

ABSTRACT

Title of Document: MOBILE COLLABORATION FOR
YOUNG CHILDREN: READING AND
CREATING STORIES

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Within the last decade, mobile devices have become an integral part of society, at home or work, in industrialized and developing countries. For children, these devices have primarily been geared towards communication, information consumption, or individual creative purposes. Prior research indicates social interaction and collaboration are essential to the social and cognitive development of young children. This dissertation research focuses on supporting collaboration among mobile users, specifically children ages 6 to 10 — while collaboratively reading and creating stories. I developed Mobile Stories, a novel software system for the Windows Mobile platform that supports collaborative story experiences, with special attention to two collocated collaboration experiences: content splitting and space sharing. Content splitting is where interface parts (e.g. words, pictures) are split between two or more devices. Space sharing is where the same content (e.g. a document) is spread or shared across devices. These collocated collaborative configurations help address mobile devices' primary limitation: a small screen.

The three research questions addressed are: how does Mobile Stories affect children's collaboration and mobility, what are some appropriate interfaces for collocated mobile collaboration with children, and when are the developed interfaces preferred and why. Mobile Stories was designed and developed using the Cooperative Inquiry design method. Formative studies furthered the design process, and gave insight as to how these collaborative interfaces might be used. A formal, mixed method study was conducted to investigate the relative advantages for each of the collocated collaborative interfaces, as well as to explore mobility and collaboration.

The results of the formal study show children were more mobile while creating stories than when reading and sharing them. As for task effectiveness, children read more pages when they were closer, and created more pages when they were further apart and more mobile. Children were closer together when they read using the content split configuration. While creating their stories, children rarely used the collocated collaborative configurations and used verbal collaboration instead. Several indicators pointed to relative advantages of the split content configuration over the share space configuration; however, the advantages of each are discussed.

MOBILE COLLABORATION FOR YOUNG CHILDREN:
READING AND CREATING STORIES

By

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Dedication

To Danae Christine Fails, my wife, and best friend. Thoughts of her and our children supported me during the long days and nights of work. Thank you for your love and support.

I also dedicate this to my parents, siblings, and other family members that have supported and encouraged me throughout this process.

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Chapter 1: Introduction

As the American flag waves above Fort McHenry, children explore the fort carrying mobile devices collecting, creating, collaborating and learning about the structure, events and people associated with this historic site. These children are creating a shared story describing their collective experience as they visit the fort. One child reads out loud and records on his mobile device a placard describing the magazine. Another child adds to the narrative by writing “this is a historic place” as he walks around the inner fort. Two children walk through an exhibit illustrating life as a soldier and capture the audio being narrated as they walk from one room to the next. Another child begins to write out the national anthem as he adds a picture of a flag to an instrumental arrangement of the national anthem as he stands by a canon overlooking the bay with the flag waving behind him. Even though children roam around the fort and can see all the changes others have made on their own device, they still occasionally yell out and run to each other to show and discuss something they have added.

The preceding paragraph describes some of the interactions that occurred during an initial investigation into the use of mobile devices as collaborative tools to construct narratives in context (discussed more in Section 3.4.1.2). This dissertation research leverages lesson learned from active, playful learning experiences such as this one to develop and evaluate new mobile, collaborative technologies for children ages 6-11. Specifically, software prototypes were developed and physical interactions evaluated to better understand collaboration between children with handheld mobile devices, specifically cell phones. True mobility not only increases

access to the available information, but can allow content creation when and where a child is inspired. Mobile devices empower children to create content or digital artifacts *in situ*, while they are in the context of the object or situation for which they are creating a representation [83, 148]. Creative, constructive, and generative activities in context are educational as they help the learner synthesize the information as well as provoke further investigation [179, 215].

In the last two decades, mobile devices have become more and more popular and ubiquitous [6]. Earlier this year, the Global System for Mobile Communications Association (GSMA) reported it had reached four billion connections [12]. The International Telecommunication Union (ITU), which is the leading United Nations agency for information and communication technology issues, issued a report shortly thereafter that reinforced that data and indicated that approximately sixty percent of the world's population had a mobile cellular phone subscription [14]. This proliferation is significant. In several places, mobile phones instead of landline phones have become the norm [5, 14]. Many developing countries have access to cell-phones, but do not have access to traditional desktop computers [5, 275]. Cell phones have empowered users even in developing countries with struggling economies, enabling opportunities not previously attainable [2, 275]. Fisherman can call ahead and find the best local market to sell their fish [275]. People can report civil rights abuse to help actuate change [25]. Indeed, handheld mobile technologies are emerging as the communication and computing platform of the 21st century [36].

