to understand the user design experience and ensure that the process had a positive impact on the participants.

Unlike traditional Bags of Stuff, which may be an open unconstrained crafting exercise, for example Yip et al. (2013), our participants constructed a straw frame to simulate a mobile screen, similar to Bertou and Shahid (2014), and this ended up being a constraint on the design space.

CHAPTER 3: HOPE BLOOMS RESEARCH

This research project began with the organization Hope Blooms in Halifax, Nova Scotia. Hope Blooms is a community urban farm project in the North End of Halifax where at-risk youth learn how to grow produce and market their product, salad dressings, while at the same time give back to the community (“Hope Blooms About”, n.d.). The facility originally contained a 3600 square foot garden and one 30’ x 20’ hoop greenhouse, which was used for growing veggies, fruits, and spices (“Hope Blooms Greenhouse”, n.d.).

The greenhouse faces several challenges. It requires careful monitoring and tending of the plants, and it is completely solar powered. Operationally, the greenhouse relies on volunteer staff for plant care and maintenance. Since the volunteer community is largely youths, scheduling conflicts are a problem.

The original goals were to study methods of participatory design for creating a mobile app when designing with non-consistent work groups who are all part of the same working community, which in this case were the volunteers of Hope Blooms. The purpose of the app was to help resolve greenhouse maintenance conflicts. I aimed to accomplish this goal through the use of environmental sensors and a shared community scheduling and sensor monitoring application for a smartphone.

Designing with youth who are subject experts may mean that designers have few real opportunities to design with them. There are a lot of constraints when working with children and youth, such as how tired they are, what days they can be available for design work, and how much interaction there is in the learning environment between researcher and subjects (Yip et al., 2013). In the Hope Blooms project, I had participants who could be considered experts in the greenhouse maintenance (as well as others who were more novice, having worked on the outdoor plots but not the greenhouse), but due to the hectic schedule of both Hope Blooms and the students themselves, it was difficult to have consistent work groups for designing the application. Because of this, our goal was to use different design techniques with different work groups to iteratively develop the mobile app. Assigning different groups of youth different design session tasks may be more helpful than giving each group the same requirement, such as identifying design needs, and then developing usability (Yip et al., 2013).

We used interviews, contextual inquiry, and iterative participatory design sessions to move toward our goal of understanding how to successfully create a community mobile application when participants were not present for each iterative design session. The design sessions were set up to iteratively build a mobile app using popular Human Computer Interaction (HCI) prototyping techniques, such as Brainstorming, Storyboarding, Paper Prototyping, and Bags of Stuff. However, due to participants' busy schedules, conducting the sessions proved infeasible, and after several aborted or sparsely attended design sessions, we decided to discontinue this part of the research. The following section presents an overview of the Hope Blooms research, including both completed and planned phases. In Chapter 6 (Discussion), I reflect on how the findings from my subsequent research provide insight into how iterative participatory design projects involving youth, such as this one, might be successfully accomplished.

3.1 PLANNED RESEARCH

PHASE 1: CONTEXTUAL INQUIRY AND PARTICIPATORY DESIGN

In this phase I conducted interview sessions using the Contextual Inquiry (CI) method with volunteer youth members of the Hope Blooms' staff, using CI, interviewees are interviewed while performing work onsite. The information gathered in this phase was to be used to inform the participatory design process.

Using the data from the CI, at least six design sessions would be conducted with the volunteer youths from the Hope Blooms staff. These design sessions would take place at the Hope Blooms office. According to the lead staff member, we would have students from grade 6-12, ages 10-17, depending on who is available.

Each design session would be iterative. The designs from the previous session will be amalgamated by the lead researcher, and the new design session would add or refine the features. Since participants may change from one session to the next, I had an opportunity to explore inconsistent groups working towards a final design: a line of inquiry that has potential benefit to volunteer organizations of different kinds.

At the end of each design session, the participants would complete a written reflection with the lead researcher. The purpose of this was to collect data regarding the design process, such as the participants' sense of ownership over design, and their sense of engagement given the design procedure (paper prototyping, storyboarding, manipulatives, etc.). We would also collect information on whether or not the participant participated in the last design session, and how many sessions they had participated in up to the end of the current session. At the end of the design phase, a summative questionnaire was to be presented to all the youth volunteers who had participated in at least one design session. The purpose of this summative questionnaire was to assess overall sense of ownership over the final design.

Phase 2: Implementation of the Design, Retrospective, and Analysis

Participants from phase 1 would be given the opportunity to be recruited for phase 2. If recruited, they were to work with the lead researcher to implement the design. These coding sessions were set to take place at the Hope Blooms office. The purpose of this phase was to create an application framework for Hope Blooms which addressed the needs identified in phase 1, and to understand if the addition of implementation to the design process increased the sense of ownership for the participants. To measure this, I was going to use questionnaires and interviews.

In this phase there was also a planned retrospective to help analyze the data collected from all phases, in order to revisit and refine our understanding of the data vis-a-vis the research questions. Focus group sessions with our collaborators were also going to be used to reflect upon the overall process, and to validate our interpretation of the data collected.

This study was designed to be exploratory, guided by research questions. The primary research questions were as follows:

Phase 1:

1. Can we create a sense of ownership over a design when the design group has inconsistent members who will be working on an iterative project, but all members are still part of the same community?
2. We will be using a new method of design each session. What are the benefits and challenges of each technique in terms of engaging teens and generating designs with them?

Phase 2:

3. How does the addition of implementation to participatory design with teens affect sense of ownership over a shared community application?

I completed the contextual inquiry and one of the planned design sessions. The research progressed up to and including design session 2 with the participants. The outline for the design sessions were as follows:

3.1.2 DESIGN SESSIONS

The six design sessions below were modeled and adapted from the PD work by Ashkortab and Vitak (2016) and Bell and Davis (2016), who identified successful PD techniques with teens. Focus Groups, Scenarios, Bags of Stuff, Mixing Ideas, Reflections, and Evaluations were modeled from Ashkortab and Vitak (2016), while paper prototyping was inspired by Bell and Davis (2016). Storyboarding was a technique that I had experienced from course work.

Session 1: Introduction and Scenario Based Brainstorming

- Focus Group for introductions and discussion about objective of the session and the research.
- Scenarios for the session will be created from the design requirements prior to session 1 and presented to the participants during this session.
- Participants will form small groups if applicable to the number of attending students.
- Participants will discuss the scenarios and brainstorm solutions for the mobile

application.

- Participants will record their ideas with drawings or text via pen and paper.
- The lead researcher will collect all design ideas and review them for what is and isn’t able to be implemented.
- Participants will write a reflection on the session (See Appendix H).

Session 2: Storyboarding

- Focus Group for introductions and discussion about objective of the session and the research with new members.
- The lead researcher will review the designs from the two previous sessions with the participants. New participants will be given a chance to understand what has previously been done.
- The participants will form small groups, or work independently based on the number present, to create their own story for the designs from the previous session.
- New ideas generated from the storyboarding may be added to previous designs.
- Designs will be reviewed by the lead researcher.
- Participants will write a reflection on the session.

Session 3A: **Review of Previous Session** and Scenario Based Low-Fidelity Prototyping

- Focus Group for introductions and discussion about objective of the session and the research with new members.
- Participants will be presented with new scenarios.
- Participants will use “Bags of Stuff” to design low-fidelity prototypes.
- The lead researcher will collect the low-fidelity prototypes and review them for what is and isn’t able to be implemented.
- Participants will write a reflection on the session.

Session 3B: Continue of Low-Fidelity Prototyping

- Participants will use “Paper Prototyping" during this design session.

- They may use their past prototype from session 3A as inspiration or start anew.
- This is a second attempt with a new strategy to encourage design ideas.
- Participants will write a reflection on the session.

Session 4: Mixing Ideas

- Focus Group for introductions and discussion about objective of the session and the research with new members.
- The lead researcher will hold a group discussion with the participants about common themes between all prototypes.
- Participants will then be given more time to refine their design from the previous session(s).
- In the case of new participants attending, they may choose to advance a previous design or work with another participant who already has a design.
- Participants will write a reflection on the session.

Sessions 5 and 6: Prototype Evaluations

- Focus Group for introductions and discussion about objective of the session and the research with new members.
- Participants will collaborate with one another to discuss their overall design and see if it meets the design requirements.
- Participants may present their design to the group.
- New participants attending may join in the discussions and critique.
- The lead researcher will collect the designs.
- Participants will write a reflection on the session.

3.2 RESULTS

3.2.1 CONTEXTUAL INQUIRY AND INTERVIEWS

Below are the summarized research findings from the CI and interview sessions with three participants. Two of the CI and interview sessions took place at the greenhouse. One participant was unable to participate in the CI, so only the interview was conducted.

CI and Interview 1

The first participant for the contextual inquiry session was working at the greenhouse. They were designing an interactive map for the wall of the greenhouse. The goal of the map was to represent where the different members of the staff were from and to show where the diverse plants within the greenhouse originated. The map was to have a feature where Velcro stickies of the greenhouse plants could be affixed to different countries and locations.

From the interview, several challenges in the greenhouse were identified. Arriving at the greenhouse on time and scheduling shifts with other staff was noted as a challenge. The participant wanted to be able to see who was currently working in the greenhouse, and what tasks needed to be completed. The participant also mentioned how environmental sensors, such as relative humidity could be useful if views from a mobile app. Push notifications for tasks completion was one idea for solving the task needs.

CI and Interview 2

The second participant only conducted the interview. Challenges in the greenhouse identified were similar to the other participants, such as forgetting to attend work shifts. They also wanted to be able to measure soil water and control air ventilation levels to help with the plant care. Like the other participant, they wanted environmental sensors linked to a mobile app.

CI and Interview 3

The final CI session was conducted while the participant was gardening in the greenhouse. They outlined several duties for their job, such as watering, seeding, transplanting, regulating heat and making schedules for the staff. From the interview and CI several challenges were identified, such as communicating and planning with the staff, keeping the plants cared for with water, soil, sun, airflow, and temperature. They suggested using sensors to monitor these needs, and they also suggested an info section on the app for plants within the greenhouse. Like other participants, they suggested a feature on the app. to help check off what needed to be done. A new feature was the ability to catalog photos of the staff and activities at the greenhouse. A group chat feature was also mentioned.

3.2.2 DESIGN SESSIONS

The design sessions were meant to use the design requirements gained from the CI and interview sessions in the first part of this research. However, the only design session conducted was design session 1: Scenario Based Brainstorming. The participants were presented with five scenarios modeled from the CI and interview session's challenges and design requirements. Design scenarios were as follows:

1. Scenario 1: Check the greenhouse environment remotely
2. Scenario 2: Check on plants' health from inside the greenhouse
3. Scenario 3: Don't forget to come to work
4. Scenario 4: Coming to work
5. Scenario 5: Giving a tour of the greenhouse

For these scenarios, the participants drew diagrams of solutions to the problems presented in the scenarios. The goal was to provide some mobile app. ideas to later be presented to the rest of the staff and eventually developed into a mobile app. Figure 6 and 7 below show samples of the scenarios.

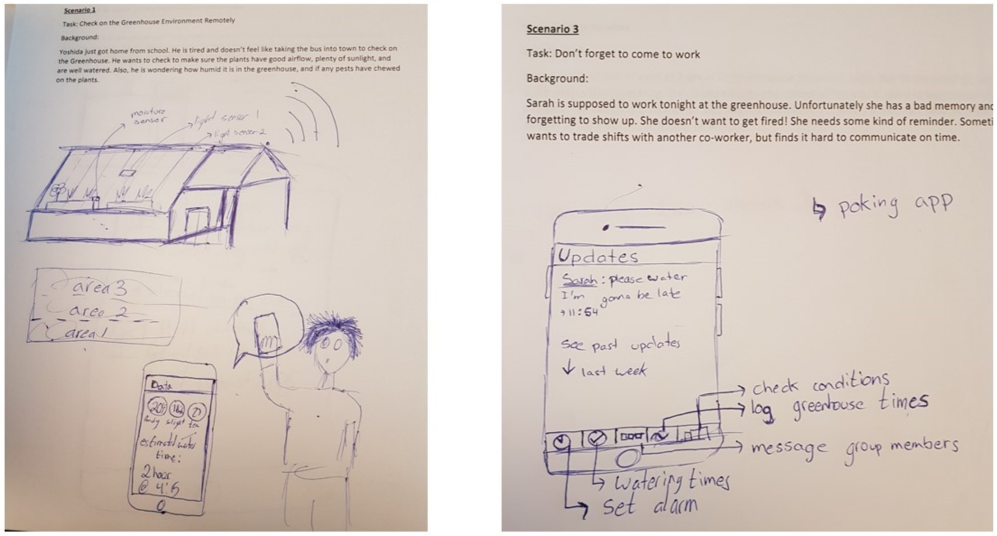

FIGURE 6 EXAMPLE SCENARIOS WITH DESIGNS

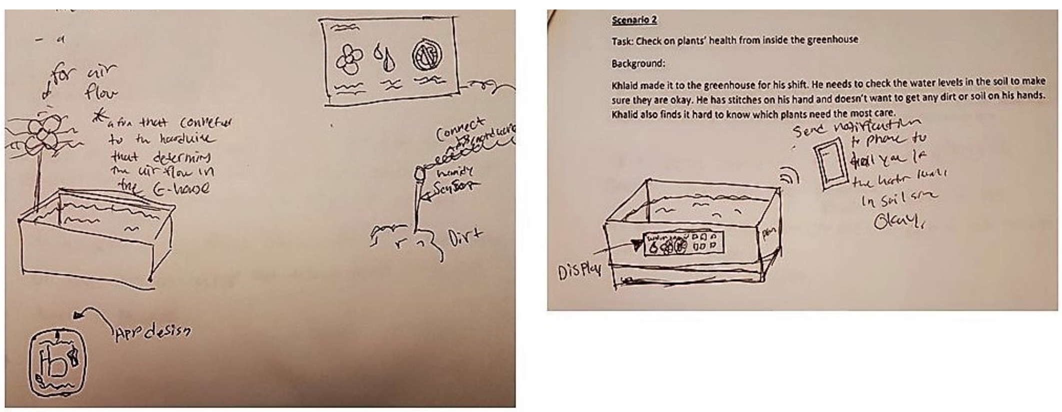

FIGURE 7 EXAMPLE SCENARIOS WITH DESIGNS

3.3 INSIGHTS INTO DESIGN SESSIONS

The participants in this research were eager to participate in the CI and interview sessions. From these sessions, we outlined several features common to all three participants, such as the need for environmental sensors linked to the mobile app. The first design session went well, and the two participants provided a lot of detail in their designs for each scenario. From what we accomplished with the requirements gathering form the CI and interviews leading into the design sessions, the app. was developing a lot of different features, such as an interactive map, remote control of environmental sensors, log updates, and a messenger feature for the staff.

The work with Hope Blooms was planned to study non-consistent work groups working together on a community-based application. A second goal was to compare prototyping methods from the design sessions. The contextual inquiry and interviews provided insight into the challenges faced at the greenhouse by the staff, and the first design session with two participants was a good starting point for discussing feasible options and gathering solutions to be iterated upon in future design sessions by other participants. However, due to scheduling problems, this was as far as the research progressed.

Managing multiple design sessions and groups with the goal of iterating upon previous design sessions and then bringing all groups together for a final critique of the designs proved to be very challenging. The added goal of comparing and critiquing prototyping methods further complicated the research. For this reason, I felt that a narrower approach to studying independent work groups participating in a single design session would be more beneficial.

The work with Hope Blooms allowed this research to extend to the SuperNOVA participants in a simplified case which focused on our second Hope Blooms research question: What are the benefits and challenges of each technique in terms of engaging and generating designs? I chose to focus on the design sessions 2, 3A and 3B, Storyboarding, Paper Prototyping, and Bags of Stuff respectively as they were the chosen prototyping techniques for the Hope Blooms sessions and would fit well with the consistent nature of the SuperNova groups' schedules. SuperNOVA also allowed us to extend the design sessions into a broader age range. Due to scheduling and time resource conflicts, the SuperNOVA sessions became the primary focus of the research.

CHAPTER 4: METHODOLOGY

4.1 OVERVIEW

During the summer months of July and August of 2017 our lab hosted several science camp groups from the organization Super Nova.

Our research focused on comparing and evaluating three different prototyping techniques with youths of various ages from the SuperNova groups who visited our lab each week. The techniques that I used were (1) Storyboarding (low tangible), (2) Paper Prototyping (medium tangible), and (3) Bags of stuff (highly tangible). While BoS, as a prototyping method, can refer to a wide range of materials, I purposely designed our Bags of stuff activity to incorporate highly tangible elements, namely straws to build a frame to mimic a tablet or phone, and pipe cleaners, tape/staples, and rigid cards which could be affixed to the frame as UI elements. I chose these three techniques due to the prevalence of Paper Prototypes (PP) and Storyboards (SB) in the literature as quick, easy, and cheap ways to develop designs with kids, as well as experience the lead researcher with these two techniques in his education. Bags of Stuff (BoS) was chosen due to its modifiable nature for prototype design since BoS can be any mix of crafting materials. In our case, I chose to structure the activity around a mobile phone frame made from straws.

I used Yip et al. (2013)'s paper as the basis for our BoS activity, however their materials contained household items like construction paper and glue that lend themselves better to a planar type of design whereas our design session with BoS was meant to foster a prototype that the participants could pick up and manipulate through the use of frames, hinges, and pop-out screens.

Each week a group of 18-20 campers ages 8-15 would participate for 45-50 min in one of the three design sessions. Their goal was to use their assigned prototyping method to develop a mobile application that would help them catalog and record sea life on a vacation to the Caribbean.

I used a pre-made scenario to give context to the purpose of design. Grundy et al. (2012) discuss how design scenarios are helpful for children to understand the activity. Mazzone (2010) states the importance of using props to help get kids started on their design. I provided a brief demo using a pre-made design for each of the three prototyping methods. Design artifacts, observations, a survey, and a written participant reflection were used for recording my data.

Children designers are not usually asked about their design experience (Schepers et al. (2018). I chose to use a post-design questionnaire, similar to Alvarado (2012), Wang et al. (2013). This questionnaire was to help us understand what the participants gained from the design experience. As reported by Schepers et al. (2018), children are not often asked what they have gained from PD sessions. Guha et al. (2010) discuss how it is important as researchers to ensure that design process is not harmful, and hopefully a positive experience for children, and how the impact of the design process is often overlooked in research. I chose to use non-open-ended questions on a Likert-scale and written observations by the researcher since open-ended interview questions may be challenging for teens (Poole and Peyton, 2013).

I also collected written observations, and this was motivated by Antle et al. (2011) and Alvarado et al. (2012). Design session artifacts were also collected. Guha et al. (2010) notes the importance of collecting qualitative data in the form of observations and artifacts for analysis.

4.2 RECRUITMENT

I recruited from SuperNOVA summer campers ages 8-15 who were visiting Dalhousie over the months of July and August. Recruitment was done via an optional recruitment bulletin to parents. Each group who visited the lab consisted of 18-20 participants. Only the participants who came with a signed parental consent form participated in our study. See appendix 3 for details. Verbal assent was also obtained.

4.3 DESIGN SESSIONS

To ensure that the session ran smoothly, and that every participant received good instruction and help when needed, I split the group of participants into two sections. One section worked from 9:30am-10:25am, and the following from 10:30am-11:25am. The campers usually took a break at 10:25am for a snack. This ensured that no more than 9-10 campers were working with the lead researcher at one time. Our conference room in the GEM lab was where the research design sessions took place.

Visitors who were not working with the lead researcher were in a separate section of the lab, where they tried various demos from our lab. To ensure that all visitors to our lab had the chance to participate in the design activity, I ran a mirrored non-research-based activity which was the same as what was ran with participants. This ensured that no visitor was left out of any activity.

Participants were given a pre-made context to motivate the design session, and to help them understand the task (Grundy et al. (2012). The context description was word-based since word-based scenarios can help children to quickly understand the goals of an activity (Antle et al., 2011). Relating classroom activities to students' interests has been shown to be an effective teaching strategy (Schroeder et al. (2007), which is why I chose to use mobile apps, something the participants would be familiar with, for our design sessions:

In one month, you and your friends are traveling to the Caribbean. For a school project, and for fun! You need to photograph sea life. Fortunately, your phone is waterproof. You decide to design an app to help you photograph and collect neat information about local sea life.

Their app had to have the following features:

1. *Snap photos of sea life*
2. *Easily add information to the photo*
3. *Send the photo and info to a friend*
4. *Easily look up names and other info about the creatures you see*
5. *Make an album with photos and info about the sea life*

The design sessions were informally structured. Participants were encouraged to implement as many design requirements as possible but told that it was not necessary to implement all the requirements. If a participant was having difficulty with a requirement, the lead researcher would assist by conversing with the participant on how they could attempt the requirements. If the task seemed too frustrating, the participant was encouraged to attempt another feature.

4.4 APPROACH AND MATERIALS

I ran design sessions with our three different prototyping techniques. Each group of participants participated in one design session with one technique, SB, PP, or BoS. I had varying group sizes between 5 and 14 participants for each session with a median size of 11.5. Each group worked with one design technique. I first held a brief discussion about the purpose of prototypes, followed by the lead researcher reading out the scenario to give context to the design. The scenario was also written on the whiteboard. I provided them with several design requirements (also written on the whiteboard), and tools for the prototyping technique. I then showed the participants an example of a pre-made prototype (Figures 6,7,8) which related to the design technique of the day to help get them started. For the Storyboarding example, I drew a 3-panel story on the white board which had a person looking at their phone in panel 1; panel 2 had a zoomed in key frame of the phone, and panel 3 showed the character pressing a button on the phone. The Paper Prototype and Bags of Stuff examples were pre-fabricated demos that had multiple activity screens. The participants were shown how both techniques could be used to show transitions from one activity screen to another. The demos were then put away after the initial introduction. This introductory process took about 5-6 min. Participants were told and encouraged that their design did not have to follow the pre-made examples. See Appendix 1 for details. They then had the remainder of the period (approximately 30-35 min) to complete their design, followed by a brief questionnaire (5 min) with an optional written reflection, see Appendix 5.

4.4.1 PROCESS

1. The participants arrived at the GEM lab. Any participants who had obtained parental consent for the study were divided into two groups. One group went with the lead researcher and a camp staff member to the study area, while the other group and any non-participant members remained in the main lab area where a version of the design activity was available. This was done to limit any feelings of exclusion for non-participants.
2. Participants were led to the design activity room with the lead researcher and a member of the camp staff.
3. The camp staff member played games with the participants while the lead researcher went over an introductory script and assent form with each of the participants outside the room. If a participant decided they didn't want to participate, they would rejoin the other group members in the main lab area.
4. The lead researcher gave a brief introduction about the himself and the purpose of the research.
5. The lead researcher read the scenario to the participants from a whiteboard. He then provided a demo and went over each of the available materials for the design process (listed in 3.4.2).
6. The materials for the design activity, listed in upcoming section 3.4.2, were placed in the centre of the table for ease of access to all participants, to help keep the design area neat and tidy, and to help accommodate the short reset time of the activates between participant groups. There were no shortages of supplies, e.g. scissors, tape, pencil crayons, for participants.
7. Participants worked to implement the design requirements into their app. Most chose to work solo, but there were a few who decided to work together.
8. The lead researcher would walk around the room assisting participants with any difficulties or questions regarding the design process. Assistance was limited to hints and minor help with the available tools. For example, if a participant was having trouble deciding how to arrange buttons for an activity screen, they were told to think about how the apps on their phone functioned. Or if they were

having difficulty using the stapler or tape, the lead researcher would offer minimal assistance.

9. The lead researcher recorded, on paper, any observations of what participants found challenging or fun. This occurred for the entire design session.
10. At the end of the session participants were asked if it was okay for the lead researcher to take a photo of their design. The photo was of the design only.
11. Participants were presented with a post-design session questionnaire and asked to do a written reflection.
12. Following the design sessions, the lead researcher would add any additional observations to the observation sheet.

4.4.2 TECHNIQUE AND MATERIALS

For our storyboarding session, participants were given an 8.5 x 11 sheet of paper with four frames. Each frame had room for a drawing and text box above each frame for a short description. Multiple sheets were available for each participant. Participants had access to pencils, colored pencils and colored pens. An example of a storyboarding prototype is shown below in Figure 8.

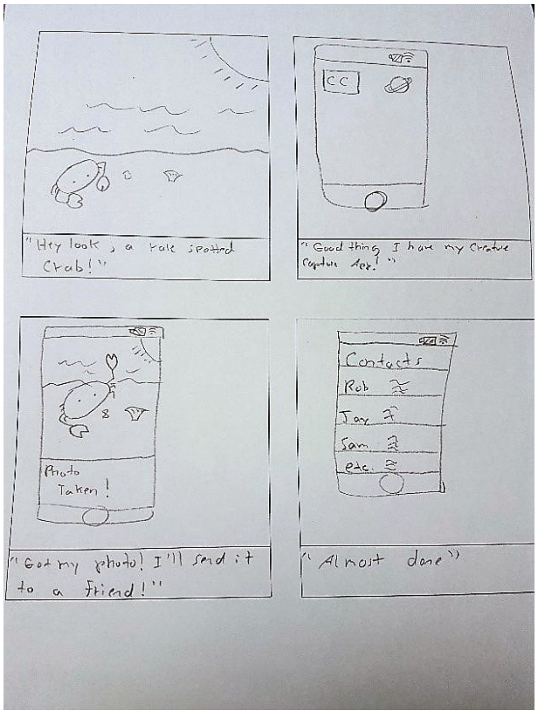

Figure 8 Storyboard example showing photo capture and contact selection in the designed app

For Paper Prototyping design sessions, participants had access to the following materials:

- Blank cue cards
- Home screen template
- Browser template
- Grid paper for widget cut outs
- Example widgets
- Glue, scissors, stapler, and tape
- Pencils, colored pencils and pens

In the interest of time, I chose to use templates for buttons, phone screens and web-browsers to give a structured approach to the design (Katterfeldt et al., 2012). Home screen and web browser templates were taken unmodified from Sneakpeekit Sketch Sheets (n.d.) a website that provides mobile app templates for printing, under the CC BY-NC-SA 4.0 license (Creative Commons, 2018). These templates can be seen in figures 9,13,14,16,29,32,33, and 34. An example of a Paper Prototype with two Mobile home screen templates taken from Sneakpeekit Sketch Sheets (n.d.) located at the bottom of the figure is shown below in Figure 9.

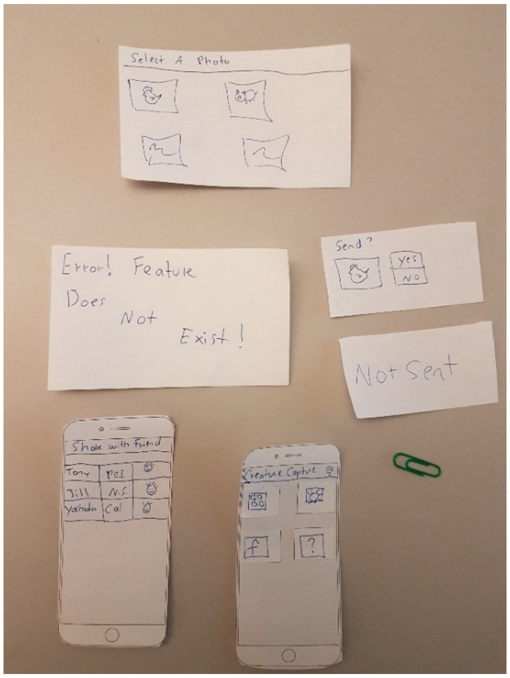

FIGURE 9: PAPER PROTOTYPE EXAMPLE SHOWING TEMPLATES AND BLANK CARDS AS SCREENS

Bags of Stuff was our final design technique. Unlike Yip et al. (2013), who used more planar items in their bags of stuff, such as glue and construction paper, I decided to encourage tactile and 3D development within the app to operate in the tangibility dimension.

I attempted this by selecting items that would allow participants to create movable screens, buttons, widgets, and text fields on their prototype. I also wanted to choose inexpensive household items that would allow teachers and educators to rapidly set up this prototyping activity. I chose a list of easily accessible household items that would also give a highly tangible design experience. Materials were placed in the centre of the table. I used the same materials as PP, with the new addition of *pipe cleaners* and *straws*:

- Pipe cleaners
- Pre-cut drinking straws

- Blank cue cards
- Grid paper for widget cut outs
- Example widgets
- Glue, scissors, and tape
- Stapler
- Pencils, colored pencils and pens
- Browser and Home Screen templates

An example of a prototype produced using the BoS method is shown below in Figure 10.

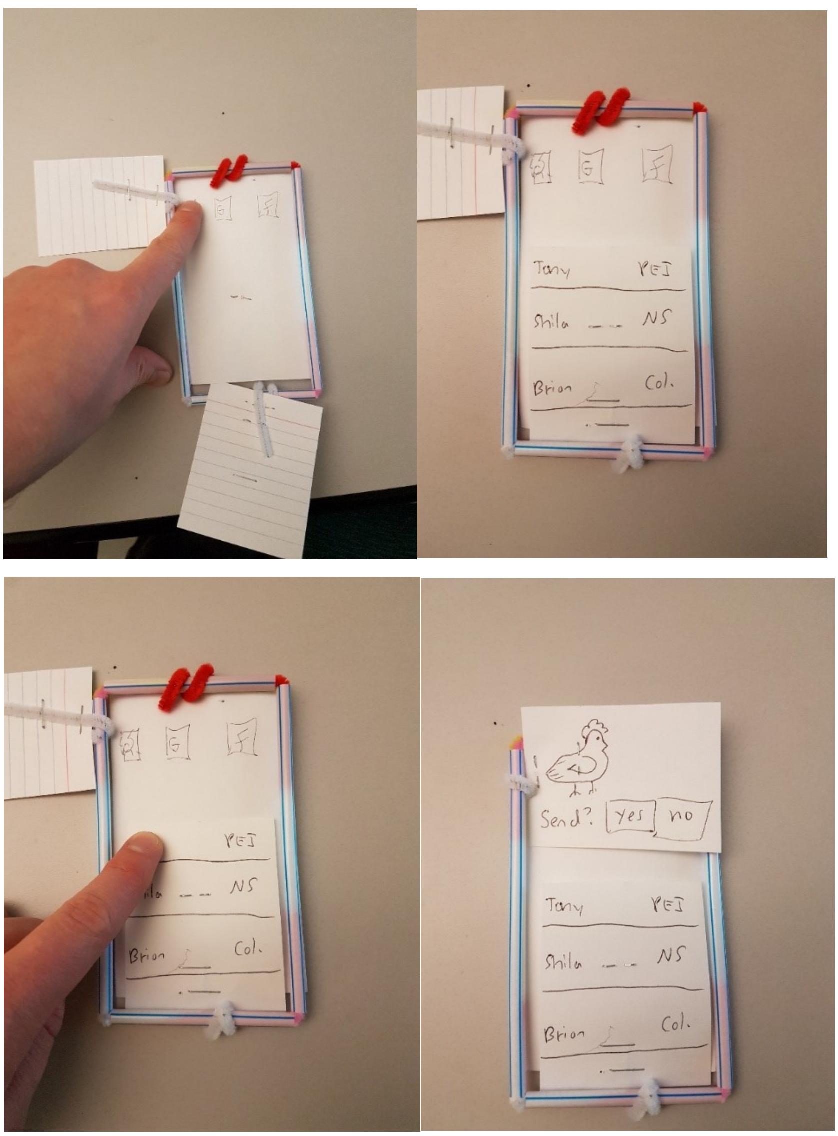

FIGURE 10: BAGS OF STUFF EXAMPLE SHOWING AFFIXED CUSTOM SCREENS TO THE FRAME

4.5 DATA COLLECTION

I collected the following data from participants:

1. Written observations by the researcher as the design activity was in progress. The researcher noted what worked well, what was challenging, when participants were on or off task.

2. Written post-session reflection by the lead researcher after the design sessions.

3. Photos of volunteered design artifacts from the participants at the end of the design session. Participants were asked if they wanted to share their design with the lead researcher. A photo of their design only was collected with their consent. Participants could then keep their design if they wished.

4. Questionnaire and written reflection from the participants at the end of the design session. Following the design session, participants were given the option to fill out a questionnaire. Almost every participant filled out the questionnaire. The questionnaire was designed to assess their attitudes and feelings towards the design technique and session. Children designers are not usually asked about their design experience (Schepers et al., 2018), and Guha et al, (2010) states the importance of ensuring that the design process is positive for the participants involved. I also wanted to understand the user design experience and ensure that the process had a positive impact on the participants. To accomplish this, I asked specific questions regarding the difficulty of the design process, their happiness with the final product, and if they felt like the design was original or owned by themselves.

I used a Likert scale of 5, with 1 being not at all, 3 being somewhat, and 5 being very much. The rating of 3 was intended to be neutral, and this was explained to the participants prior to the survey. I asked the following questions:

1. **Helpfulness:** How helpful was this activity to make the design that you wanted?

2. **Easiness:** Was it easy to make your app work the way you wanted it to?

3. **Ownership (individual):** Do you feel like this design is owned by you?

4. **Ownership (shared):** If you worked with a friend on the design, do you feel like this design is owned by you and your friend?

5. **Happiness:** Are you happy with your final design of the app?

6. **Frustration:** Were you ever frustrated when designing your app?

In addition to these questions, participants were asked to write a reflection about anything they liked, found helpful, disliked, or could be improved about the designed technique used.

4.6 DATA ANALYSIS

4.6.1 QUESTIONNAIRE ANALYSIS

I compared Likert-scale questionnaire results by activity types within one age group, and compared age groups within one activity type for significant differences (p = 0.05) between each response on the questionnaire. I also looked at the entire data set while ignoring age as a variable for significant differences between activity types. I treated our survey results as interval data. I classified a value of 3 as the middle rating or neutral rating, with gives an equal distance from our 1 value ("not at all") and our 5 value ("very much"). I then reported the group means for the different survey groups (Boone and Boone, 2012). This helped us further examine differences between groups. I used parametric tests, such as ANOVA and t-tests (Boone and Boone (2012), Wang et al. (2013), de Winter and Dodou (2010), Norman (2010)) for significance testing from the questionnaire likert-scale questions. Non-parametric tests, such as the Mann-Whitney U test were also used.

I didn't collect the individual ages of the participants, only the age range of the groups. I acknowledge that this approach is less precise that individual age measurement and that

I have likely overlaps within the age groups. I pooled the age groups of 10-14 and 11-14, as well as 8-10 and 8-11. However, I kept ages 10-11 as their own separate group. Our reason for keeping 10-11 as their own group was because mixing them with the 10-14 group would skew the ages to the lower bound. I then filtered individual by activity type: SB, PP, and BoS and compared across ages. Due to the uncertainty in the distribution of the participants' ages within the age groups, the results of this analysis will be considered secondary to the upcoming qualitative data.

4.6.2 OBSERVATIONS AND QUOTES ANALYSIS

From our design sessions I collected photos of the participants' final designs. I examined written comments from participants during the session similar to Sheriff et al. (2017), Sheehan et al. (2015), and Antle et al. (2011). For our analysis of the observations and quotes, I used an affinity diagram, as describe by other researchers for example, Beyer and Holtzblatt (1998), to identify themes and patterns from the three design activities, SB, PP, and BoS. The themes and patterns from our affinity diagram were compared to our questionnaire results and used to support or contrast the results.

Observations and quotes from the design sessions were written on sticky notes by the lead researcher. The participants were encouraged to write quotes about how they liked the activity. This was optional, so not all the participants provided free-form feedback. Since we had three age groups, and three design activities, we used colored sticky notes and stickers to track both age category and activity type. The co-investigators who assisted with the affinity diagram did not know how the markings were used. This helped to reduce bias. We used the following markings to track the observations and quotes:

TABLE 1: AFFINITY DIAGRAM CODING

Sticky Note Color	**Note Color Meaning: Activity**	**Sticker Color**	**Sticker Color Meaning: Age Group**
Blue	SB	Purple	: 8-11
Yellow	PP	Green	: 10-11

Sticky Note Color	Note Color Meaning: Activity	Sticker Color	Sticker Color Meaning: Age Group
Red	BoS	Red/Pink/Orange	: 10-14

We used the same pooled age groups as the questionnaire for this process. This gave us a youngest group, an oldest group, and a middle group with some overlap into the oldest group. Again, we kept the 10-11 group separate to not skew the oldest group towards the lower end of the age range. By using a two-colored system (sticky notes and stickers) we were able to track age groups with activity types.

We spent an afternoon posting the comments and observations onto sticky notes. These notes were then posted onto a wall. Each investigator participating in the affinity diagram process was able to post new notes and move previously posted notes to new locations. It should be noted that each sticker corresponds to an observation or a quote from a participant. We chose to use counts of classified observations, similar to Sheehan et al. (2015). Since the observations may be general on an entire group, the counts of colored cards/stickers do not say anything numeric about a particular group other than the frequency of the observations about the entire group. For example, seeing 10 positive observations on PP does not mean that 10 of the participants reported something positive, only that the observer made at least 10 positive notes during the design sessions.

4.6.3 DESIGN ARTIFACTS ANALYSIS

Working with a co-investigator, we performed independent analyses of the design artifacts. Anything noteworthy was recorded on paper attached to the design. After several passes, patterns in the designs started to emerge. On the first pass through the artifacts, we developed codes inductively, meaning that codes were developed during the artifact analysis process, rather than entering the analysis process with pre-existing

(Miles et al., 2014). We discussed the patterns from the designs and compared our notes. The following codes and counting methods were developed by both investigators independently, and so were used in the artifact analysis:

<u>Codes</u>

Templates

Between PP and BoS we noticed that there was a difference in the use of screen templates. In both PP and BoS design sessions, participants had the choice between pre-printed screen templates or blank cards to make their design. We coded the designs according to three different template categories: Pure Template (TP) where only template items were used for the design, Mixed Template (TM) were template items and blank cards were used as screens, and No Template (TN) where the design was made with no templates used.

Screen Size

All home screens were full sized templates or blank cards. However, between PP and BoS the size of the additional activity screens was another discussed observation. We coded the designs by three different screen size categories: Full Screen (SFu), Half Screen (SHa) for a screen that was close to half the size of the home screen, and Thin Screen (STh) for any screen that was less than 25% of the home screen.

Screen Placement

BoS had a variety of locations to attach activity screens to the home screen. We used the following codes for activity screen location: Left Side (SL), Right Side (SR), Top (ST), Bottom (SB).

<u>Counts</u>

Number of Successful Design Requirements

Between all three activity types, we noticed a difference in the number of implemented design requirements, so we decided to note these. Participants were asked to implement a total of 5 design requirements. We went through each design and compared the activity screens to the 5 design requirements. If there was an attempt made to implement a design requirement, we counted that as a success.

Number of Activity Screens Used

The designs for PP and BoS usually started with a home screen and then branched out into additional activity screens to fulfill the design requirements. We noticed a difference in the number of activity screens between PP and BoS, so we kept counts of how many screens were used, not including the home screen.

CHAPTER 5: RESULTS

5.1 DATA ARTIFACT RESULTS

I had a total of 46 participants for our design sessions. Table 2 below shows the breakdown by age and design type.

TABLE 2: PARTICIPANT BREAKDOWN

Age Group	Paper Prototype	Storyboard	Bags of Stuff
8-10	-	-	5
8-11	-	6	-
10-11	8	-	-
10-14	4	-	8
11-14	5	5	5
Total	17	11	18

There were 24 direct quotes from participants across all ages: 3 from BoS, 12 from PP, and 9 from SB. It should be noted that one participant may have multiple quotes. 11 participants (3 BoS, 3 SB, 5 PP) reported collaboration with another participant on their questionnaire. I had a total of written 87 observations across all groups. Observations mainly focused on positive and challenging experiences that the participants faced during the design session.

I had a total of 28 collected design artifacts, 26 of which were from participants in the age groups of 10-11, 10-14, and 11-14, and 2 in the age group of 8-10. The investigator neglected to collect the designs from the youngest age group for one SB session, which limits the analysis on this age group.

Of our 28 collected design artifacts, 13 were from BoS, 12 from PP, and 3 from SB. I examined 5 areas of design pertaining to the design artifacts. Table 3 below shows the breakdown by age and design type.

TABLE 3: DESIGN ARTIFACT BREAKDOWN

Age Group	Paper Prototyping	Storyboarding	Bags of Stuff
8-10		-	2
10-11	5	-	
10-14	3	-	7
11-14	4	3	4
Total	12	3	13

5.1.1 NUMBER OF SUCCESSFUL DESIGN REQUIREMENTS AND ACTIVITY SCREENS

I requested that the participants implement the following features into their design:

1. *Snap photos of sea life*
2. *Easily add information to the photo*
3. *Send the photo and info to a friend*
4. *Easily look up names and other info about the creatures you see*
5. *Make an album with photos and info about the sea life*

I compared between SB, PP, and BoS in terms of number of successful design requirements. I compared between PP and BoS in terms of Number of Activity Screens used. Figure 11 below shows the median of successfully implemented design requirements and the number of used activity screens in the participants' designs. Figure 12 displays the spread of this data. In terms of *fulfilled design requirements*, PP participants had a greater median score than BoS. SB did have a higher median than BoS, but due to only having 3 collected artifacts, a comparison between the activities may not be meaningful.

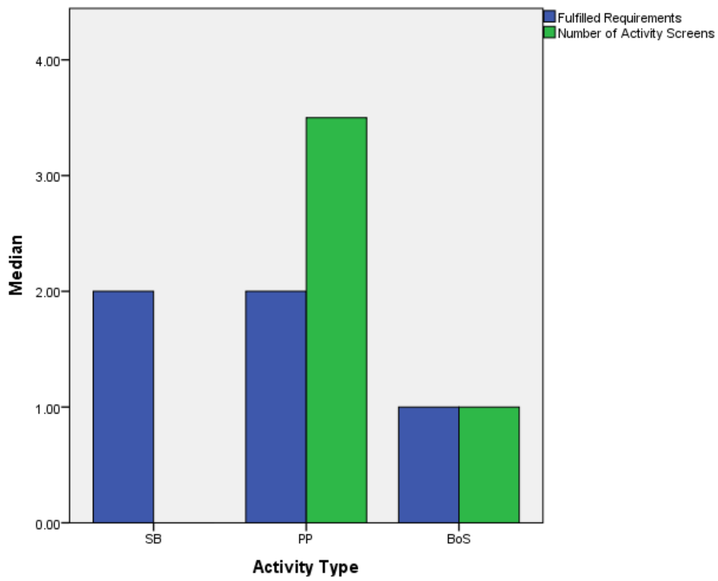

FIGURE 11: DESIGN REQUIREMENTS AND NUMBER OF SCREENS

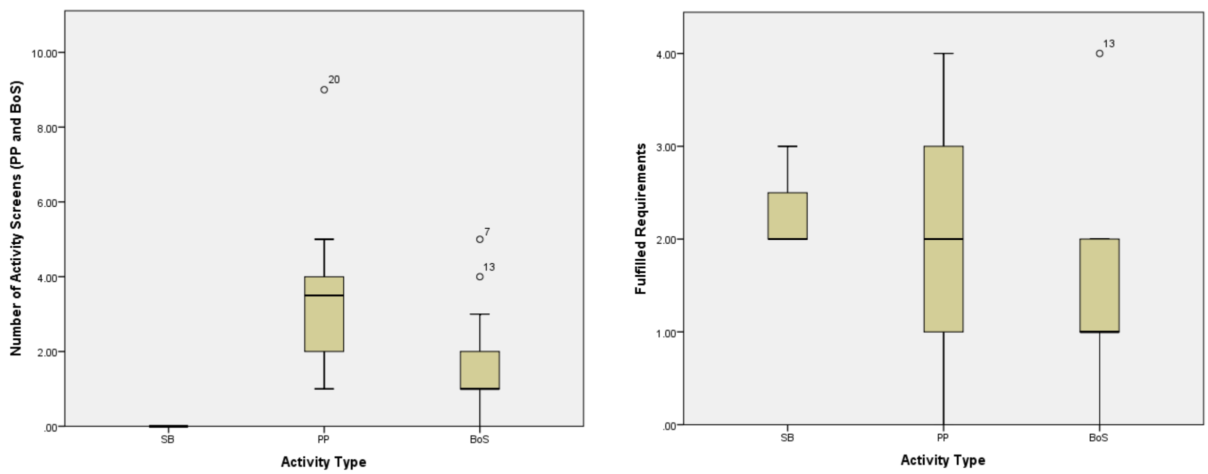

FIGURE 12: NUMBER OF SCREENS AND NUMBER OF FULFILLED REQUIREMENTS

In terms of the number of activity screens, PP participants had more screens than BoS on average (4 to 1). SB was exempt from the number of activity screen statistic due to the nature of the activity not having required activity screens. Figures 13 and 14 below shows two examples of activity screen frequency between PP and BoS.

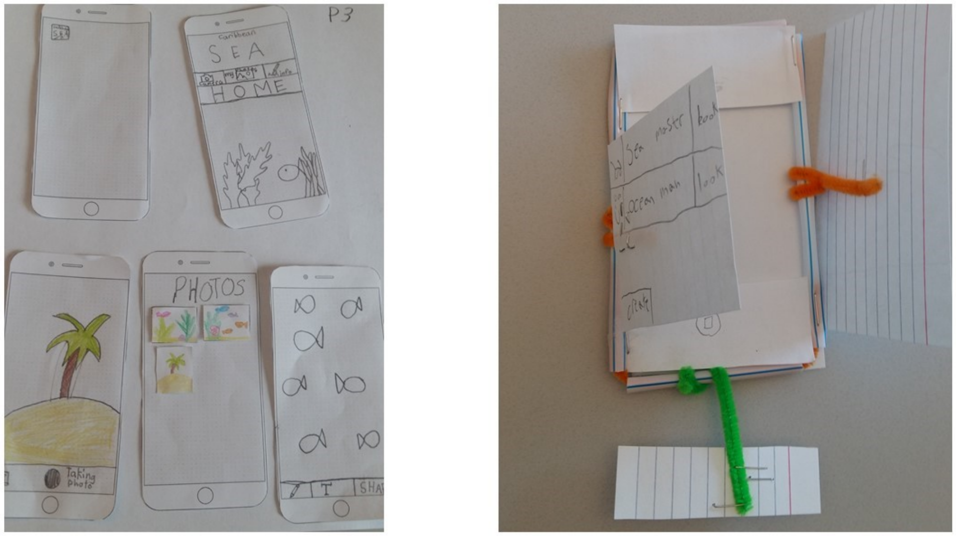

FIGURE 13 SB VS. BOS ACTIVITY SCREENS

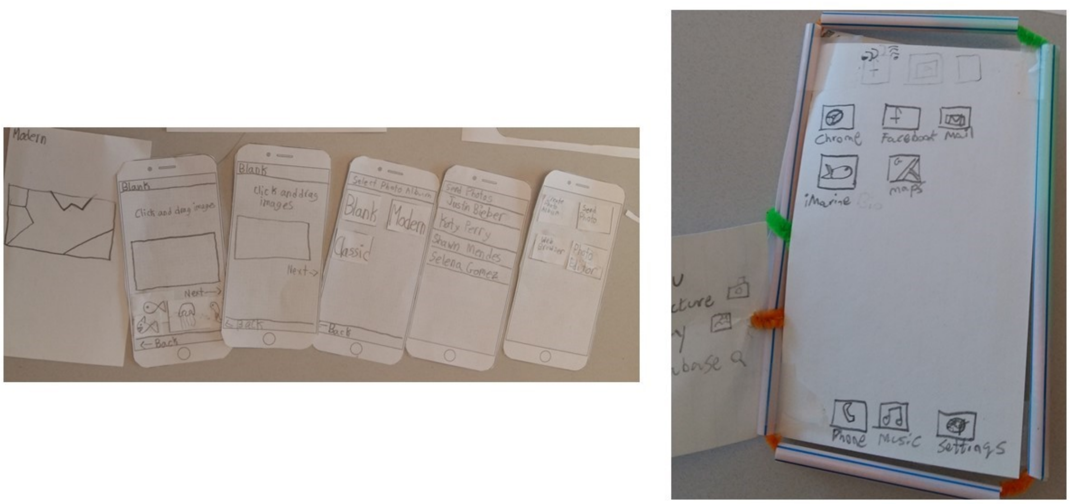

FIGURE 14 SB VS. BOS ACTIVITY SCREENS

5.1.2 POPULAR IMPLEMENTED DESIGN REQUIREMENTS

Figure 15 below shows the proportion and counts of each of the design requirements per activity type. It should be noted that I had different numbers of artifacts per design type. For this reason, the height of the bar charts is not meaningful.

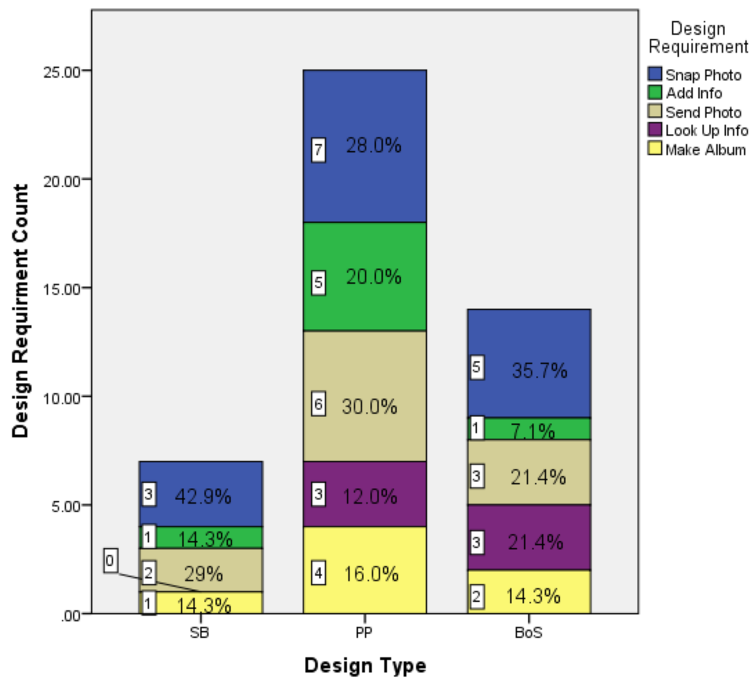

FIGURE 15 PROPORTIONAL BREAKING OF DESIGN REQUIREMENTS PER ACTIVITY

The most popular design requirements with SB was "Snap Photo of Sea Life", however I only have 3 observations of this in total due to the low number of SB artifacts. With PP, the most popular design elements were snapping photos and sending photos, while BoS had a focus on snapping photos. For BoS, due to only having a photo of the final design, it was sometimes not possible to see all the BoS activity screens. For this reason, I counted a design requirement as being implemented if I could either see an activity screen with a requirement or if the home screen had buttons that fulfilled a design requirement and at least the same number of activity screens as these buttons. For example, if I saw a button for taking a photo and a button for a social media sharing option as well as two unclear activity screens, I assumed those two screens were for those buttons. I realize it is possible that the unclear activity screens could be blank.

Figures 16 and 17 below show examples of designs with the highest number of completed design requirements per activity.

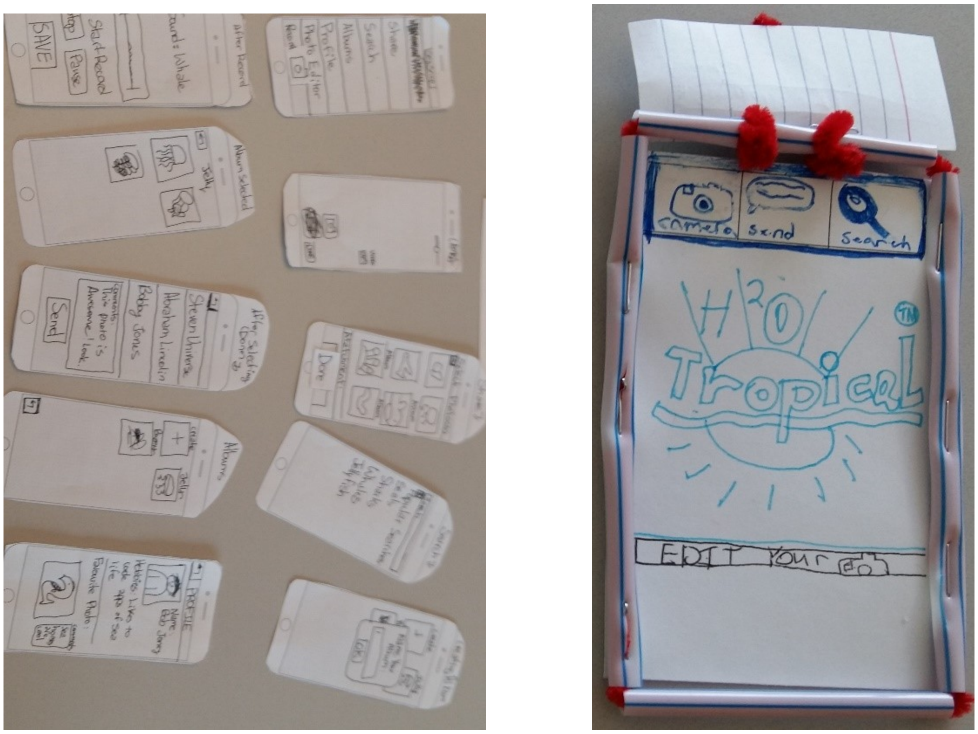

FIGURE 16 PP DESIGN WITH 4 COMPLETED REQUIREMENTS AND BOS DESIGN WITH 2 COMPLETED DESIGN REQUIREMENTS

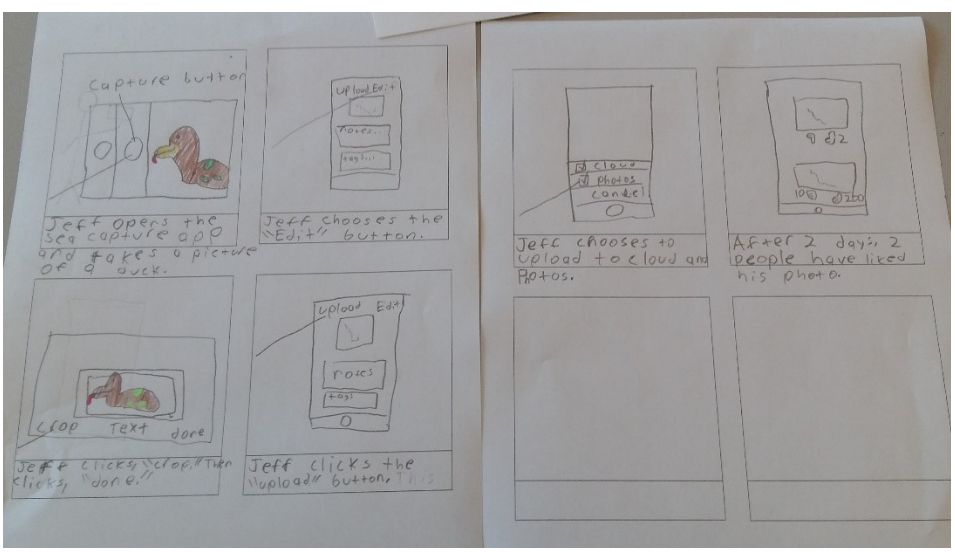

FIGURE 17 SB DESIGN WITH 3 COMPLETED REQUIREMENTS

5.1.3 TEMPLATES AND SCREEN SIZES

For our PP and BoS activities, participants had the option to use templates or blank cards as screens in their app.

Of the 13 BoS designs, 11 chose no template and completed all work on blank cards which were then attached to the frame, 1 chose to forego the frame entirely and strayed into more of a PP design using many screens, and 1 participant chose a mixed design involving templates and blank cards for screens. See Figure 14 above as an example of pure template (PP) and blank cards (BoS).

Of the 14 PP designs 10 chose a pure template (used all template cards) approach for their screens, and 4 choose to mix between templates and blank cards as screens.

Activity screen size was another area examined from the PP and BoS designs.

Of the 13 BoS designs, 9 had varying screens sizes, such as thin or half sized screens. 1 had no activity screens, and 3 had only full-sized activity screens. All 14 PP designs had full-sized screens.

5.1.4 SCREEN PLACEMENT

The location of activity screens was noted during the analysis of the BoS designs. Of the 13 BoS designs, 6 had a thin activity screen located and attached to either the top or bottom of the frame. Thin screens were only observed to be attached to either the left or the right side in 3 of the designs, often along with a thin top or bottom screen as well. Full screens were always attached to the left or right side of the frame when used in all cases but one. Figure 18 below shows two examples of BoS with different screen placements and sizes.

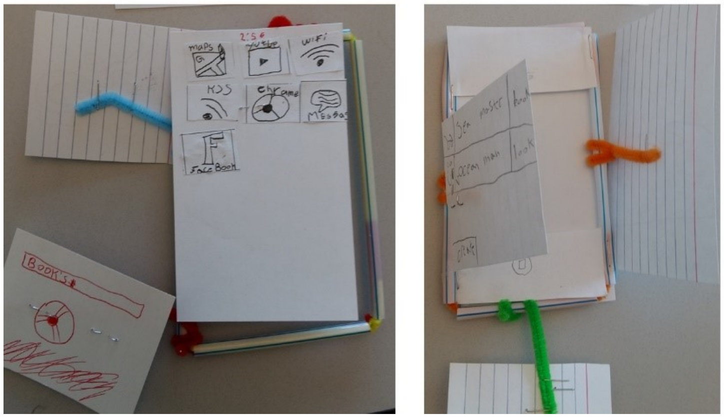

FIGURE 18 HALF SIZED SCREENS (LEFT) AND MIXED SCREENS (RIGHT)

5.1.5 STORYBOARD DESIGNS

The demo for the participants contained panels an actor showing a mobile phone in their hand. The next panel would then cut to a zoomed in key frame of the app showing its features. This was meant to show the function of a SB. The artifacts collected from the SB sessions mainly had a mix of actors and key frames, and the number of panels used was usually 4. However, one participant chose to use 6 panels (Figure 17 in 5.1.2) and no visible actors to tell their story. They completed the most design requirements (3) of their group, and they had a similar level of detail in their drawings as their peers. The group they worked with were ages 11-14, were quiet and engaged for the entire session, required no assistance from the researcher or camp leader and did not collaborate with one another.

5.2 AFFINITY DIAGRAM RESULTS

The affinity diagram was created from the design session observations by the lead researcher as well as quotes written by the participants on their reflection sheet at the end of the design session.

As mentioned in the methodology, I used an affinity diagram with two color coding techniques. I used counts of quotes and observations for categorical referencing, similar to Sheriff et al. (2017). From the affinity diagram, seven major themes emerged:

1. On Task/Off Task which is a collection of observations from when participants were working or distracted;

2. Difficulty with Design describes moments that participants had trouble with their design;
3. Time Constraints is a collection of moments from when participants felt limited by time;
4. Positive Comments is a collection of comments and observations that support the design session;
5. Collaboration is any observation where participants either worked together or chose to work independently;
6. Boys/Girls Work Ethics speak about the differences observed with the two groups;
7. Popular Tools is a collection of comments and observations about what design items were used the most during the sessions.

Figure 19 below shows samples of our completed affinity diagram categories.

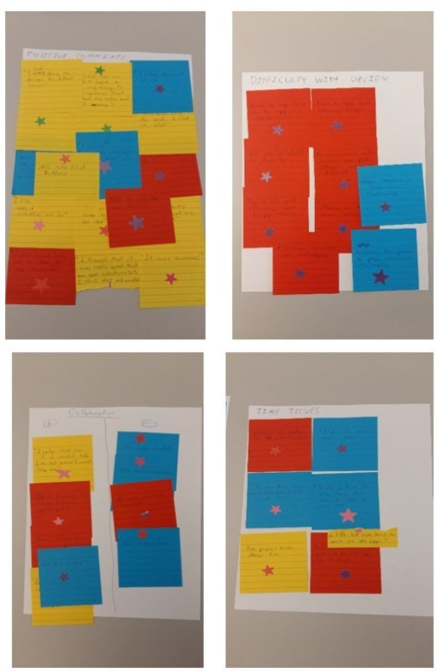

FIGURE 19 AFFINITY DIAGRAM THEMES POSITIVE COMMENTS (TOP LEFT) DIFFICULTY WITH DESIGN (TOP RIGHT) COLLABORATION (BOTTOM LEFT) AND TIME ISSUES (BOTTOM RIGHT)

I broke each category from our affinity diagram down into table counts. However, since not every participant reported comments, and I had varying group sizes per activity, these should only be taken as general criticism for the activity type and means to organize the observations and quotes for future analysis, not a comparison across all three activities. I also reported common observations and participant quotes per category.

Because of the ad hoc nature of the observations during the design sessions, the number of observations per category doesn't necessarily represent the strength of each theme. It is possible that observations were missed during the design sessions, for example, if the lead researcher was assisting a participant. However, the themes are still worth noting as patterns for the design processes.

5.2.1 ON TASK/OFF TASK

BoS and PP had many observations in this category., such as "most finished their design", 2 [participants] had a good working design with at least 4/5 features", and off task observations, such as "off task often", "Some only finished one requirement", one participant had little done", and "not many using cards". SB had no on or off task observations recorded.

5.2.2 DIFFICULTY WITH DESIGN

Another category from the affinity diagram was Difficulty with Design. For BoS, the majority of the challenges came from creating hinges, working with straws and pipe cleaners, and attaching screens. I had observations, such as "Had to help with creating hinges", "Had to help with attaching screen to pipe cleaners", and "Physical work with straws and pipe cleaners was difficult". These physical components of the design session took participants 5-7 min to set up their frame, and 1-2 min to attach a screen to the frame. The attachment of activity screens was an ongoing process and usually occurred after a participant had drawn something on the screen. The lead researcher or camp leader would assist if a participant was taking more than the average time.

From our observations, it appears that Storyboarding participants had less difficulty with the design process. This is evidenced by only two observations in this category. These challenges came from starting a story and switching from person to phone view.

This difficulty with design theme is primarily centered on BoS with the youngest group. From the observations, it appears that most of the difficulty came from the physical work of the design process, which supports our findings from the survey data that the youngest group probably had trouble with the fine motor skills needed to create straw frames and attaching screens.

5.2.3 TIME CONSTRAINTS

Issues regarding allotted time for the activity was another emergent theme. In all three design conditions, a small number of participants expressed pressure due to the limitations on the session time. For example, one participant said, and "…a little bit more time to work on the app".

One PP participant who said "I think that we needed a little bit more time to work on the apps" created a PP design with 1 activity screen but did not complete any design requirements. However, they had set up widgets on the home screen for requirements to be implemented and created an off-task activity screen. One SB participant said, "The only thing that would make [the activity] better is more time", but they finished 3 of the design requirements and used 6 panels with high levels of detail for their SB design. Another SB participant from the same group said "Really I think the only thing that could be better is more time"; they completed 2 requirements and had 4 detailed panels.

5.2.4 POSITIVE COMMENTS

All three activities received positive comments from the participants. I received the most direct quotes from participants for this category. Table 7 below shows these quotes.

TABLE 7

	SB Direct Quotes	PP Direct Quotes	BoS Direct Quotes
	"I like doing all of it" "I love it, I wish there was more time" "I like that I can take pictures, and have information about the thing you took it of" "I loved making this app"	"I loved doing the design for different screens" "I liked how we didn't have to do anything. It was optional. That helped me relax and not worry" "This was very fun and I liked it a lot" "I liked this activity. It was very fun" "It was very fun" "I found it very easy to get my ideas out" "I like to design my app. I found it interesting and fun" "It was a cool way to design an app" "It was awesome!" "I found it really great that you gave instructions"	"This was super fun" "I really enjoyed being able to choose the app requirements"

5.2.5 COLLABORATION

The collaboration theme was split into positive and negative notes. All three activity types had notes under positive collaboration. BoS and PP only appeared for ages 11-14, and SB only for ages 8-11. One PP pair who worked on the same artifact only finished one design requirement and used 2 activity screens. It seems that they spent the majority of their time cutting out and creating widgets for the home screen. However, in the same PP group, another pair completed 3 requirements and used 4 activity screens. Based on their artifact, it looks like two different art styles. They may have split the workload.

5.2.6 BOYS/GIRLS WORK ETHIC

From observations with PP age 11-14 and BoS age 8-11, I noticed that the girls worked faster than the boys in terms of completing design requirements, had more detail in their designs by filling more of the activity screens, and started working immediately.

5.2.7 POPULAR TOOLS

I also observed which tools within each design sessions were popular. This may be useful information for anyone trying to decide which tools to include in their workshops for particular design activities. Table 8 below breaks down the observations for each activity and age group.

TABLE 8: CATEGORIZED OBSERVATIONS

	SB	PP	BoS
Ages 8-11	Liked gel pens		
Ages 10-11		Liked cutting out widgets Liked the home screen, and web browser template Like blank cards Liked pens and pencils	

	SB	PP	BoS
Ages 10-14	Didn't like pens Liked pencils	Liked blank cards Liked the grid buttons Preferred pens over pencils Liked creating icons	Used a lot of tape Liked pipe cleaners for the frame Like being able to manipulate physical objects

PP participants enjoyed cutting out their own widgets, and I noticed that both the screen templates and blank cards were being used. Participants mostly enjoyed using a pre-designed screens, but also created some of their own from scratch. For the SB groups, the younger groups enjoyed the gel pens, while the older group liked pencils. For BoS, pipe cleaners, and tape worked well, and one participant from the oldest group for BoS commented "I enjoyed being able to manipulate physical objects, and it allowed for more creativity…". This comment on enjoying manipulating physical objects to enhance creativity may support to BoS as a prototyping technique or motivate future research.

5.3 QUESTIONNAIRE RESULTS

Each of our participants were presented with a post-design session questionnaire to help assess their attitudes towards different aspects of the prototyping method used for the design session. I asked 6 questions on a 5-point Likert scale.

Unfortunately, due to scheduling issues and low participant days, I do not have a comparison for every activity at every age group.

I used a 95% CI of the means to check if there were significant differences between groups per question from our survey scores. In all cases, the confidence intervals overlapped between the means of the groups. A Mann Whitney U test was also used for specific groups.

I ran a one-way ANOVA against all questions in the following data sets:

1. 5.3.1 All responses across all ages
2. 5.3.2 Same age group comparing activities:
    a. 5.3.2.1 Ages 8-11 comparing SB and BoS
    b. 5.3.2.2 Ages 10-14 comparing SB, PP, BoS
3. 5.3.3 Same activity group comparing ages
    a. 5.3.3.1 BoS comparing age groups 8-10 and 10-14.
        i. BoS comparing age groups 8-10 and 11-14.
    b. 5.3.3.2 SB comparing age groups 8-11 and 11-14
    c. 5.3.3.3 PP comparing age groups 10-11 and 10-14

5.3.1 ALL RESPONSES

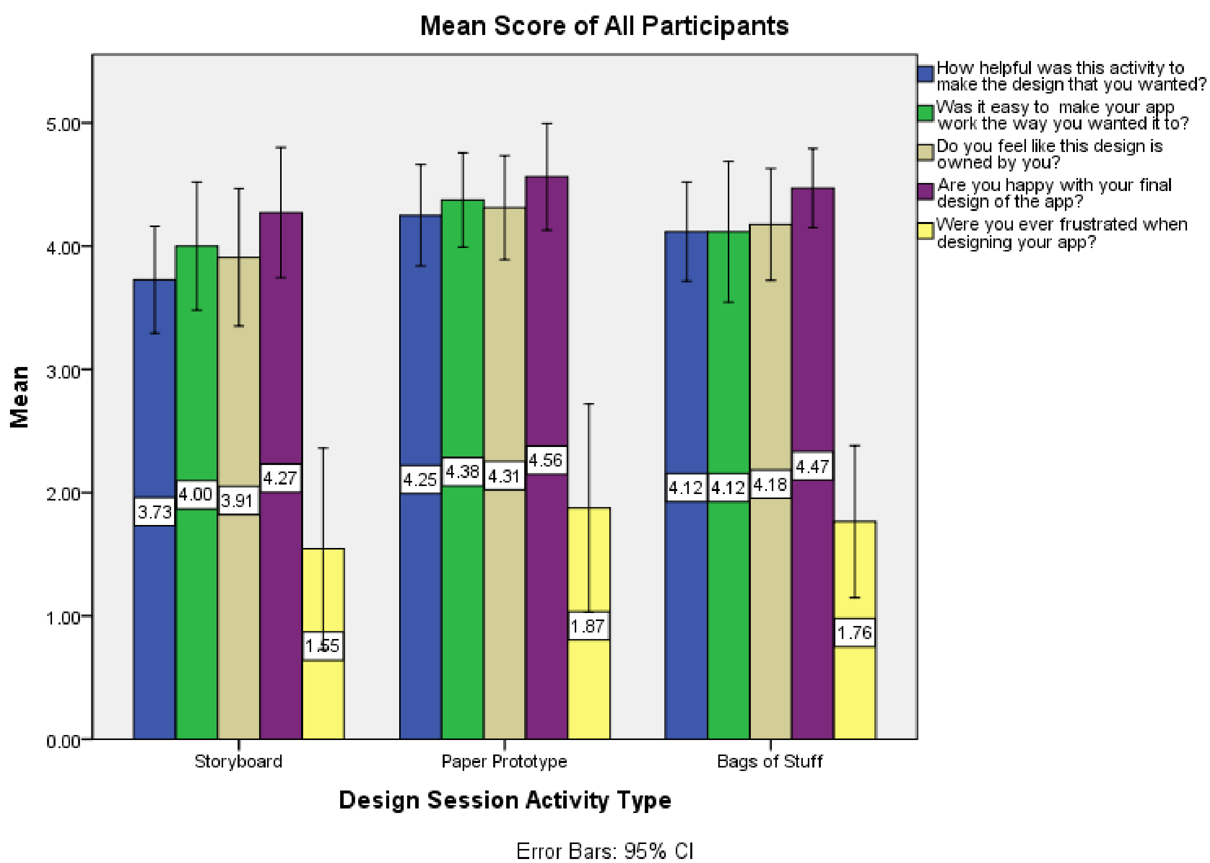

FIGURE 20 MEAN SCORES OF ALL PARTICIPANTS

Figure 20 above shows the mean scores of all participants across all three activity types per survey question. Mean scores of positive attributes (i.e., helpfulness, easiness, ownership, and happiness) were between 3.73 and 4.56 for all activities, whereas mean scores for the negative attributes (i.e., frustration) were between 1.55 and 1.87. Based on the ranges of these means in Figure 20, all three activity types performed favorability in terms of helpfulness, easiness, happiness, ownership, and low frustration. There were no significant differences between the three activity types in terms of the participants responses per category. This may indicate that all three prototyping techniques are useful as design tools for the specific activity of making an app.

All three prototyping methods were successful for helping the participants to easily create their intended design. The prototyping methods worked well as a design tool, as indicated by high mean scores in helpfulness and happiness with design. The three methods were also successful in promoting student engagement for the design process as indicated by high ownership and easiness scores, and low frustration scores.

Students enjoyed designing their own app using our approach. I had many positive participant quotes, that support our questionnaire data, from the Positive Comments theme of our affinity diagram analysis (see section 5.2) for the activities.

5.3.2 SAME AGE GROUP COMPARING ACTIVITIES

5.3.2.1 AGES 8-11 COMPARING SB AND BOS

I compared the groups SB ages 8-11 and BoS ages 8-10. Figure 19 below shows the mean scores of the SB and BoS groups per question All of the 95% confidence intervals overlapped. Ages 8-11 had two results which were not statistically significant but had p values close to 0.05. Specifically, "Were you ever frustrated when designing your app" P=0.056, and "How helpful was this activity to make the design that you wanted?" P=0.070. Analyzing the results of this age group will hopefully help us to understand some differences between the activities of SB and BoS for the youngest age group.

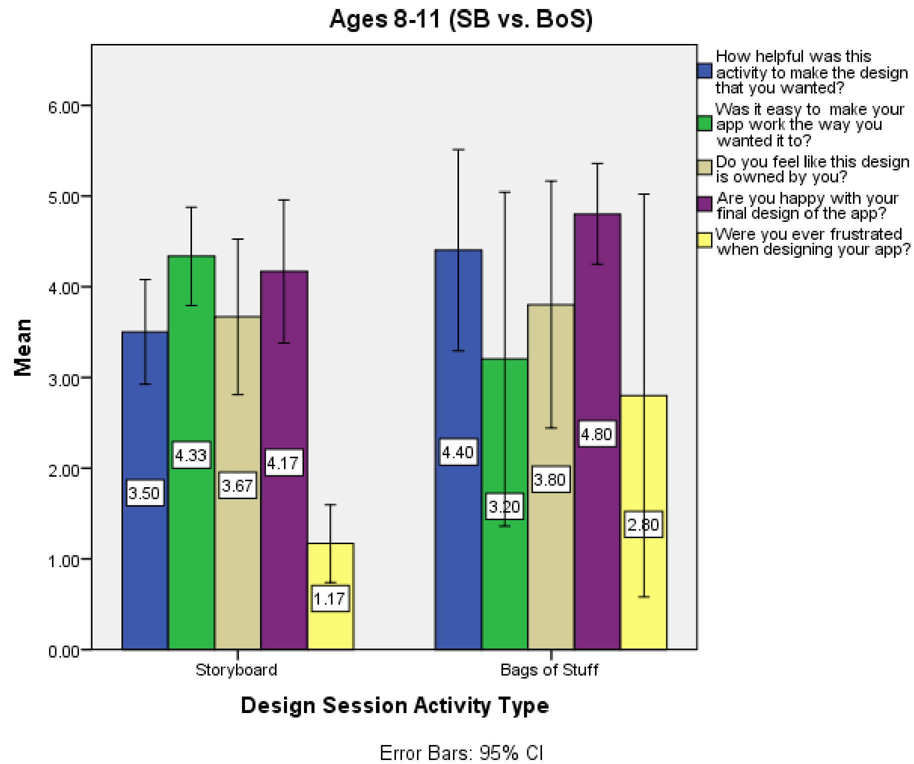

FIGURE 21 AGES 8-11 SB AND BOS

FRUSTRATION

I had no significant results, p=0.056, for our frustration score. Looking at the SB mean, median, and mode scores of 1.17,1 and 1 respectively compared to BoS 2.8, 3, 1, it looks as if SB was less frustrating overall. Remember, frustration scores are reversed, and a score of 1 is least frustrating. SB also has the lower standard deviation, and a consistent score across the mean, media and mode close to 1. BoS has more variation, with a median of 3, and a mode of 1.

Figure 22 below shows percentage scores and counts for “Were you ever frustrated when designing your app?” for SB and BoS. Looking at Figure 22, the percent scores helps to explain the variation in BoS. While SB has a very consistent score of 83% of participants reporting 1 (“not at all”) for frustration, and 17% reporting 2, BoS only has 40% reporting 1, with the remaining 60% split between 3, 4, and 5 (“Very Much”). BoS seems to be the more frustrating of the two activities and also fairly frustrating overall, with 60% of the BoS group reporting a score of 3 or more.

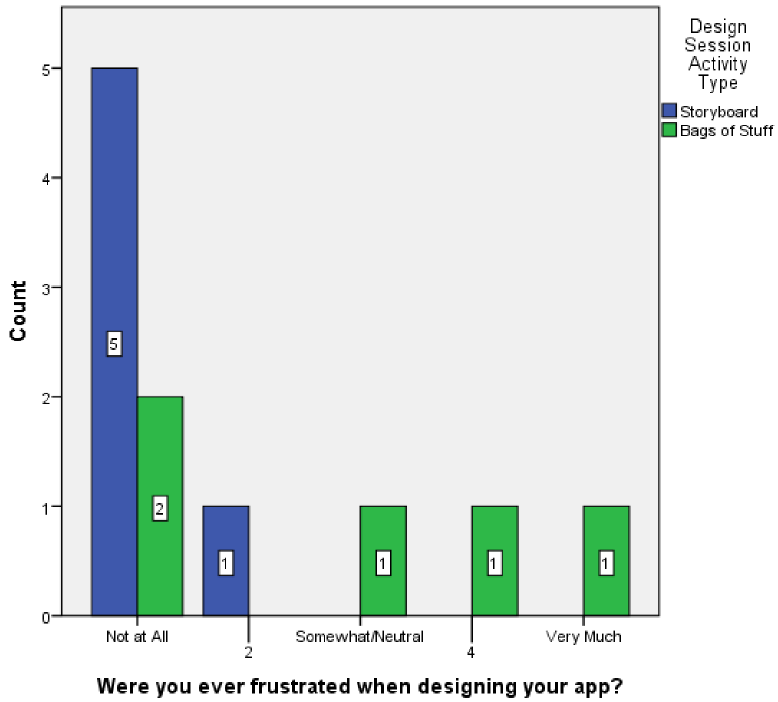

FIGURE 22 SB AND BOS PERCENTAGE SCORES

5.3.2.2 AGES 10-14 COMPARING SB, PP AND BOS

I pooled the age groups for participants who had a difference of one year as follows: SB Ages 11-14, PP Ages 10-14 (10-14 pooled with 11-14), and BoS: Ages 10-14(10-14 pooled with 11-14). I did not include PP ages 10-11 in the pool for PP ages 10-14. I felt that PP ages 10-11 were their own group since they had a low spread in age variance and if added to PP ages 10-14, would bias the spread of ages towards the lower end.

Figure 23 below shows the mean scores of the pooled ages 10-14 across the three activities SB and PP and BoS per question. I used a 95% confidence interval check for significance, but there was none detected. I then ran a one-way ANOVA table between all means per questions. No significant main effects of prototyping technique were detected.

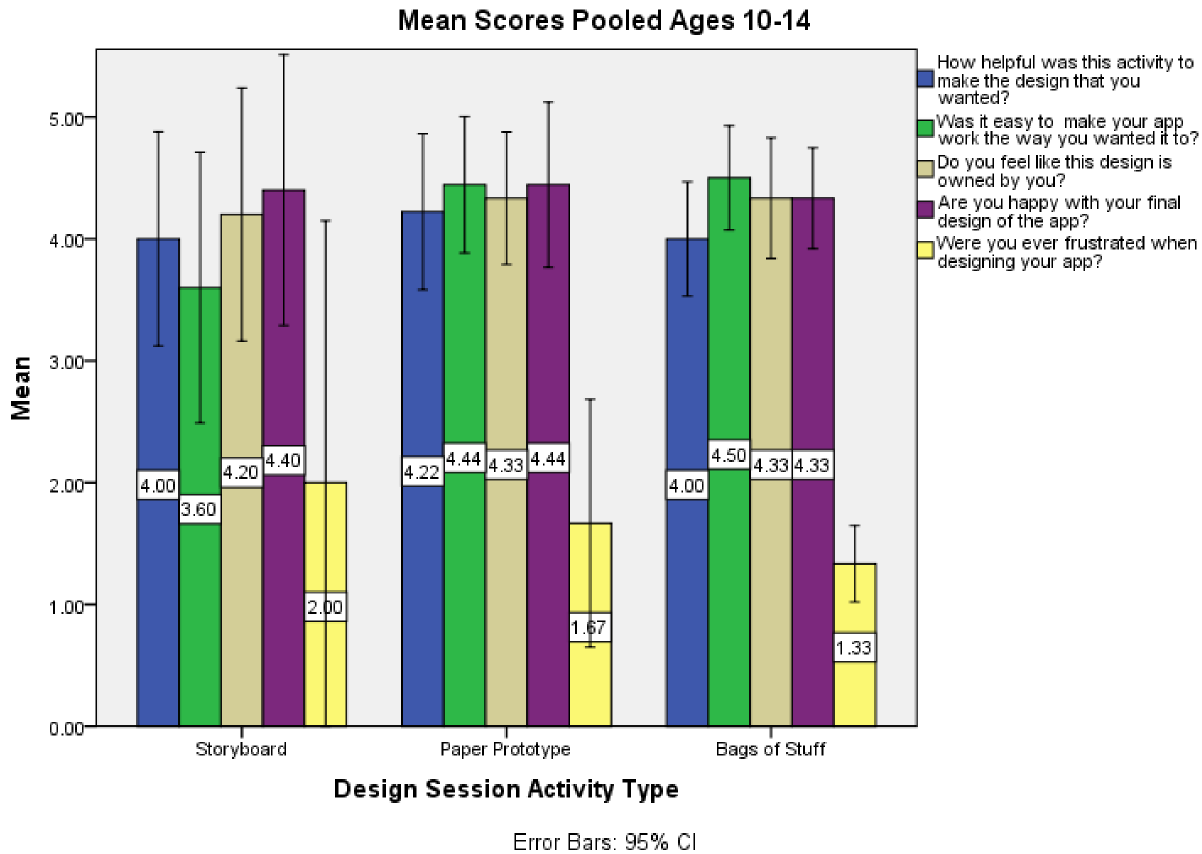

FIGURE 23 MEAN SCORES POOLED AGES 10-14

5.3.3 SAME ACTIVITY COMPARING AGES

5.3.3.1 BOS COMPARING BETWEEN AGE GROUPS AGES 8-10,10-14, AND 11-14

For BoS I first compared the disjoint age groups 8-10 and 11-14 across all questionnaire questions using a one-way ANOVA table and a Mann-Whitney U test. There were no significant results.

I pooled age groups 10-14 with 11-14 to help compare BoS across two age groups, now 8-10 vs. 10-14 (pooled). Figure 24 below shows the mean scores of each age group per question. I used 95% confidence intervals to test for significance. There was an overlap detected between the intervals, so I used a one-way ANOVA table for further testing. I found *two significant results* These differences occurred for the questions “Was it easy to make your app work the way you wanted it to” P=0.038, and “Were you ever frustrated when designing your app?” P=0.016. I used a box plot to test for outliers on all significant results. There was one outlier detected beyond 1.5 IQR, but not classified as an extreme outlier beyond 3 IQR.

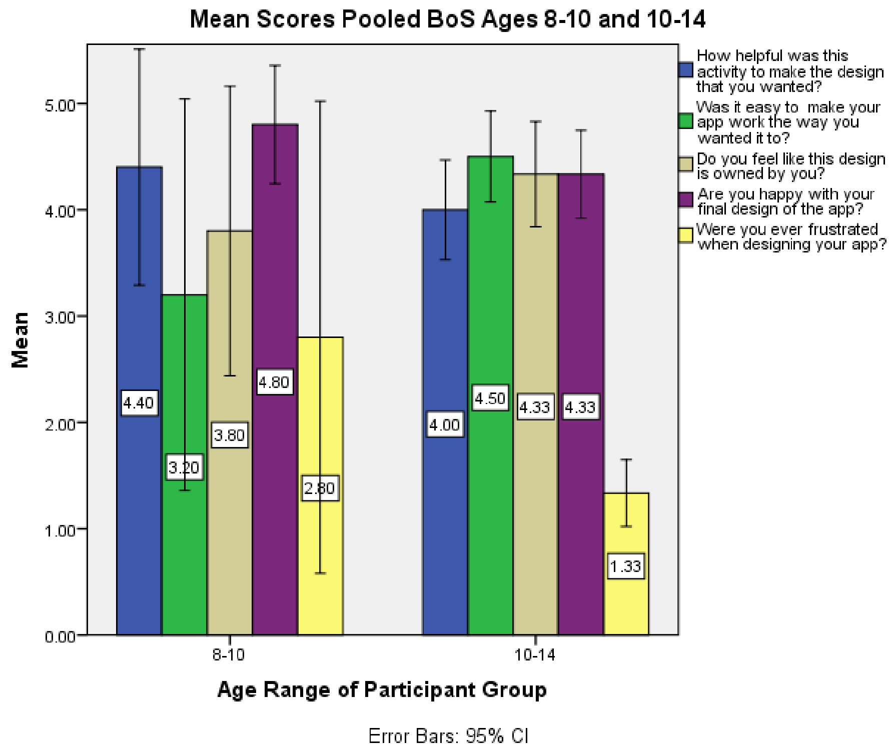

FIGURE 24 MEAN SCORES POOLED BOS AGES 8-10 AND 10-14

Easiness

I had a significant difference between the means of these two age groups for easiness (p=0.038). Looking at Figure 24 above, there is a difference in terms of how easy each age group found the BoS activity. Ages 8-10 were slightly above neutral with a mean score of 3.2 and a median and mode of 3.0. Whereas ages 10-14 reported a mean score of 4.38, and a median and mode of 5.0, indicating that this activity was well received in terms of easiness.

Figure 25 below shows percent scores for easiness for the two age groups. We can see that ages 8-10 had more variances in their responses, with 20% reporting “not at all”, 40% reporting neutral, 20% reporting 4, and 20% reporting “very much”, this also aligns with their higher standard deviation of 1.48.

Ages 10-14 seemed to find the activity much easier, with only 15.38% reporting neutral, 30.77% reporting 4, and 53.85% reporting "very much". This age group also had a much smaller standard deviation of 0.77, and no score below a 3.

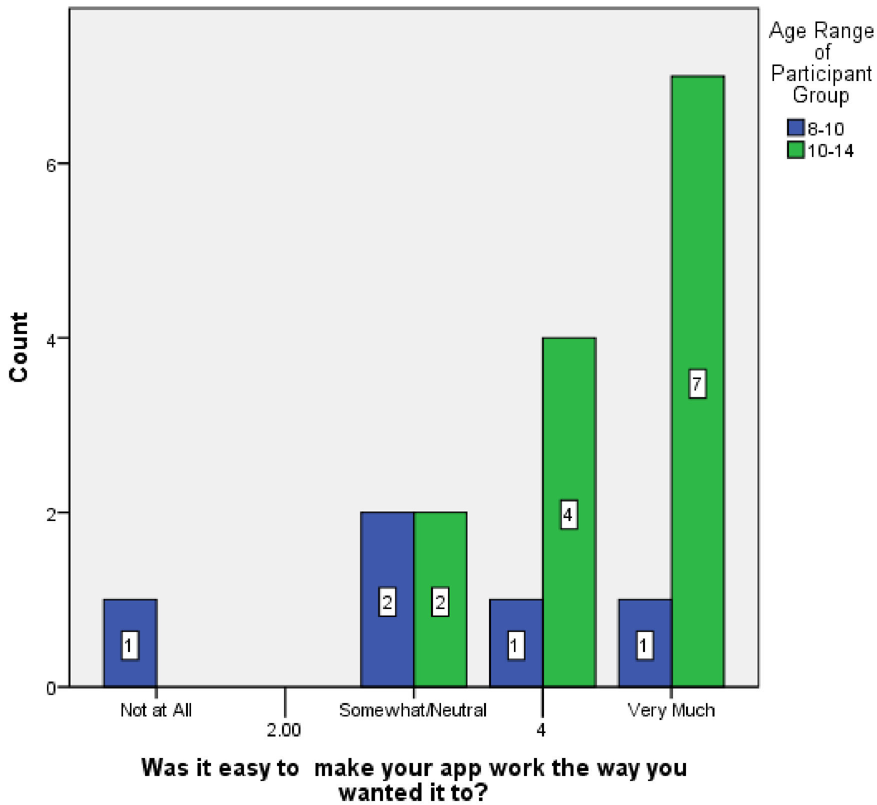

FIGURE 25 PERCENT SCORES BOS AGES 8-10 AND 10-14

Frustration

I had a significant result for frustration (p=0.016). Similarly to easiness scores, I also measured frustration between the two age groups for BoS. From Figure 23 above, ages 8-10 reported a higher mean and median score of 2.8 and 3.0 respectively than ages 10-14, with a mean of 1.38 and median of 1.0. Again, ages 8-10 had a higher standard deviation than age 10-14, 1.78 compared to 0.50. Looking at the percent scores from Figure 4, we can see that ages 8-10 had a higher variance in their responses, reporting on every score except 2. Whereas age 10-14 are tightly grouped around score 1 and 2, with 61.54% reporting a score of 1, indicating that they had low frustration with this activity. Again, I used a box plot for our outlier test. No outliers were detected.

Figure 26 below shows percent scores for frustration for the two age groups. In terms of frustration, ages 10-14 found the activity less frustrating than ages 8-10. This aligns with our analysis of easiness of this activity. However, unlike easiness scores, the ages 8-10 are more divided in their responses in terms of frustration. 40% of the 8-10 group were "not at all" frustrated, while the remaining 80% were split between neutral, 4, and "very much".

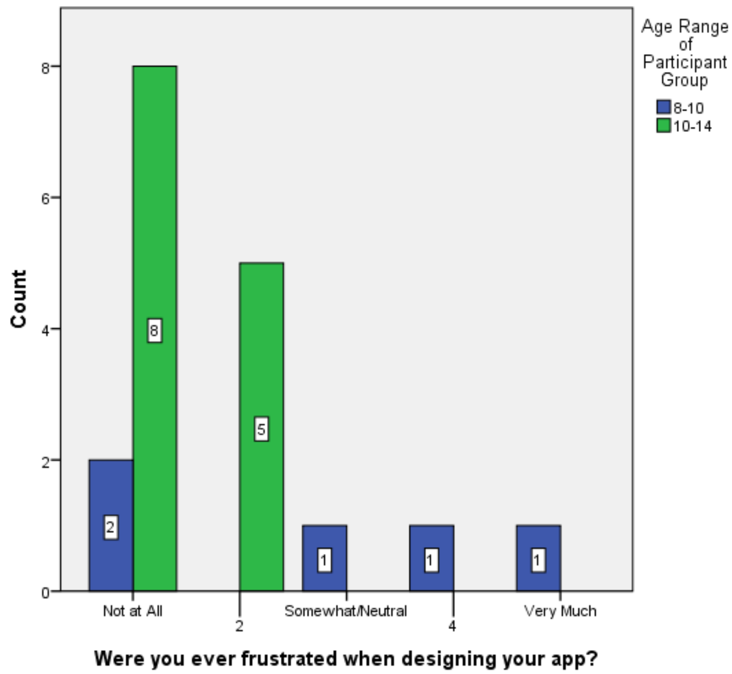

FIGURE 26 BOS PERCENT SCORES AGES 8-10 AND 10-14

5.3.3.2 SB COMPARING AGE GROUPS 8-11 AND 11-14

I compared the SB activity between age groups 8-11 and 11-14. I used 95% confidence intervals and a one-way ANOVA table to test for significance between the means of the groups. No significant results were detected.

Figure 27 below shows the mean scores of the two age groups per question.

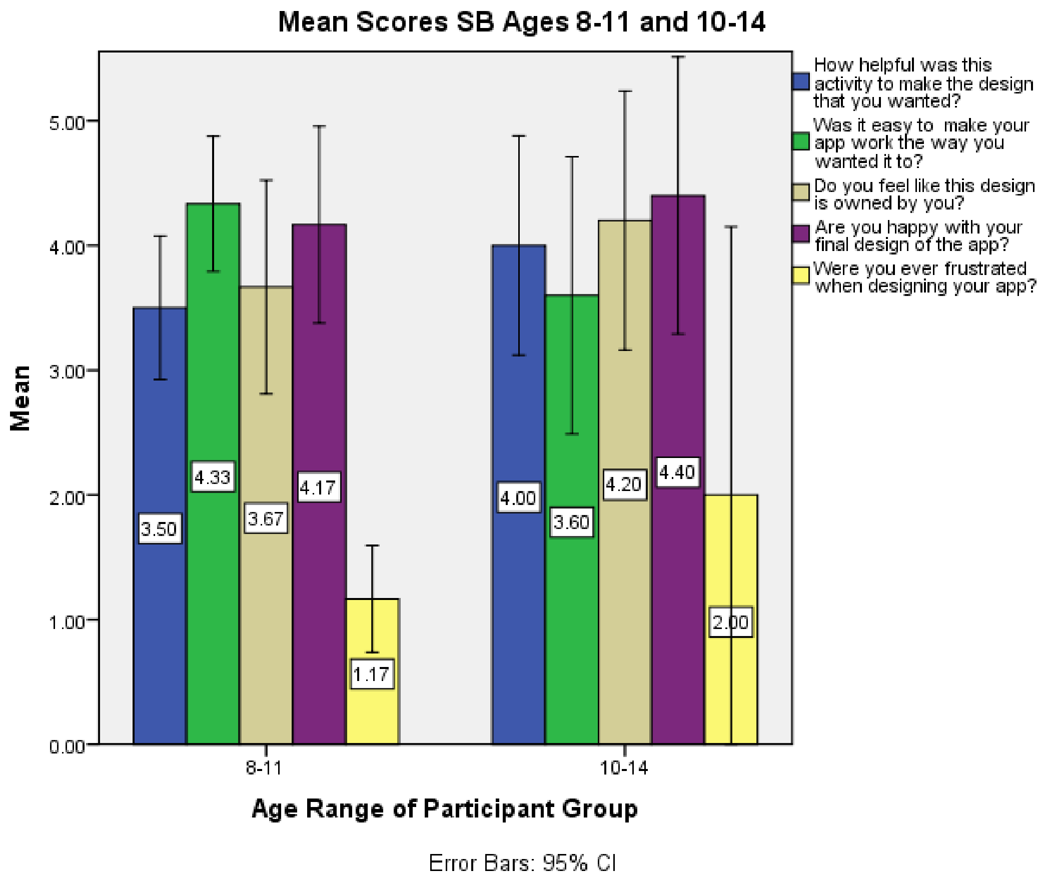

FIGURE 27 MEAN SCORES SB AGES 8-11 AND 10-14

5.3.3.3 PP COMPARING AGE GROUPS 10-11 AND 10-14

I compared PP groups from ages 10-11 and 10-14 (pooled 10-14 with 11-14). I did not have any participants in the age range of 8-11 for PP.

Figure 28 below shows the mean scores for each question from our survey. There were no statistically significant results between the mean scores of groups per question tested by 95% confidence intervals and a one-way ANOVA table.

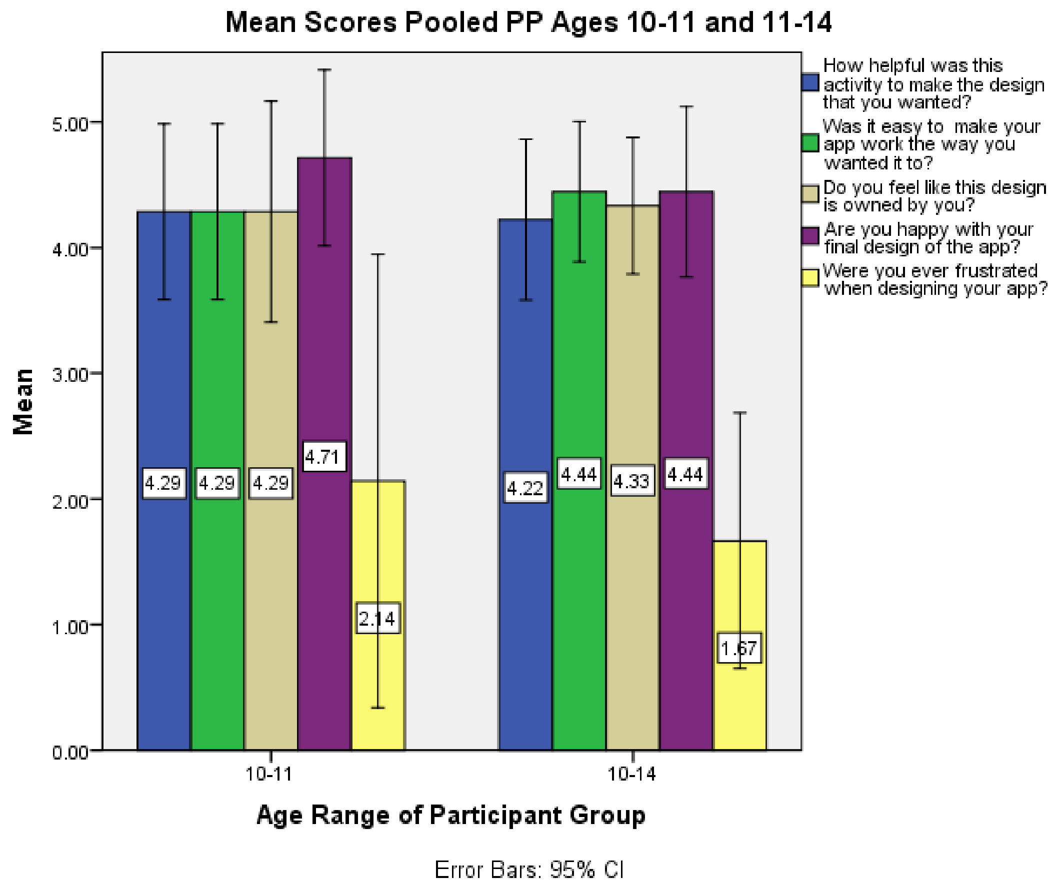

FIGURE 28 MEAN SCORES POOLED PP AGES 10-11 AND 11-14

CHAPTER 6 DISCUSSION

6.1 SUPERNOVA

6.1.1 IMPACT OF PROTOTYPING METHOD ON DESIGNER EXPERIENCE

The results of the questionnaire data, as well as participant quotes and observations indicate two findings with regards to the participants' experience working with the prototyping methods. Overall, the participants regarded the design sessions as a positive experience. However, working with BoS was found to be somewhat frustrating for the participants.

6.1.1.1 POSITIVE EXPERIENCE

Using the survey data, I compared all three activity types across all age groups. In the aggregate, SB, PP, and BoS had favorable results in all categories. All three prototyping methods were successful for helping the participants to easily create their intended design with low degrees of frustration. The prototyping methods also worked well as a design tool indicated by favorable scores in happiness, helpfulness, and ownership.

The participant responses with respect to happiness, helpfulness and ownership were remarkably robust, with no significant differences appearing in these categories when the data was broken down by age groups and prototyping method. This suggests that there was no strong preference for one prototyping method over another, however due to the between-subjects design we did not collect comparison data from our participants.

Looking at each activity independently, BoS on its own may be a somewhat less easy and more frustrating activity for younger participants, but still gives the participants a happy and useful design experience.

These findings may contrast with Katterfeldt et al. (2012), who found that childlike activities, such as drawing, did not work well with teens in a design context, and also Dunn & Dunn (1978), who note that childish kinesthetic materials may be considered too childish by older students. Our Storyboard mean scores were close to 4 for all positive attributes, which contrasts Katterfeldt et al., (2012)'s drawing claim. However, these findings, while not significant, may agree with Katerfeldt et al., (2012) who found that minor changes in a design activities structure, such as templates and art supplies, can affect the satisfaction of the participants.

Dunn and Dunn (1978) state how tactile and kinesthetic materials can be motivational for students due to their game-like nature, but they may also seem too childish to some students depending on the activity type and the age range of the students, and this can ruin motivation for the activity. While I didn't directly measure participant motivation, our measurements of high happiness, high helpfulness, high ownership, and low frustration on the more tactile activities (PP and BoS) may contrast that claim. For both PP and BoS, the older participants had more activity screens. See Figure 29 and 30 below as an example.

FIGURE 29 PP AGE 10-11 (LEFT) AND 11-14 (RIGHT)

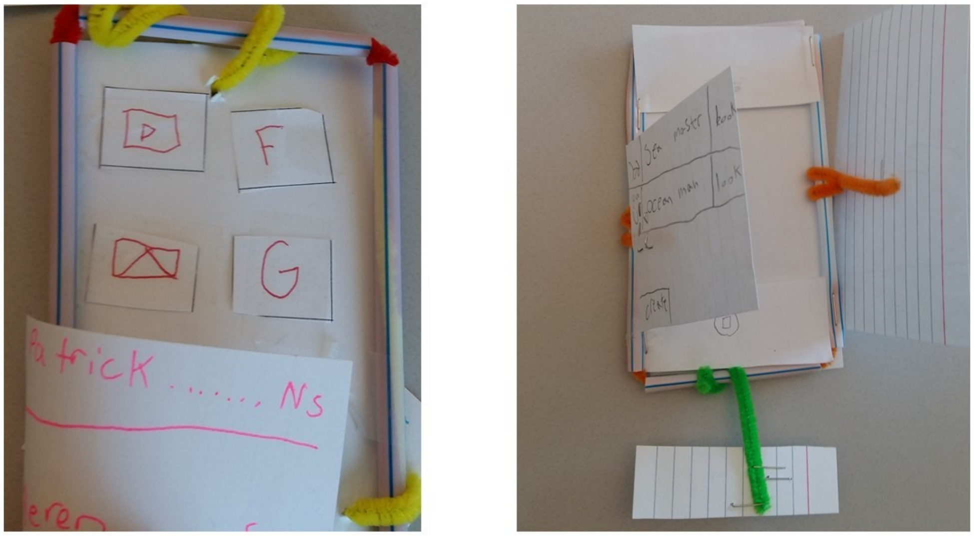

FIGURE 30 BOS AGE 8-10 (LEFT) AGE 11-14 (RIGHT)

This might indicate that they were engaged in the activity, and this may be due to the context of the activity. Mobile apps are ubiquitous which may help the participants see the purpose of sketching out a rough design for how an app should function. The comments from the aged 10+ PP groups help to show that the type of activity chosen is important, such as:

- “I loved doing the design for different screens” -PP
- “I liked how we didn’t have to do anything. IT was optional. That helped me relax and not worry” -PP
- “This was very fun and I liked it a lot” -PP
- “I liked this activity. It was very fun” -PP
- “It was very fun” -PP
- “I found it very easy to get my ideas out” -PP
- “I like to design my app. I found it interesting and fun” -PP

6.1.1.2 TIME ISSUES

Time issues was something that I noticed during the design sessions and also in the written reflection at the end of the design sessions. For example, participants said, “I think that we needed a little bit more time to work on the apps” and “The only thing that would make [the activity] better is more time”.

Our results with the younger group for BoS align with Mazzone et al. (2010), who found that younger children needed more time and explanation to get started with a craft-based design project. This may support our youngest group finding BoS difficult due to time limitations. These findings could be an important consideration to anyone running design sessions and other workshops with younger participants. It might indicate that researchers or teachers should not cater to easy design activities for younger groups in fear of the children ending up unhappy with their design. There may be initial frustration due to lack of fine motor skills and complexity of the activity, but young participants might enjoy the challenge and be happy with their final design. One of our themes from the affinity diagram was Time Constraints. Based on our analysis of the participants work who requested more time, it might be necessary to help participants stay on task, since the only PP participant who requested more time went completely off task as evidenced from their design artifact. The SB participants who requested more time still completed a high number of design requirements in good detail (3 and 4 requirements), and one had used 6 instead of 4 panels. This might indicate that some participants might find SB to take longer, possibly due to trying to show the actors in the story using features on the app, as well as zoomed in views of the application screens.

These findings help to explain why BoS performed not as well as PP for creating activity screens, and also why it had lower numbers of implemented design requirements. Two interesting artifacts, both created by the older BoS groups involved ignoring the frame entirely. One participant used staples to attach screens, resulting in a lot of work completed, and another treated the BoS activity like PP, which also resulted in a lot of completed work. These two participants may have decided that they could get more work finished if they ignored the straw frame altogether.

More time may be needed when a tangible crafting component is part of the design process such as creating the frame for the BoS activity. Also, the BoS activity encouraged participants to attach their screens to the frame. Doing this also required time and forced the participants to think about altering the screen sizes to make everything fit and function in a constrained design space. This attaching and altering of the screen sizes may also be a reason as to why the participants needed more time.

6.1.1.3 FRUSTRATION OLDER VS. YOUNGER PARTICIPANTS

From our questionnaire data, I found that, compared to older participants, our younger participants (ages 8-10) found BoS to be significantly more frustrating and less easy. This contrasts Druin (1999)'s claim that the use of basic art supplies for prototyping comes naturally to young and old design partners. I also found that the younger participants found BoS to be more frustrating than SB, although this result was not statistically significant. BoS is more tactile than SB, and it requires more explanation and help with the younger participants. This pattern can also be seen from our qualitative data in our affinity diagram. I had two themes related to challenges faced in the design process, namely Difficulty With Design, and Time Constraints. Our observations from BoS noted problems with participants working with hinges and other physical work with straws and pipe cleaners, as well as making new screens to affix to the main screen. Another theme from our affinity diagram was Creation of the Frame, which we broke down into positive and negative observations and quotes. We received 2 notes from the age 8-11 group commenting about how the straw frame was challenging to work with. Finally, the theme of Time Issues had one observation for BoS ages 8-10 about how long it took the participants to set up the straw frame. From our survey results, it appears that BoS is the more challenging activity for ages 8-10 participants, and this seems to come from hands on work with the crafting objects when trying to create a tangible 3D design as indicated in our qualitative results.

Another theme from our affinity diagram which may help to explain the higher frustration scores for BoS is On Task/Off Task. We had observations from BoS ages 8-10 noting how staying on tasks was challenging from this activity.

From our questionnaire and qualitative analysis, it appears that the younger BoS group had difficulty with the hands on, tactile aspect of this activity, and this may have caused the difference in easiness and frustration scores between the two groups. The complexity of the activity may have also played a role, as the younger group had more difficulty staying focused and on task.

It is also interesting is that in the cases where BoS was reported to be more frustrating, there were no differences observed in terms of helpfulness and happiness. This finding supports our earlier idea that even though an activity can be challenging for the youngest group, such as working with their hands to create a 3D design, that challenge helps to create a better sense of happiness and satisfaction in their final design. Because of this, researchers and teachers should consider giving young students challenging and highly tactile design activates, even though it may frustrate the students. This supports Read et al. (2013)'s idea that teenagers are concerned with something they must work hard to create, and that designs should have high value created from achievement. It also supports Schepers et al. (2018) who used low-tech crafting as a design activity and found that children found overcoming challenges to be fun, specifically assembling a tactile-challenging puzzle box.

6.1.2 IMPACT OF PROTOTYPING METHOD ON DESIGN OUTCOMES

I found that the type of prototyping activity used had an impact on the types of designs that emerged from the design session. In particular, the tangible elements of BoS lead to participants having to deal with the design in a holistic manner, as all design elements remained accessible in the design space. Having to work within the straw frame became a constraint on the design space. While this led to more creative outcomes, as evidenced by greater use of blank cards (rather than templates), and different screen sizes, it also appeared to be more time consuming. This resulted in fewer design requirements being met during the BoS session, as compared to the SB and PP sessions.

6.1.2.1 DESIGN REQUIREMENTS AND NUMBER OF SCREENS

I compared the number of successfully implemented design requirements on all three prototype artifacts. I found that PP and SB had more implemented design requirements than BoS. I also compared PP and BoS in terms of number of used activity screens. Again, PP performed better than BoS. I attribute these findings to the constrained design space of the BoS activity.

The frame for the BoS activity may have had an influence on the number of fulfilled requirements and activity screens created due to limiting the working design space. This may force the participants to work creatively with or around the frame, which may have limited available time to complete design requirements. These results suggest that SB and PP may be better suited than BoS for fulfilling design requirements when there isn't a physical constraint on the design space in which the app needs to function. Or this may mean that the frame took up too much of the participants design time. PP's ability to remove the screens from the design canvas upon a user click vs. BoS's persistent design canvas may give PP a design advantage for unconstrained design problems.

In terms of popular design requirements per activity type (Figure 15), SB had the highest proportion of its implemented requirements focused on *snapping photos of sea life*, and *sending photos to a friend*. However, the other design requirements were all present, with the largest difference being *looking up info*. BoS also had the highest proportion on *snapping photos of sea life* but had its lowest proportion on *adding info to the photo*. Adding information to a photo may require significant screen space, allowing PP to use a full activity screen for this information, whereas BoS had varying screen sizes, and this may have led to limited room to write information about the photo. This might suggest that features which require writing information on a mobile app may lend themselves to full sized activity screens, instead of sub-screens, such as menus.

Figure 31 below shows how PP and BoS can be applied to a design space continuum. In PP, participants are free to move unused screens out of the user's view, whereas with BoS the activity screens are always present in the design space, forcing the user to find a way to manage multiple activity screens. This is similar to Bertou and Shahid (2014)'s

Background (flip over non-present interface elements) and Blinder (layer interface elements) prototyping techniques.

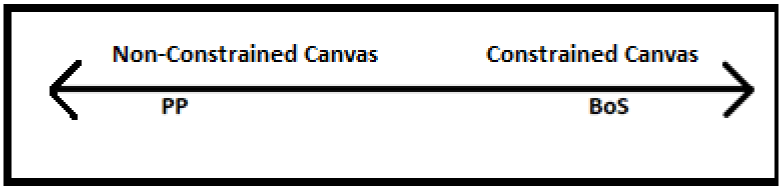

FIGURE 31 CONSTRAINED DESIGN SPACE DIMENSION

6.1.2.2 TEMPLATE USAGE AND SCREEN SIZE

BoS participants chose to use fewer templates and had more use of blank cards than PP participants. Also, BoS participants had a lot of variation in the sizes of the affixed screens. 9/13 BoS artifacts had some modification to screen size whereas none of the 14 PP artifacts had modifications to screen size, even when blank cards were chosen as activity screens. 6/13 BoS designs had thin screens attached to the top of the frame, and 3 of the designs had thin screens attached to the sides, but still on the top or bottom of the frame. All but one full sized screen in BoS were attached to the side of the frame.

Figure 32 below shows a BoS design with a high variation in screen types created from blank cards compared to a pure non-modified template PP design.

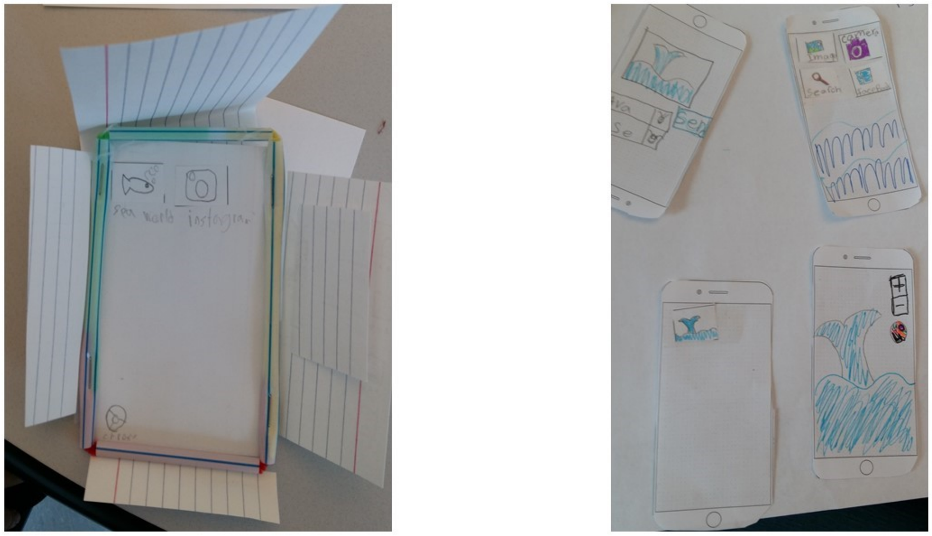

FIGURE 32 BOS (LEFT) WITH SCREENS OF VARIOUS SIZES AND PP (RIGHT) WITH ALL UN-MODIFIED TEMPLATES

Reasons for these observations might have to do with the constrained and persistent nature of the BoS design canvas, vs. the removable and un-constrained nature of PP. When working on a BoS type design, participants had the straw frame continuously in front of their work area, and they were concerned with attaching many activity screens to a single frame, whereas Paper Prototyping encourages participants to create a single activity screen which transitions to another single activity screen upon some type of user interaction. These results may indicate that the frame and choice of activity screen attachment to the frame was the factor that caused varying screen sizes. Our results may support Bertou and Shahid (2014), who found that layered interface elements in their Blinder method (elements on top of one another) were more beneficial for communicating screen constraints when compared to flipped elements in their Background method. Our BoS activity may force participants to layer their interface elements over one another due to the constrained design space, forcing participants to think about where each element is placed. Flipping interface elements is similar to removing screens in PP, and from our results I had no adaptation of screen sizes for the

PP sessions. This might indicate that participants didn't think about were the interface elements or screens were going to be placed for the PP designs.

Between BoS and PP, there is a difference of a persistent canvas vs. a removable and out of mind canvas. The blank cards might present a more open and malleable option for creating persistent screens of different sizes to layer over the home screen, compared to rigid template screens associated with PP.

We might attribute the different sizes of screens and their placement to the constrained persistent canvas of the BoS activity. Participants may want to have multiple screens layered over each other while still displaying important information on background screens. The differences in screen sizes might also ensure that any activity screen is independently callable at any time without worrying about the order in which to layer the called screens. In contrast, with PP designs all screen sizes in PP were full, which may be due to the removable nature of the canvas during the activity.

Another theory is that the blank cards may lend themselves better to the crafting activity due to their thickness and rigidity. However, the blank cards were still chosen as activity screens for the PP activity, which supports the idea that the blank cards are popular for reasons besides their physical rigidness since PP doesn't require any 3D manipulation of the activity screens.

6.1.2.3 BOS AS AN EVALUATION TOOL

Bertou and Shahid (2014) had a view screen for their prototype evaluations where they used three different approaches to prototyping, Background, Blinder, and Paper in Screen. One difficulty they mention is that with the Background approach, the researchers had to continually rebuild the interface which was time consuming and caused the children to lose focus. Their blinder approach had less issues, and the researchers did not need to spend time rebuilding the interface, which led to a better prototype evaluation. They mention how Paper in Screen was difficult due to the photo app interface, and how handling the tablet distracted from the evaluation and felt unrealistic. While I did not do prototype evaluations with our participants, our BoS design with the straw frame might offer a way for researchers to easily and quickly rebuild a UI via screens on hinges, while also allowing immutable UI elements to be moved out of view during an evaluation. However, drag and drop actions would not be possible in a BoS interface. In addition, the entire prototype could be handled by the participants, mimicking a mobile phone, and wouldn't need to sit in the plane of a table, which might add a sense of physical realism to the evaluation.

6.1.2.4 SUMMARY

From the results of section 5, SB, PP, and BoS have different strengths for app design. SB and PP can be useful for completing design requirements and generating many ideas for meeting those requirements. This draws parallels to the work by Yip et al. (2013) and their work with subject and design experts. They suggest having subject experts identify needs of a design and having design experts create ideas for usability. The same may be true for SB and PP compared to BoS. Participants could identify needs with SB and PP as a preliminary design activity with little constraints on the design space and focus on the usability in the constrained canvas with BoS as if the screens were active in a mobile application.

Working with SB and PP produces high numbers of completed requirements. BoS may be more useful when the design space is limited, such as exploring how multiple interface elements might fit together on one activity screen, such as drop-down menus, search bars, and other items that don't necessarily require an entire screen in an app. This may encourage the designers to creatively find ways to transition from one activity or menu to another while the other activities remain in the design space, such as using thin top screens layered over larger activity screens. We saw how screen size, template design, and screen placement varied on the BoS designs compared to the PP designs.

We can think of PP as a design canvas where the user interface elements can easily be forgotten since they are usually pushed out of view when they are not in use, whereas with BoS, the UI elements may be folded out of view on a hinge, remaining in close proximity, or they may be layered. In either case, with BoS, the UI elements remain affixed to their position in the frame, whereas with PP, they are free to be rearranged. This forces BoS users to work with a more constrained and constant UI, compared to PP.

From the analysis of the affinity diagram, we saw that BoS can be frustrating due to time constraints and working with the frame, but it also had many positive comments in terms of it being an enjoyable and fun activity.

There may be benefits to using these activities in conjunction. For example, a SB or PP activity could be used to generate many design ideas quickly. This activity could be followed by a longer design session, in which designers to use some of these ideas on a BoS type activity with a constrained design space. This layering of the design techniques may prove more helpful for the constrained BoS activity. Using design activities in conjunction with different groups working on different areas of the design process is something that Yip et al., (2013) suggests in their conclusions to their work with two groups of children, subject experts and design experts. They also mention that the constraints of the design session, such as tiredness and researcher interactivity, play an important role in the outcome. In my research I had certain groups of participants who would require more assistance. To mitigate this, the camp leader also assisted participants with their work if needed. However, it is possible that the uneven distribution of help affected the design outcomes.

The constrained design space differences between PP and BoS may also have different relevance to different design goals. BoS may be more useful for examining a specific design requirement and how it needs to function in a limited space, such as a menu, whereas PP may be more useful when exploring many design requirements that don't have to work together in the same space, at least not at first. This relates to Gedenryd (1998)'s idea of *Horizontal vs Vertical relevance* in prototype design, focusing on many outcomes of the design by leaving out details (Horizontal) or focusing on the details of one outcome (Vertical). Horizontal relevance is useful for understanding aspects of the design and facilitating discussions, whereas Vertical relevance aids in understanding one point of the design (Antle, 2008). Again, the different strengths of each of our prototyping techniques may suggest that they be used in conjunction at different points in a larger prototyping session.

6.1.3 SALIENT ARTIFACTS

I did notice that some artifacts deviated in design or achievement within and between groups, and that group dynamics changed from session to session. Several of the participants clearly had more work completed than others during the design sessions.

Comparing between the BoS groups, there was more accomplished in terms of design requirements from the older participants than the younger participants. This is likely the result of the older participants being more focused and requiring less help with the tangible nature of the activity. Between the two older groups there was different levels of achievement. This might be due to group dynamics, as one of the groups was more focused than the other.

An interesting PP group was the 10-14 aged participants. Unlike the other PP groups, the artifacts in the group, had a mix of templates and blank cards. The template was used for the home screen, while the blank cards were used for the activity screens, similar to most BoS designs, however without any size modifications to the screens. This supports the idea that the blank cards had a creative draw besides their physical rigidity for the BoS screens. Figure 33 below shows these designs.

FIGURE 33 MIX OF TEMPLATES AND BLANK CARDS

One PP participant chose not to cut out their screens from the printed paper and instead used arrows to show the transitions from one activity screen to another. See Figure 34 below:

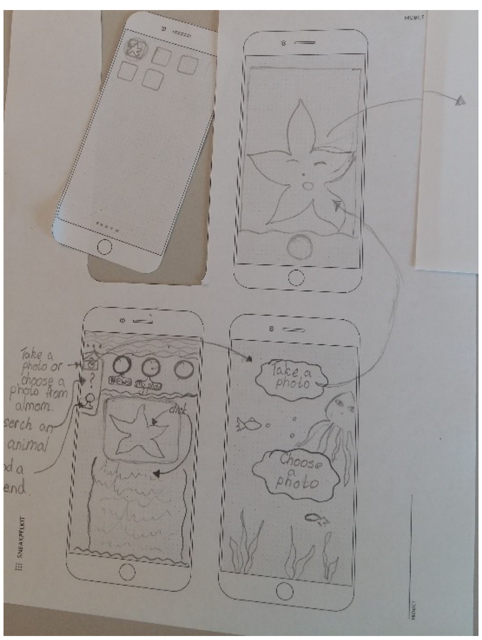

FIGURE 34 PP WITH ARROWS

The same participant also wrote instructions with arrows in the margin of the paper, similar to a SB design describing how the app functions. Their design looked similar to Ha et al. (2014)'s paper prototype designs created from a wireframe tool. This is an interesting adaptation for the PP activity, as it allows for a written description of the functionality of the app while also showing the transitions from one activity screen to the next. However, this adaptation did not seem to save the participant any time with their design compared to the rest of their group, as they were on the low end for number of screens and completed design requirements.

From our SB artifacts, most were limited to 4 panels. However, there was one artifact that used 6 panels. All 6 panels were of the app screen with high detail, not showing any actors in the SB. This participant had more requirements completed than the other artifacts from the same group. See Figure 35 below.

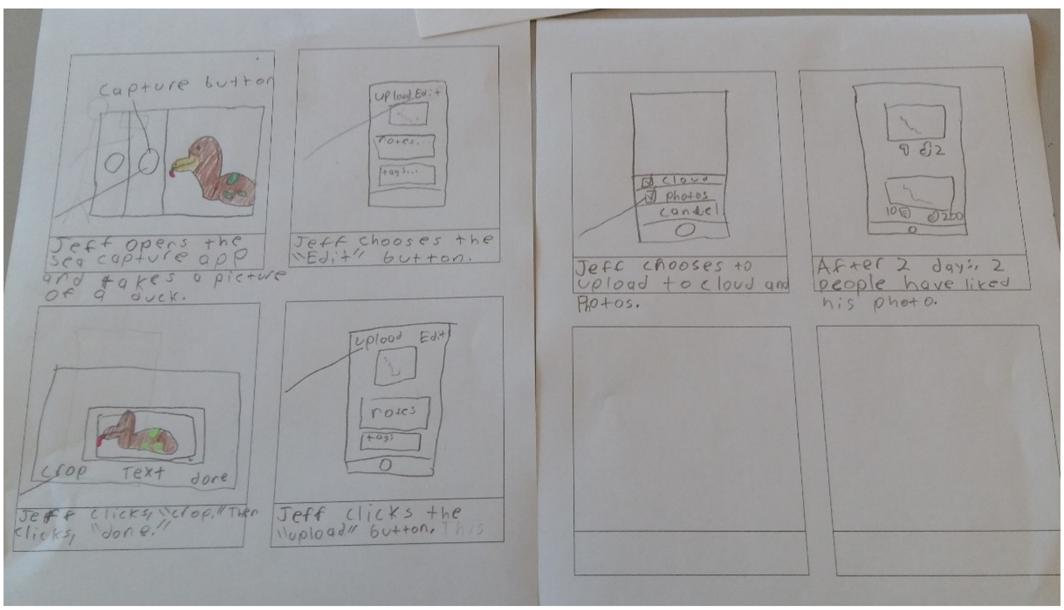

FIGURE 35 SB WITH HIGH DETAIL AND NO ACTORS

This contrasts the other SB artifacts in the group that all had a mix of actors and zoomed in key frames of the app. The higher number completed of requirements (3 vs 2) is likely due to more focus on the key frames showing the app's functions, whereas other participants chose to draw the actor as well. This group, age 11-14, was quiet and engage with their work. They asked few questions, and no one needed assistance with their work. While I only had 3 artifacts collected for SB, the idea of eliminating actors in a SB and focusing on key frames may be useful to consider.

6.1.4 PEDAGOGICAL CONSIDERATIONS

BoS with the straw frame constrained the design space and encouraged participants to think about how they want to work the design requirements into their app. From a teaching perspective, this could be used to introduce or refine UI design to young participants. The constrained nature could be used to discuss menu bar or search bar placement, layered screens, etc. However, the disadvantage to this constrained activity is that it requires more time than other non-crafting-based activities. Also, participants with little mobile app experience may not understand why layering UI elements can be useful to a design. The frame might also serve two positive functions. It could act as a tangible activity to help relax students in the design process and help to let their ideas develop, and it might also act as a strict constraint on the design activity which may be important depending on the type of application being built.

PP may be used as a preliminary design to flesh out overall functionality of the app, seeing how to transition from one screen to another and how each screen should function to fulfill the design requirements. The advantage to PP is that it is faster than BoS with much less setup and gets the designers working on the design requirements immediately, whereas BoS has an initial, slow crafting and planning phase.

SB is useful for showing a use case of the app as well as some functionality of the app and its features. This could be used after PP but before BoS to further flesh out ideas about where and when the app will be used in the real world.

PP and SB do have their own constraints, in that PP seems to favor more template and pre-designed UI use, and SB may be constrained by how many panels the participant has to work with as well as the sequential nature of reading panels right-left and top-bottom.

6.1.5 RECOMMENDATIONS FOR FUTURE DESIGN METHODS RESEARCH INVOLVING CHILDREN AND YOUTH

I have several suggestions for future work. First, I would suggest a comparison between BoS and PP for younger participants in the same realm as our study. Due to the nature of our groups and time conflicts, I was unable to compare these two groups for younger participants.

Consistent comparison of age groups was difficult in our work due to the nature of the SuperNOVA camp. If possible, I recommend more consistent age groups for comparisons between activity types. For example, I only had one young group of SB participants.

In terms of collaboration, it appears that participants either got a lot of work done, or they did very little work. This might be due to participants going off task when working with a friend. In the groups where collaboration did occur, there was usually more talking and interaction among the participants. However, this could either be off task behavior or discussing how to work together. We saw two PP collaborative artifacts from the same group with very different results, one with almost nothing done, and one with 3 requirements and multiple activity screens. Like any classroom activity, choosing good work pairs is probably necessary.

From the artifact analysis, I saw some evidence of how a constrained design space may influence the choice of materials and how these materials may be modified in that space. BoS designs had very different activity screens than PP, such as screen type and screen size, and I attribute this to the persistent and non-persistent nature of the design space and how each prototyping technique is meant to function. PP screens move out of view when not in use, and BoS screens always remain. It might be interesting to run a full study exploring this discrepancy across different prototyping methods and age groups.

Finally, frustration between age groups for the same activity was something that I explored from our survey results. However, due to the nature of our age ranges overlapping and lack of measuring individual ages, these results are not conclusive. However, they may be useful for a future study.

6.1.6 LIMITATIONS

The questionnaire used a likert scale, and I used parametric tests for statistical analysis. I treated our survey data as interval data instead of ordinal data. This allowed us to compute the mean and perform ANOVAs and t-tests. I realize that this is a grey area for self-reporting data. Our scale was from 1-5 with labels on 1, 3, and 5. By adding these labels it might be questionable as to whether our survey was interval (okay to use means) or ordinal (should use medians), and if I should use parametric (ANOVA, t-tests) or non-parametric (Mann-U) statistical tests. I believe that the 1-5 scale can be treated as interval data, even with the addition of “neutral” on 3, as the middle ground for interval data would naturally be 3, and that the distance between scores does have meaning. A participant’s perception of a difference in easiness, for example, could be twice as easy when rating from 1 to 2 and 1 to 3. I realize that this is debatable, and I ran a Mann-U test with no significance detected on the questionnaire data as well.

Lack of control group was another issue. I had three activities, with three conditions (SB, PP, BoS), across three different age groups. I made claims of statistical significance for BoS youngest vs. oldest participants. However, I did not have a control group to compare our claims against. Perhaps students doing a general crafting or drawing activity with no specific technique would have had the same noticeable differences for our measured attributes, such as easiness, frustration, happiness, or even ownership.

Lack of observational power by researcher. I only had one researcher (myself) who was working with the entire group of participants each day. Because of the participants’ group sizes, the researcher was sometimes called to help or explain details to participants. This shifted the focus of the session from observations to teaching/helping and may have caused the researcher to miss important information for the observation sheets.

Participant reluctance to participate in the survey or sharing of their designs was an issue as some participants didn't want to fill out the survey or share their designs. This seemed to be due to the time constraints, as they were more eager to keep working on their design until the session ended than stop their crafting to fill out a survey or share their design. Some participants also didn't want to share an incomplete design.

Different group sizes per activity was another limitation. Due to the nature of the camp groups, some days I would have cancelations or too small a group to run the activity, since the camp leaders needed to be present with the session group and couldn't safely divide themselves for 2 or 3 participants. Because of this, there is some unbalancing in the participant numbers.

Small sample sizes for statistical comparison was an issue. I used parametric tests, such as independent sample t tests, and ANOVA tables, to compare the sample means. There is a lot of debate regarding the use of parametric tests for likert scale data. de Winter and Dodou (2010) state that t-tests are a good measure for likert scale data and tested for samples as small as 10. Norman (2010) also state that parametric tests are safe and useful for very small samples of likert scale data, and this is further supported by Pearson, 1931 who examined samples as small as 4 and came to the conclusion that ANOVA can be useful for small, non-normal distributed samples. For some of our comparisons, for example BoS ages 8-10, I only had 5 samples, whereas others I had more than 10. While I still used parametric tests to look for significance between compared sample means, it should be noted that more data may be necessary to make a stronger statistical significance claim.

6.2 HOPE BLOOMS

6.2.1 CONTEXTUAL INQUIRY SESSIONS

The contextual inquiry sessions with the Hope Blooms participants were critical in understanding the needs of the greenhouse. The onsite CI was helpful to see what resources Hope Blooms had to work with, and how these resources may influence the design choices. During the CI, there were other staff working and based on what duties the staff were performing, the CI outcomes changed. For example, the idea of an interactive map for the mobile greenhouse app was a result of someone creating a map in the greenhouse the same day as the CI session. In contrast to the completely structed SuperNOVA design sessions, they worked from the same design context for each session. While this consistent context made the work easier for myself, the dynamic environment of the Hope Blooms greenhouse during the CI sessions made for some interesting design requirements, such as an interactive map, and push notifications for completed tasks at the greenhouse.

6.2.2 DESIGN SESSIONS

The design sessions were run in an open-style manner where the group participants would be whoever signed up for the sessions and was available on that particular day. We had a small number of participants elect to participate in the design sessions, and of those that wished to participate, only two were able to commit to an entire design session, the scenario-based brain storming. I attribute this low turnout of participants to busy participant schedules. In contrast to the Hope Blooms participants, where each week's session was not strictly structured into their timetable, the SuperNOVA participants made consistent planning of design sessions easier

While we only conducted one design session, one potential future problem with the design sessions was that several sessions were iterative and required data to be collected and organized from a previous session and then presented to new participants. This would have been difficult in an open work environment when the number of daily participants was unknown and when participants' schedules were not well defined and stalling of future sessions would have occurred. In contrast, the SuperNOVA design sessions were independent from one another, and could be deployed without the need for past-sessions data.

6.2.3 RECOMMENDATIONS FOR OPEN WORK GROUP SESSIONS

For future sessions with open style work groups, I have two recommendations to facilitate research. First, I would recommend having non-dependent design sessions, so that the scheduling of each sessions is dynamic and could be deployed whenever the researcher felt the time was appropriate. Second, it might be helpful to have an online or remote option for participants to complete design work. Difficulties in participants' schedules could be mitigated if this was an option. Finally, there was a clear benefit to the on-site contextual inquiry in that it allowed daily activities to influence the outcomes of the requirement gathering sessions. I would recommend on site CI for any similar research.

6.3 INTEGRATING PARTICIPATORY DESIGN AND STRUCTURED DESIGN

The work with Hope Blooms allowed us to explore contextual inquiry in a real world setting with young participants who were also stakeholders in the research. The Hope blooms CI changed depending on the activity of the day. For example, the map activity at the greenhouse was unique to one CI and interview session. While we only had a small number of participants for the CI and the design sessions, there was still valuable input explored for the planned greenhouse monitoring application. SuperNOVA allowed for consistent, temporally bound design sessions that produced many prototype designs, however, without the real-world context or motivation for those design sessions.

Because of the possibility of a small number of participants or participant drop out in an on-site real-world context research session when working with young participants, it might be useful to combine in the field CI and design sessions with temporally bound, independent design groups. In the field on-site CI is useful to capture subtle and unique design requirements and combine it with consistent design sessions with a known number of participants to help with the research goals. The outcomes from on-site CI sessions could be synthesized into structured specific design session goals and feedback sessions for the non-user-based design groups. In this way, we would be looking for other participants to help act as a proxy for participants when there is a limit to the time the participants can donate to the researcher, and this would be useful when designing with young participants because of their high level of extracurricular commitments. Because of this, the actual user group would not be required to participate in all aspects of the research. This would allow the researcher to be more opportunistic when choosing projects with user groups who may be limited in the time they can donate to the researcher. Scaffolding the user group participants' ideas and designer participants together in this way could extend the work by Yip et al., (2013) that compared subject expert and design expert groups except that the two groups would be working together towards a common goal instead of a comparative analysis.

CHAPTER 7 CONCLUSIONS

This research began as a means to study methods of participatory design for creating a community mobile app when designing with non-consistent work groups and evolved into an exploration of how different levels of tangibility and design constraints in low-cost, low-fidelity prototype design sessions influenced participant satisfaction over their design and the design session.

From our work with Hope Blooms, we saw the benefits of in situ field work for identifying requirements for future technologies. This led to suggestions for future researchers working with young people in dynamic environments.

From the SuperNOVA sessions, we analyzed survey results and design artifacts of three low-cost, low-fidelity prototyping techniques. We found that there were no strong preferences between these activities. However, within activities there were differences in measurements, such as frustration between young and older participants. This study also examined the choices of tools and materials used between and within the prototyping activities and examined how templates and crafting from scratch are affected by the constraints on the design activity. The conclusions can be summarized as the following:

- All three prototyping methods evaluated (i.e., SB, PP, and Bos) had all had favorable results in all survey categories (i.e., happiness, helpfulness, easiness, ownership and frustration). This indicates that there was no strong preference for one prototyping method over another. All three prototyping methods were successful for helping the participants to easily create their intended design with low degrees of frustration. The prototyping methods also worked well as a design tool indicated by favorable scores in happiness, helpfulness, and ownership.

- BoS was found to be more frustrating and less easy for younger participants (i.e., ages 8-10) than for older participants (i.e., ages 10-14). This seems to be due to the tangible nature of the BoS activity as evidenced from direct quotes wishing for more time to complete the activity, and from our artifact analysis which showed low counts of implemented design requirements and low numbers of activity screens on the designs themselves. I believe that the constrained design space of the BoS activity also played a role in the challenges. Younger participants may have had more of a challenge manipulating their artifact to fit all the design requirements. However, BoS had similar favorable scores in all other categories, indicating that it still allowed participants to create a design they were happy with despite experiencing some difficulties.

- Design activities were observed to influence the tools chosen by the participants, and also how those tools were modified given the nature of the design activity itself. Specifically, Paper Prototyping had a high degree of screens created from design templates, whereas Bags of Stuff had some mixed templates, but mostly the use of blank cards for screen creation. The screens created for Bags of Stuff were also highly modified into different sizes. For example, I saw many of the artifacts with thin banner-like screens affixed to the top and bottom of the design, and full and half screens attached to the sides. I attributed these differences between PP and BoS to the constrained and non-constrained design canvas. PP creates a fresh canvas on each button click, where the other activity screens are pushed out of sight, whereas BoS always has persistent other activity screens in the same design space. Perhaps this persistency is what causes the mixed nature of different sized activity screens for BoS. This could be an important consideration in the area of mobile app design.

- Prototyping methods may lend themselves to different stages of the design process. SB and PP may be useful for early general idea generation due to the non-constrained design spaces, and BoS more useful for how those ideas may function in the actual limited screen space of the application. BoS may also serve as an introductory tool to design. The tangible nature may help participants relax and develop their creative ideas. The framed nature of the BoS may also act as an important constraint on the design activity which would depend on the type of application being developed.
- Contextual Inquiry with the user-based participants may be able to be combined with non-user-based participants to help facilitate opportunistic in-context technological research when working with participants who have limitations on the amount of time they can donate to research

REFERENCES

Allen, C. (2007). *An Action Based Research Study on How Using Manipulatives will Increase Students' Achievement in Mathematics*. Retrieved from https://eric.ed.gov/?id=ED499956

Alvarado, D. (2012). Supporting Non-formal Learning Through Co-design of Social Games with Children. In *Proceedings of the 11th International Conference on Interaction Design and Children* (pp. 347–350). New York, NY, USA: ACM. https://doi.org/10.1145/2307096.2307164

Antle, A. N. (2008). Inquiring Materials for Tangible Prototyping. In *Proceedings of the 2Nd International Conference on Tangible and Embedded Interaction* (pp. 139–140). New York, NY, USA: ACM. https://doi.org/10.1145/1347390.1347420

Antle, A. N., Wise, A. F., & Nielsen, K. (2011). Towards Utopia: Designing Tangibles for Learning. In *Proceedings of the 10th International Conference on Interaction Design and Children* (pp. 11–20). New York, NY, USA: ACM. https://doi.org/10.1145/1999030.1999032

Ashktorab, Z., & Vitak, J. (2016). Designing Cyberbullying Mitigation and Prevention Solutions Through Participatory Design With Teenagers. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (pp. 3895–3905). New York, NY, USA: ACM. https://doi.org/10.1145/2858036.2858548

Baltes, S., & Diehl, S. (2014). Sketches and Diagrams in Practice. In *Proceedings of the 22Nd ACM SIGSOFT International Symposium on Foundations of Software Engineering* (pp. 530–541). New York, NY, USA: ACM. https://doi.org/10.1145/2635868.2635891

Batson, L. and S. Feinberg, Game Designs that Enhance Motivation and Learning for Teenagers, Electronic Journal for the Integration of Technology in Education, 5, pages. 34 - 43, 2006.

Bekker, M., Beusmans, J., Keyson, D., & Lloyd, P. (2003). KidReporter: a user requirements gathering technique for designing with children. *Interacting with Computers*, *15*(2), 187–202. https://doi.org/10.1016/S0953-5438(03)00007-9

Bell, A., & Davis, K. (2016). Learning Through Participatory Design: Designing Digital Badges for and with Teens. In *Proceedings of the The 15th International Conference on Interaction Design and Children* (pp. 218–229). New York, NY, USA: ACM. https://doi.org/10.1145/2930674.2930705

Bertou, E., & Shahid, S. (2014). Lowfidelity Prototyping Tablet Applications for Children. In *Proceedings of the 2014 Conference on Interaction Design and Children* (pp. 257–260). New York, NY, USA: ACM. https://doi.org/10.1145/2593968.2610466

Beyer, H. & Holtzblatt, K. (1998). In "Contextual Design", pp 154-163, Morgan Kaufmann Publishers, Inc.

Beyer, H., & Holtzblatt, K. (1997). *Contextual design: defining customer-centered systems*. Elsevier.

Blackmon, M. H. (2004). Cognitive Walkthrough. In W. S. Bainbridge (Ed.), Encyclopedia of Human Computer Interaction, 2 volumes (Vol. 1, pp. 104–107). Great Barrington, MA: Berkshire Publishing Group.

Boone, H. N., & Boone, D. A. (2012). Analyzing likert data. *Journal of extension*, *50*(2), 1-5.

Burke, K., Guastello, F., Dunn, R., Griggs, S. A., Beasley, M., Gemake, J., Sinatra, R., & Lewthwaite, B. (1999/2000). Relationship(s) between global-format and analytic-format learning-style assessments based on the Dunn and Dunn Model. National Forunz of Applied Educational Research Journal, 13(l), 76- 96.

Buxton,B. *Sketching User Experiences: Getting the Design Right and the Right Design.* Morgan Kaufmann, San Franciso, CA, 2007.

Computing Research Association (2017). Generation CS: Computer Science Undergraduate Enrollments Surge Since 2006. *https://cra.org/data/Generation-CS/*

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Danielsson, K., and Wiberg, C. Participatory Design of Learning Media: Designing Educational Computer Games with and for Teenagers. Interactive Technology and Smart Education 3, 4 275–291. 2006.

de Winter, J. C. F., & Dodou, D. (2010). Five-Point Likert Items: t Test versus Mann-Whitney-Wilcoxon. *Practical Assessment, Research & Evaluation*, *15*(11).

Department of Computer Science Western University (n.d.). Job Market and Opportunities Retrieved December 13, 2017, from https://www.csd.uwo.ca/prospective_students/undergraduate_students/job_market_and_opportunities.html

Derboven, J., Van Mechelen, M., & Slegers, K. (2015). Multimodal Analysis in Participatory Design with Children: A Primary School Case Study. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (pp. 2825–2828). New York, NY, USA: ACM. https://doi.org/10.1145/2702123.2702475

Dindler, C., Eriksson, E., Iversen, O. S., Lykke-Olesen, A., & Ludvigsen, M. (2005). Mission from Mars: A Method for Exploring User Requirements for Children in a Narrative Space. In *Proceedings of the 2005 Conference on Interaction Design and Children* (pp. 40–47). New York, NY, USA: ACM. https://doi.org/10.1145/1109540.1109546

Druin, A. (1999). Cooperative Inquiry: Developing New Technologies for Children with Children. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 592–599). New York, NY, USA: ACM. https://doi.org/10.1145/302979.303166

Druin, A., Bederson, B., Boltman, A., Miura, A., Knotts-Callahan, D., & Platt, M. (1998). Chapter 3: Children as Our Technology Design Partners+. Retrieved from http://drum.lib.umd.edu/handle/1903/947

Druin, A. (2002). The role of children in the design of new technology. *Behaviour & Information Technology*, *21*(1), 1–25. https://doi.org/10.1080/01449290110108659

Dunn, R., & Griggs, S. A. (1995). *Multiculturalism and learning style: Teaching and counseling adolescents.* Westport, CT: Praeger.

Dunn, R. S., & Griggs, S. A. (2000). *Practical Approaches to Using Learning Styles in Higher Education*. Westport, Conn: Greenwood Publishing Group.

Dunn, Rita, & Dunn, Kenneth J. (1978). *Teaching students through their individual learning styles : A practical approach*. Reston, Va.: Reston Pub.

Fitton, D., Read, J. C. C., & Horton, M. (2013). The Challenge of Working with Teens As Participants in Interaction Design. In *CHI '13 Extended Abstracts on Human Factors in Computing Systems* (pp. 205–210). New York, NY, USA: ACM. https://doi.org/10.1145/2468356.2468394

Gedenryd, H. (1998). How designers work - making sense of authentic cognitive activities. *Lund University Cognitive Studies*, *75*. Retrieved from https://www.lunduniversity.lu.se/lup/publication/d88efa51-c2f9-4551-a259-00bd36fe8d03

Grundy, C., Pemberton, L., & Morris, R. (2012). Characters As Agents for the Co-design Process. In *Proceedings of the 11th International Conference on Interaction Design and Children* (pp. 180–183). New York, NY, USA: ACM. https://doi.org/10.1145/2307096.2307120

Guha, M. L., Druin, A., & Fails, J. A. (2010). Investigating the Impact of Design Processes on Children. In *Proceedings of the 9th International Conference on Interaction Design and Children* (pp. 198–201). New York, NY, USA: ACM. https://doi.org/10.1145/1810543.1810570

Guha, M. L., Druin, A., Chipman, G., Fails, J. A., Simms, S., & Farber, A. (2004). Mixing Ideas: A New Technique for Working with Young Children As Design Partners. In *Proceedings of the 2004 Conference on Interaction Design and Children: Building a Community* (pp. 35–42). New York, NY, USA: ACM. https://doi.org/10.1145/1017833.1017838

Ha, S., Park, J., & Lee, J. (2014). Increasing Interactivity of Paper Prototyping with Smart Pen. In *Proceedings of HCI Korea* (pp. 76–82). South Korea: Hanbit Media, Inc. Retrieved from http://dl.acm.org/citation.cfm?id=2729485.2729498

Hinzman, K. P. (1997). *Use of Manipulatives in Mathematics at the Middle School Level and Their Effects on Students' Grades and Attitudes*. Retrieved from https://eric.ed.gov/?id=ED411150

Hope Blooms Our Story (n.d.). Our Story. Retrieved from http://hopeblooms.ca/our-story/

Hope Blooms Greenhouse (n.d.)). Greenhouse. Retrieved from http://hopeblooms.ca/greenhouse/

Hope Blooms About (n.d.). Retrieved from https://hopeblooms.ca/about/

Iversen, O. S., & Smith, R. C. (2012). Scandinavian Participatory Design: Dialogic Curation with Teenagers. In *Proceedings of the 11th International Conference on Interaction Design and Children* (pp. 106–115). New York, NY, USA: ACM. https://doi.org/10.1145/2307096.2307109

Katterfeldt, E.-S., Zeising, A., & Schelhowe, H. (2012). Designing Digital Media for Teen-aged Apprentices: A Participatory Approach. In *Proceedings of the 11th International Conference on Interaction Design and Children* (pp. 196–199). New York, NY, USA: ACM. https://doi.org/10.1145/2307096.2307124

Kelly, S. R., Mazzone, E., Horton, M., & Read, J. C. (2006). Bluebells: A Design Method for Child-centred Product Development. In *Proceedings of the 4th Nordic Conference on Human-computer Interaction: Changing Roles* (pp. 361–368). New York, NY, USA: ACM. https://doi.org/10.1145/1182475.1182513

Leduc-Mills, B., & Eisenberg, M. (2011). The UCube: A Child-friendly Device for Introductory Three-dimensional Design. In *Proceedings of the 10th International Conference on Interaction Design and Children* (pp. 72–80). New York, NY, USA: ACM. https://doi.org/10.1145/1999030.1999039

Mazzone, E., Iivari, N., Tikkanen, R., Read, J. C., & Beale, R. (2010). Considering Context, Content, Management, and Engagement in Design Activities with Children. In *Proceedings of the 9th International Conference on Interaction Design and Children* (pp. 108–117). New York, NY, USA: ACM. https://doi.org/10.1145/1810543.1810556

McGookin, D., Robertson, E., & Brewster, S. (2010). Clutching at Straws: Using Tangible Interaction to Provide Non-visual Access to Graphs. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1715–1724). New York, NY, USA: ACM. https://doi.org/10.1145/1753326.1753583

Miles, M., Huberman, A., Saldana, J. (2014). Qualitative Data Analysis: A Methods Sourcebook. Third Edition. Arizona State University. SAGE Publications, Inc.

Moraveji, N., Li, J., Ding, J., O'Kelley, P., & Woolf, S. (2007). Comicboarding: Using Comics As Proxies for Participatory Design with Children. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1371–1374). New York, NY, USA: ACM. https://doi.org/10.1145/1240624.1240832

Myers, B. A., Ko, A. J., LaToza, T. D., & Yoon, Y. (2016). Programmers Are Users Too: Human-Centered Methods for Improving Programming Tools. *Computer*, *49*(7), 44–52. https://doi.org/10.1109/MC.2016.200

Nielsen, J., & Molich, R. (1990). Heuristic Evaluation of User Interfaces. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 249–256). New York, NY, USA: ACM. https://doi.org/10.1145/97243.97281

Norman, G. (2010). Likert scales, levels of measurement and the "laws" of statistics. *Advances in Health Sciences Education: Theory and Practice*, *15*(5), 625–632. https://doi.org/10.1007/s10459-010-9222-y

Pearson, E. S. (1931). The Analysis of Variance in Cases of Non-Normal Variation. *Biometrika*, *23*(1/2), 114–133. https://doi.org/10.2307/2333631

Poole, E. S., & Peyton, T. (2013). Interaction Design Research with Adolescents: Methodological Challenges and Best Practices. In *Proceedings of the 12th International Conference on Interaction Design and Children* (pp. 211–217). New York, NY, USA: ACM. https://doi.org/10.1145/2485760.2485766

Raiyn, J. (2016). The Role of Visual Learning in Improving Students' High-Order Thinking Skills. *Journal of Education and Practice*, *7*(24), 115–121.

Read, J. C., Fitton, D., & Mazzone, E. (2010). Using Obstructed Theatre with Child Designers to Convey Requirements. In *CHI '10 Extended Abstracts on Human Factors in Computing Systems* (pp. 4063–4068). New York, NY, USA: ACM. https://doi.org/10.1145/1753846.1754103

Read, J. C., Horton, M., Fitton, D., Little, L., Beale, R., & Toth, N. (2013). On Being Cool: Exploring Interaction Design for Teenagers. In *Proceedings of the 27th International BCS Human Computer Interaction Conference* (pp. 10:1–10:10). Swinton, UK, UK: British Computer Society. Retrieved from http://dl.acm.org/citation.cfm?id=2578048.2578063

Roberts, P. H. (1999). Effects of multisensory resources on the achievement and science attitudes of seventh-grade suburban students taught on- and above- grade level. Doctoral dissertation, St. John's University

Schiering, M. (1999). Effects of meta-cognition on fifth-grade, suburban students' achievement, attitudes, and ability to teach themselves: A comparison of tra- ditional versus learning-style instruction. Doctoral dissertation, St. John's University.

Schepers, S., Dreessen, K., & Zaman, B. (2018). Fun As a User Gain in Participatory Design Processes Involving Children: A Case Study. In *Proceedings of the 17th ACM Conference on Interaction Design and Children* (pp. 396–404). New York, NY, USA: ACM. https://doi.org/10.1145/3202185.3202763

Schroeder, C. M., Scott, T. P., Tolson, H., Huang, T.-Y., & Lee, Y.-H. (2007). A meta-analysis of national research: Effects of teaching strategies on student achievement in science in the United States. *Journal of Research in Science Teaching*, *44*(10), 1436–1460. https://doi.org/10.1002/tea.20212

Schuler, D. and Namioka, A. (1993). Participatory Design: Principles and Practices. L. Erlbaum Assoc. Inc.

Sheehan, R., Haden, D., & Metz, S. (2015). Using Children's Drawings to Improve a Programming App. In *Proceedings of the 14th International Conference on Interaction Design and Children* (pp. 303–306). New York, NY, USA: ACM. https://doi.org/10.1145/2771839.2771902

Sheriff, A., Sadan, R., Keats, Y., & Zuckerman, O. (2017). From Smart Homes to Smart Kids: Design Research for CataKit. In *Proceedings of the 2017 Conference on Interaction Design and Children* (pp. 159–169). New York, NY, USA: ACM. https://doi.org/10.1145/3078072.3079729

Sluis-Thiescheffer, W., Bekker, T., & Eggen, B. (2007). Comparing Early Design Methods for Children. In *Proceedings of the 6th International Conference on Interaction Design and Children* (pp. 17–24). New York, NY, USA: ACM. https://doi.org/10.1145/1297277.1297281

Sneakpeekit Sketch Sheets. (n.d.). Retrieved July 5, 2018, from http://sneakpeekit.com/

Spencer, R. (2000). The Streamlined Cognitive Walkthrough Method, Working Around Social Constraints Encountered in a Software Development Company. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 353–359). New York, NY, USA: ACM. https://doi.org/10.1145/332040.332456

Truong, K. N., Hayes, G. R., & Abowd, G. D. (2006). Storyboarding: An Empirical Determination of Best Practices and Effective Guidelines. In *Proceedings of the 6th Conference on Designing Interactive Systems* (pp. 12–21). New York, NY, USA: ACM. https://doi.org/10.1145/1142405.1142410

Wahid, S., McCrickard, D. S., DeGol, J., Elias, N., & Harrison, S. (2011). Don'T Drop It!: Pick It Up and Storyboard. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1571–1580). New York, NY, USA: ACM. https://doi.org/10.1145/1978942.1979171

Walsh, G., Druin, A., Guha, M. L., Foss, E., Golub, E., Hatley, L.,Bonsignore, E., Franckel, S. (2010). Layered Elaboration: A New Technique for Co-design with Children. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1237–1240). New York, NY, USA: ACM. https://doi.org/10.1145/1753326.1753512

Walsh, G., Foss, E., Yip, J., & Druin, A. (2013). FACIT PD: A Framework for Analysis and Creation of Intergenerational Techniques for Participatory Design. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 2893–2902). New York, NY, USA: ACM. https://doi.org/10.1145/2470654.2481400

Wang, D., Qi, Y., Zhang, Y., & Wang, T. (2013). TanPro-kit: A Tangible Programming Tool for Children. In *Proceedings of the 12th International Conference on Interaction Design and Children* (pp. 344–347). New York, NY, USA: ACM. https://doi.org/10.1145/2485760.2485841

Whitley, E., & Ball, J. (2002). Statistics review 1: Presenting and summarising data. *Critical Care*, *6*(1), 66–71.

Yarosh, S., Radu, I., Hunter, S., & Rosenbaum, E. (2011). Examining Values: An Analysis of Nine Years of IDC Research. In *Proceedings of the 10th International Conference on Interaction Design and Children* (pp. 136–144). New York, NY, USA: ACM. https://doi.org/10.1145/1999030.1999046

Yip, J. C., Foss, E., Bonsignore, E., Guha, M. L., Norooz, L., Rhodes, E.,McNally, B., Papadatos, P., Golub, E., Druin, A. (2013b). Children Initiating and Leading Cooperative Inquiry Sessions. In *Proceedings of the 12th International Conference on Interaction Design and Children* (pp. 293–296). New York, NY, USA: ACM. https://doi.org/10.1145/2485760.2485796

Yip, J., Clegg, T., Bonsignore, E., Gelderblom, H., Rhodes, E., & Druin, A. (2013). Brownies or Bags-of-stuff?: Domain Expertise in Cooperative Inquiry with Children. In *Proceedings of the 12th International Conference on Interaction Design and Children* (pp. 201–210). New York, NY, USA: ACM. https://doi.org/10.1145/2485760.2485763

APPENDICES

APPENDIX 1 TRANSCRIPT OF BEGINNING OF DESIGN SESSIONS

“Hey everyone, thanks for participating today. Today we are going to be using prototyping techniques to help design a mobile app. You’ll have all the materials on the tables to make your prototype. First, who knows what a prototype is?”

<Discussion on what a prototype is, stressing it was an early design of an app to try out new ideas>

“Here is a story to help motivate why you’re creating this app.”

<Read design scenario to participants and explain the design requirements>

“I’d like you to try to add these design requirements to your app. It’s okay if you can’t add them all, just do your best.”

“I have a pre-made prototype here on the table, let me show you how my design works. You don’t have to do your design like mine, this is only to show you what a prototype might be.”

<Shows prototype functionality to participants>

“Okay, let’s get started. You’ll have about 35 min to work on your design. If you get stuck, just ask me or your camp leader for help.”

APPENDIX 2 RECRUITMENT NOTICE

Rob Mundle is a graduate student researcher in computer science at Dalhousie University under the supervision of Dr. Derek Reilly. He is recruiting participants for a research study on the Dalhousie Campus within the age range of **7-17** years old. The purpose of this study is to help understand the best ways to design a mobile app.

We will be using different design methods to try to create the best possible mobile app. In addition, Rob will be studying the benefits and challenges of each design session. There will be a bit of writing and a brief questionnaire at the end of the session to help Rob understand how your child feels about the design technique. Each design session will be about 45-60 min, and it will happen at the GEM lab in the Mona Campbell building on the Dalhousie Campus.

This research study is completely voluntary and will not affect your child's participation in camp activities. While this research is being conducted, an optional non-research version of the activity will also be available for any campers who do not wish to participate in the study.

A consent form for the study has been sent with this form. If you and your child are interested in this study, please print and fill out the consent form. Our study is run Wednesday morning when campers visit our lab. Consent forms can be collected on Wednesday morning by camp counselors. Our study will be running until the end of August. A consent form has been sent with this notice and contains further information.

If you require any further information regarding the study, feel free to contact Rob at <email removed>

There will be no rewards or compensation provided for participating in this part of the study.

APPENDIX 3 CONSENT FORM FOR SuperNOVA

Project Title: Development of a shared community mobile application through participatory design

Lead Researcher: Rob Mundle

Contact: <email removed>

Other Researchers: None

Your child is invited to take part in a researcher study which will involve the design of a mobile application for Android and iPhones. Participation in this study is voluntary, and there is no compensation for participating. At any point during the study, your child may withdraw by telling the lead researcher, Rob, or any camp counselor. Our study is intended for youths in the age range of 7-17 years of age.

In this part of the study, we will be studying methods of participatory design when developing a mobile application.

Participatory design is when the participants (your child) help researchers to design a product (the mobile app.). We hope to explore the benefits and challenges of participatory design approaches, which create the best sense of ownership and appropriation, to the design and the application.

For this part of the study, your child is invited to take part in one design session. We will be rotating through different design techniques each week, such as paper drawings and storyboarding to design a mobile application.

Observations, a questionnaire, and a written reflections at the end of the session will be used to help us understand how successful each design session is for engaging youths. Pseudonyms will be used if we talk about any information that your child gives us.

The design session should take roughly an hour, and your child is free to stop the session at any time. If your child chooses to withdraw from the study, their data will be discarded. To withdraw from the study, they can tell Rob or a camp counselor at any time.

There will also be a written questionnaire and short written reflection at the end of the design session. The purpose of this questionnaire is to understand how your child feels about their involvement with the application and the design process. These will be completed at the end of the design session (roughly one hour).

In terms of confidentiality during the study, there will be other people present in the lab who are not part of the study, such as other campers or lab members. To mitigate any risks to your child's confidentiality during the study, they will work in a separate area within our lab from non-research campers. A camp counselor will be present at all times.

The lead researcher has no role associated with SuperNova other than running this research study.

This study is completely optional, and there will be other activities going on in the lab including a non-research version of the study made available to all campers.

Participation in this study has no more risk than any group school activity.

No identifying information other than this form and an assent form will be collected, and all data will be kept secure and confidential. Any information recorded on paper will be kept in a locked cabinet in our lab at Dalhousie. Any information that will be moved to a computer will be kept on a password protected file server. Your child's name will never be used in the reporting of this research. The only record of their participation in this part of the study will be this consent form and its accompanying assent form.

Your child will be assigned a pseudonym in any references made. This will ensure that their real name is never recorded during the study. If for some reason their real name is used by accident, the information containing their name will be destroyed.

We will be happy to share the results of this study with you at your request by email. However, emailing might identify you or your child as a participant in this study.

We are free to answer any questions you may have regarding this study.

All of the following are OPTIONAL and NOT required to participate in the study.

Please answer yes/no to each of the following questions:

"I agree to let you directly quote any comments or statements made by my child in any written reports without viewing the quotes prior to their use and I understand that the confidentiality of textual data will be preserved by using pseudonyms."	□ Yes □ No Initial:
"I would like to be notified by email when results are available via publication" If yes, provide an email address:	□ Yes □ No Initial:

"*I have read the explanation about this study. I have been given the opportunity to address any questions. By signing below, I hereby consent to let my child take part in this phase of the study. However, I understand that my participation is voluntary and that I am free to withdraw my child from the study at any time."*

Guardian

Name:_______________________________

Signature:____________________________

Date:________________________________

Child's/Subject's Name (printed):

____

Researcher

Name:______________________________

Signature:___________________________

Date: _______________________________

APPENDIX 4 ASSENT FORM FOR SuperNOVA

ASSENT SCRIPT

Project Title: Development of a shared community mobile application through participatory design

Principal Investigator: Rob Mundle

I'd like to tell you about a research study we are doing. A researcher study is usually done to understand how things work or how to improve something that already exists. In this study, we want to build a mobile application. We also want to understand the best way to design the application to make you feel like you own it.

In this study, only people who want to take part will participate. You do not have to participate if you don't want to.

If we talk about you or write any information down, we will use a pseudonym (which is a fake name). This is so that no one can tell who said what on any written information collected. If for some reason your name is accidently used, we will destroy the information.

Today we will pick a design technique to work with. We may be creating stories, working with models, or other fun activities. If you don't want to participate, there are many other activities in the lab that you can try.

I do not know if participating in the study will make you happy or benefit you in any way. However, I may learn something that will help other people.

You do not have to do this study. It is up to you. You can say no now or you can even change your mind later. All you have to do is tell me. No one will be mad at you if you change your mind.

If you decide that you don't want to participate in later design sessions, I'd still like to use your data for my research.

Your parents/people taking care of you say it is okay for you to be in this study. If you have any questions, please ask them now or at any time.

DO YOU UNDERSTAND WHAT I AM SAYING AND ARE YOU WILLING TO PARTICIPATE IN AT LEAST ONE DESIGN SESSION?

End of verbal script.

CHECK WHICH APPLIES BELOW:

TO BE COMPLETED BY PERSON OBTAINING VERBAL ASSENT FROM THE CHILD/SUBJECT. THEY MAY PARTICIPATE IF THEY SAY NO TO ANY OR ALL OF THESE:

Do you agree to let the researcher make written observations during the design session?

Child's/Subject's response: □Yes □No

Do you agree to write a short reflection at the end of each session?

Child's/Subject's response: □Yes □No

Do you agree to completing a short questionnaire at the end of the session if you participate in any of the sessions?

Child's/Subject's response: □Yes □No

CHECK WHICH APPLIES BELOW:

TO BE COMPLETED BY PERSON OBTAINING VERBAL ASSENT FROM THE CHILD/SUBJECT:

The child/Subject is capable of understanding the study: □Yes □No

The child/Subject is not capable of understanding the study: □Yes □No

____

Child's/Subject's Name (printed)

____ _________________

Name (printed) and Signature of Person Obtaining Consent Date

APPENDIX 5 POST DESIGN QUESTIONNAIRE FOR SuperNOVA

1 = not at all **3 = somewhat** **5 = very much.**

7. How helpful was this activity to make the design that you wanted?

   1 2 3 4 5

8. Was it easy to make your app work the way you wanted it to?

   1 2 3 4 5

9. Do you feel like this design is owned by you?

   1 2 3 4 5

10. If you worked with a friend on the design, do you feel like this design is owned by you and your friend?

    1 2 3 4 5

11. Are you happy with your final design of the app?

    1 2 3 4 5

12. Were you ever frustrated when designing your app?

    1 2 3 4 5

Please remember to write a short reflection on anything that you liked, found helpful, disliked, or could be improved about the design technique we used today. You can use the back of this paper to write your reflection.

Please hand this paper to ***Rob*** *when you're finished.*

APPENDIX 6 CONTEXT SHEET FOR DESIGN SESSIONS

In one month, you and your friends are traveling to the Caribbean. For a school project, and for fun! you need to photograph sea life. Fortunately your phone is waterproof. You decide to design an app to help you photograph and collect neat information about local sea life. The app must have the following features:

1. Snap photos of sea life
2. Easily add information to the photo
3. Send the photo and info to a friend
4. Easily look up names and other info about the creatures you see
5. Make an album with photos and info about the sea life

APPENDIX 7 RESEARCH ETHICS BOARD APPROVAL LETTER

DALHOUSIE
UNIVERSITY

Research Services

Social Sciences & Humanities Research Ethics Board
Letter of Approval

April 21, 2017

Rob Mundle
Computer Science\Computer Science

Dear Rob,

REB #:
Project Title: Development of a shared community mobile application through participatory design

Effective Date: April 21, 2017
Expiry Date: April 21, 2018

The Social Sciences & Humanities Research Ethics Board has reviewed your application for research involving humans and found the proposed research to be in accordance with the Tri-Council Policy Statement on *Ethical Conduct for Research Involving Humans*. This approval will be in effect for 12 months as indicated above. This approval is subject to the conditions listed below which constitute your on-going responsibilities with respect to the ethical conduct of this research.

Sincerely,

Dr. Karen Beazley, Chair

Post REB Approval: On-going Responsibilities of Researchers

After receiving ethical approval for the conduct of research involving humans, there are several ongoing responsibilities that researchers must meet to remain in compliance with University and Tri-Council policies.

1. Additional Research Ethics approval

Prior to conducting any research, researchers must ensure that all required research ethics approvals are secured (in addition to this one). This includes, but is not limited to, securing appropriate research ethics approvals from: other institutions with whom the PI is affiliated; the research institutions of research team members; the institution at which participants may be recruited or from which data may be collected; organizations or groups (e.g. school boards, Aboriginal communities, correctional services, long-term care facilities, service agencies and community groups) and from any other responsible review body or bodies at the research site

APPENDIX 8 HOPE BLOOMS CONTEXTUAL INQUIRY CONSENT FORM

Project Title: Development of a shared community mobile application through participatory design

Lead Researcher: Rob Mundle

Contact: rb581409@dal.ca

Other Researchers: None

Your child is invited to take part in a research study which will involve the design of a mobile scheduling application for Android and iPhones. Participation in this study is voluntary, and there is no compensation for participating. At any point during the study, your child may withdraw. Contextual inquiry is the first part of this study.

Contextual inquiry is like job shadowing. We use it to understand what someone does at their job and any challenges they may encounter. We use this information to help us understand what we need to do to help with those challenges.

The purpose of this study is to address challenges faced within the Hope Blooms greenhouse, such as maintenance conflicts. In addition, we will also be studying methods of participatory design when developing the mobile application and how they affect sense of ownership over the application. This will happen in the second part of the research. We hope to explore participatory design approaches, which maximize sense of ownership and appropriation, to the design and implementation of a shared community application.

For this contextual inquiry session, we will be observing and asking questions about your child's work at hope blooms in order to understand the challenges faced when working with the greenhouse, and any suggestions that they may have for a mobile application to help with these issues.

The lead researcher will observe alongside your child as they go about their work at Hope Blooms. The lead researcher will ask questions about their work, record answers, and try to understand what could be improved to make work easier for anyone who works at Hope Blooms. When your child has finished their work, the lead researcher would like to ask your child a few interview questions about their work.

Their contextual inquiry and interview information will be recorded on paper. We would also like to use an audio recording. False names will be used. The information collected by the researcher will be used to help us understand the design requirements for later stages of this project.

Audio recordings will be done on a smartphone that is operating in Airplane mode. No recordings will be transferred over any networks. Audio recordings will be transferred to a password locked USB stick to be looked at in this study. Only the lead researcher and his supervisor will have access to these recordings.

The session will take as long as a normal work session, and they are free to stop the session at any time, and their data will be discarded. However, we would like to use their design suggestions. If they choose to not participate in later stages of this study, we would still like to use their data and suggestions for later phases of this study.

Participation in this study has no more risk than their work already done at Hope Blooms.

No identifying information other than this form will be collected, and all data will be kept secure and confidential. Any information recorded on paper will be kept in a locked cabinet in our lab at Dalhousie. Any information that will be moved to a computer will be kept on a password protected file server. Your child's name will never be used in the reporting of this research. The only record of their participation in this part of the study will be this consent form.

Your child will be assigned a pseudonym to refer to themselves on any written or audio recordings. This will ensure that their real name is never recorded during the study. If for some reason their real name is used by accident, the audio file or written record will be destroyed.

Any software developed using the info from these sessions will be an open source application. It will not be sold for commercial use. The only reference to involvement in the software description will be 'People from Hope Blooms'.

Since recruitment will be done via the Hope Blooms activity board, confidentiality on recruitment may be difficult, as other people present in the Hope Blooms office may see the participant obtaining consent forms.

We will be happy to share the results of this study with you at your request by email. However, emailing might identify you or your child as a participant in this study.

We are free to answer any questions you may have regarding this study.

All of the following are OPTIONAL and NOT required to participate in the study.

Please answer yes/no to each of the following questions:

"I agree to let you directly quote any comments or statements made in any written reports by my child without viewing the quotes prior to their use and I understand that the confidentiality of textual data will be preserved by using pseudonyms."	□ Yes □ No Initial:
"I would like to be notified by email when results are available via publication" If yes, provide an email address:	□ Yes □ No Initial:

"I have read the explanation about this study. I have been given the opportunity to address any questions. By signing below, I hereby consent to let my child take part in this phase of the study. However, I understand that my participation is voluntary and that I am free to withdraw my child from the study at any time."

Guardian	**Researcher**
Name:________________________________	Name:_______________________________
Signature:_____________________________	Signature:____________________________

Please answer yes/no to each of the following questions:

"I agree to let the lead researcher use audio recordings for the contextual inquiry sessions."	□ Yes □ No Initial:
"I agree to let the lead researcher use quotes from the audio recordings by my child without viewing the quotes prior to their use and I understand that the confidentiality of audio data will be preserved by using pseudonyms."	□ Yes □ No Initial:

Guardian	**Researcher**
Name:_______________________________	Name:______________________________
Signature:____________________________	Signature:___________________________
Date:________________________________	Date: _______________________________

____

Child's/Subject's Name (printed)

APPENDIX 9 HOPE BLOOMS ASSENT CONTEXTUAL INQUIRY INTERVIEW SCRIPT

ASSENT SCRIPT

Project Title: Development of a shared community mobile application through participatory design

Principal Investigator: Rob Mundle

Supported by: ~~Natural Sciences and Engineering Research Council of Canada (NSERC)~~

I'd like to tell you about a research study we are doing. A researcher study is usually done to understand how things work or how to improve something that already exists. In this study, we want to build a mobile application to help with managing the greenhouse. We also want to understand the best way to design the application to make you feel like you own it.

You're being asked to participate because you work here at Hope Blooms and have some involvement with the greenhouse. In this study, only people who want to take part will participate. You do not have to participate if you don't want to. This contextual inquiry is the first part of the study.

If it's okay with you, I'd like to ask you some questions while you go about your work here at Hope Blooms, and I hope you can help me understand some things that we could make easier with the greenhouse work. You're in complete control. I just want to tag along and understand what you do and what we might be able to improve with a mobile application.

Also, I'd like to record our conversation on this smart phone. The phone is in Airplane mode, so nothing you say will leave the phone. Later I'd like to transfer our recording to a password locked USB stick.

We will give you a pseudonym (which is a fake name) to use during the study. This is so that no one can tell who said what on the audio or written recordings. If for some reason your name is accidently used, we will destroy the audio or written information.

I do not know if participating in the study will make you happy or benefit you in any way. However, I may learn something that will help other people.

You do not have to do this study. It is up to you. You can say no now or you can even change your mind later. All you have to do is tell me. No one will be mad at you if you change your mind.

If you decided that you don't want to participate in the activities after this part of the study, I'd still like to use your suggestions for my study and to help build the app.

Your parents/people taking care of you say it is okay for you to be in this study. If you have any questions, please ask them now or at any time.

DO YOU UNDERSTAND WHAT I AM SAYING AND ARE YOU WILLING TO PARTICIPATE IN THE INTERVIEW?

End of verbal script.

CHECK WHICH APPLIES BELOW:

TO BE COMPLETED BY PERSON OBTAINING VERBAL ASSENT FROM THE CHILD/SUBJECT:
Child's/Subject's response: □Yes □No

Do you agree for the researcher to record written information from the interview?

Child's/Subject's response: □Yes □No

Do you agree for the researcher to record audio information from the interview?

Child's/Subject's response: □Yes □No

CHECK WHICH APPLIES BELOW:

TO BE COMPLETED BY PERSON OBTAINING VERBAL ASSENT FROM THE CHILD/SUBJECT:

The child/Subject is capable of understanding the study: □Yes □No

The child/Subject is not capable of understanding the study: □Yes □No

____

Child's/Subject's Name (printed)

____ _________________

Name (printed) and Signature of Person Obtaining Consent Date

APPENDIX 10 HOPE BLOOMS CONSENT FORM FOR DESIGN SESSIONS

Project Title: Development of a shared community mobile application through participatory design

Lead Researcher: Rob Mundle

Contact: rb581409@dal.ca

Other Researchers: None

Your child is invited to take part in a researcher study which will involve the design of a mobile scheduling application for Android and iPhones. Participation in this study is voluntary, and there is no compensation for participating. At any point during the study, your child may withdraw.

The purpose of this study is to address challenges faced within the Hope Blooms greenhouse, such as maintenance conflicts. In addition, we will also be studying methods of participatory design when developing the mobile application and how they affect sense of ownership over the application.

Participatory design is when the participants (your child) help researchers to design a product (the mobile app.). We hope to explore participatory design approaches, which create the best sense of ownership and appropriation, to the design and implementation of a shared community application.

For this part of the study, there will be at least six design sessions at the Hope Blooms Cornwallis Street office. Your child is invited to take part in as many of the sessions as they wish. These sessions will use different design techniques, such as paper drawings and storyboarding to design a mobile application to help with their work.

Observations and a written reflections at the end of each session will be used to help us understand how successful each design session is for engaging youths and creating a sense of ownership over their design. False names will be used if we talk about any information that your child gives us.

Each session should take roughly an hour, and your child is free to stop the session at any time, and their data will for that session will be discarded. However, we would still like to use their design suggestions. If your child chooses to not participate in future sessions, we would still like to use their data for our research.

There will also be a questionnaire at the end of all the design sessions. The purpose of this questionnaire is to understand how your child feels about their involvement with the application. This questionnaire can be completed at your child's convenience. We would like to present this questionnaire to everyone who joined us for at least one design session.

Any software developed in the future from these sessions will be an open source application. It will not be sold for commercial use. The only reference to involvement in the software description will be ‘People from Hope Blooms’.

Since recruitment will be done via the Hope Blooms activity board, confidentiality on recruitment may be difficult, as other people present in the Hope Blooms office may see the participant obtaining consent forms. Also, for group design sessions, it may be possible that some other people will be present in the office who are not part of the study.

Participation in this study has no more risk than their work already done at Hope Blooms.

No identifying information other than this form will be collected, and all data will be kept secure and confidential. Any information recorded on paper will be kept in a locked cabinet in our lab at Dalhousie. Any information that will be moved to a computer will be kept on a password protected file server. Your child’s name will never be used in the reporting of this research. The only record of their participation in this part of the study will be this consent form.

Your child will be assigned a pseudonym to refer to themselves. This will ensure that their real name is never recorded during the study. If for some reason their real name is used by accident, the information containing their name will be destroyed.

We will be happy to share the results of this study with you at your request by email. However, emailing might identify you or your child as a participant in this study.

We are free to answer any questions you may have regarding this study.

All of the following are OPTIONAL and NOT required to participate in the study.

Please answer yes/no to each of the following questions:

“I agree to let you directly quote any comments or statements made by my child in any written reports without	□ Yes □ No

viewing the quotes prior to their use and I understand that the confidentiality of textual data will be preserved by using pseudonyms."	Initial:
"I would like to be notified by email when results are available via publication" If yes, provide an email address:	□ Yes □ No Initial:

"I have read the explanation about this study. I have been given the opportunity to address any questions. By signing below, I hereby consent to let my child take part in this phase of the study. However, I understand that my participation is voluntary and that I am free to withdraw my child from the study at any time."

Guardian

Name:________________________________

Signature:_____________________________

Date:_________________________________

Researcher

Name:_______________________________

Signature:_____________________________

Date: ________________________________

____

Child's/Subject's Name (printed)

APPENDIX 11 HOPE BLOOMS ASSENT FORM FOR DESIGN SESSIONS

ASSENT SCRIPT

Project Title: Development of a shared community mobile application through participatory design

Principal Investigator: Rob Mundle

Supported by: ~~Natural Sciences and Engineering Research Council of Canada (NSERC)~~

I'd like to tell you about a research study we are doing. A researcher study is usually done to understand how things work or how to improve something that already exists. In this study, we want to build a mobile application to help with managing the greenhouse. We also want to understand the best way to design the application to make you feel like you own it.

You're being asked to participate because you work here at Hope Blooms and have some involvement with the greenhouse. In this study, only people who want to take part will participate. You do not have to participate if you don't want to. This is the design part of the study where we will use information from other people who work here to design an app.

We will give you a pseudonym (which is a fake name) to use during the study. This is so that no one can tell who said what on any written information collected. If for some reason your name is accidently used, we will destroy the information.

We will be doing at least 6 design sessions like the one today, but each one will have a different twist. We will be creating stories, working with models, and other fun activities.

I do not know if participating in the study will make you happy or benefit you in any way. However, I may learn something that will help other people.

You do not have to do this study. It is up to you. You can say no now or you can even change your mind later. All you have to do is tell me. No one will be mad at you if you change your mind.

If you decide that you don't want to participate in later design sessions, I'd still like to use your data for my research.

Your parents/people taking care of you say it is okay for you to be in this study. If you have any questions, please ask them now or at any time.

DO YOU UNDERSTAND WHAT I AM SAYING AND ARE YOU WILLING TO PARTICIPATE IN AT LEAST ONE DESIGN SESSION?

End of verbal script.

CHECK WHICH APPLIES BELOW:

TO BE COMPLETED BY PERSON OBTAINING VERBAL ASSENT FROM THE CHILD/SUBJECT:
Child's/Subject's response: □Yes □No

Do you agree to let the researcher make written observations during the design session?

Child's/Subject's response: □Yes □No

Do you agree to write a short reflection at the end of each session?

Child's/Subject's response: □Yes □No

Do you agree to completing a short questionnaire at your convenience (when it is easy for you) if you participate in any of the sessions?

Child's/Subject's response: □Yes □No

CHECK WHICH APPLIES BELOW:

TO BE COMPLETED BY PERSON OBTAINING VERBAL ASSENT FROM THE CHILD/SUBJECT:

The child/Subject is capable of understanding the study: □Yes □No

The child/Subject is not capable of understanding the study: □Yes □No

____

Child's/Subject's Name (printed)

____   _________________

Name (printed) and Signature of Person Obtaining Consent   Date

APPENDIX 12 HOPE BLOOMS BRIEFING SCRIPT

Hello, thanks for agreeing to participate in this study. My name is [researcher], and I'll be asking you a few questions about your work here at Hope Blooms.

The overall goal of this study is to design a mobile application to help you and your community members manage your duties in the greenhouse. We are hoping to develop an Android or iPhone application to make your work and scheduling easier.

For this part of the study, we are focusing on contextual inquiry and design. Contextual inquiry is like job shadowing. It helps us to understand what you do at work. Before we can design, we need to understand what you think would be helpful and required in a mobile application. We will use your suggestions and Peter Wilkinson's in the design. I'd like to ask you a few questions as you go about your work.

APPENDIX 13 HOPE BLOOMS CONTEXTUAL INQUIRY

Thanks for agreeing to participate in this CI session. The purpose of this part of the study is to gather requirements for the design of a management application for the greenhouse. We would like to understand what challenges you face when working in the Greenhouse and any recommendations you may have for a mobile application. I'd like to observe your work here at Hope Blooms and ask a few questions as you go about your routine. You're in complete control; I'm just along for the ride. Immediately after, I'd like to ask you a few interview questions. If at any point you want to stop, just let me know. You're free to not answer any questions as well.

I just need to review your consent form and then we can begin.

[Start contextual inquiry]

Post CI Interview Questions

Question 1: Can you tell me about what you do here at Hope Blooms?

Question 2: What do you find challenging in your work around the greenhouse?

Question 3: Are there any challenges with scheduling shifts?

Question 4: If you could use your phone to solve a problem with your work, how would you do it?

Question 5: Can you recommend any more features that may be helpful in a mobile application?