Besides being used for telephone communication, mobile devices have been used for consumption, collection, and controlling. Consumption generally takes the

form of music, video, words, games, or receiving alerts. In some cases, content has been authored specifically for mobile phones including novels [17] and video [18]. Mobile devices such as PDAs (Personal Digital Assistants) have been used for collecting brief text or audio notes [137, 274]. More recently cell phones have been used to collect pictures and video [25, 73, 74]. Projects have been developed to enable mobile devices as a personal universal controller (PUC) that controls everything from a Microsoft PowerPoint presentation to a VCR [201, 202]. Mobile device usage as a control or input device has also been proposed in many multi-modal systems where multiple devices can be used in partnership (e.g. a PDA controls a TV, which could enable voice tagging of comments about a particular document) [88, 201, 210].

Mobile devices have also supported creative content creation and different modes of collaboration. There are several music and drawing applications that allow you to create and share music and images. Some drawing examples are the iPhone apps: iDoodle2, Scribble, Etch a Sketch, and Sketches. Whiteboard, another iPhone app, is an interesting application that allows two phones to connect with one another via a wireless network and mirror each others, thus enabling two users to work on one picture. The new iPhone 3.0 SDK has direct support for peer-to-peer (P2P) connections which simplifies the process of connecting to and sharing information with nearby devices. Mobile phones are broadly used for texting and emailing, both of which are creative and support different modes of collaboration.

While past mobile devices have been geared towards consumption, collection and controlling, others have introduced creativity and collaboration. This research

represents a shift in that it combines the creative and constructive with an explicit focus on collaboration. Although generating content has been supported on mobile devices, there are interactive limitations to these relatively small devices – primary of which is their small screen size [260]. This research explores ways to overcome these limitations via collocated collaboration. It also looks at how supporting a wide range of spatial and temporal collaborative possibilities affects mobility and collaboration.

Collocated collaboration occurs when people meet at the same time and place to “work together, especially in a joint intellectual effort” [3]. The context, or joint intellectual effort, chosen as the context for this research is reading, creating, and sharing stories. This research looks at different ways of bringing children ages 6-11 together to collaboratively accomplish these tasks using mobile devices. It includes an investigation into some of the appropriate interfaces for collocated collaboration, and how supporting an expanded collaborative interface brings people (and devices) together in the same place. Specifically, it seeks to design, develop and evaluate different collocated collaboration configurations by using off-the-shelf mobile devices. It also looks at how this collocated experience supports and encourages collaboration among young children.

Moving beyond consumption enables interactive learning and the creation of artifacts. Generative processes go beyond recall and recognition learning and suggest a deeper understanding [221]. This adheres to Papert’s learning theory of *constructionism* which is based on manipulating objects and building a public artifact — it is in the construction of the artifact that children learn. An instructive but a somewhat simplified definition of constructionist theory is: one learns by creating or

constructing [28, 214, 215]. This principle has been used to develop several systems including *Logo* where elementary school children explore the world of math by controlling a turtle graphics object via a simplified programming language [214] and *LEGO/Logo* and the *LEGO® Bricks* which provided more direct physical manipulation allowing children to touch, move and program physical creations [239, 240]. Constructionism applies to the target age range of this study (6-11 years old), but is not only applicable to young children, but also on up to middle-school-aged children [28, 214, 215].

Creating or authoring is essential for educational purposes, and technology continues to improve yielding mobile devices with more computing power and advanced functionality. Numerous mobile devices, such as the Apple iPhone and its competitors, have advanced features including: phone, expandable memory, camera, MP3 player, wireless connectivity (802.11 and Bluetooth), global positioning systems. These devices have increasingly rich computational power and features at lower cost (~\$200), and broad distribution. With the added computing potential promised to future mobile devices corresponding advances in the types of interactions and collaboration are necessary to overcome the various limitations and challenges attributed to mobile devices. Collocated mobile collaboration, the focus of this research, addresses many of these important issues. Bringing multiple devices together in face-to-face collaborative settings not only increases the total number of pixels which helps to overcome the small-screen size limitation, but it can also impact the different types of collaborative interactions that are possible.

Narrative systems have started to address issues of mobility by using ubiquitous and tangible computing technologies. Ubiquitous computing technologies are technologies that are embedded and integrated into the environment [291]. They generally use sensing of some sort to enable user interaction [114]. This type of technology has been used in mobile field trip environments to encourage capture or collection of data [137, 245]. Graspable or tangible computing involves physical manipulation of objects such as coupling a digital document to a physical brick or a triangle and modifying the virtual by physically manipulating the physical [117, 118, 125]. This technology has been used in narrative systems to enable programming or configuring stories [30, 124, 125, 197, 198]. Instead of embedding technology into the environment or using tangible props, the perspective of this research is to equip children with mobile devices to enable true mobility.

Collaboration and creativity are not only important aspects of children's development [215, 287], but also life skills crucial to "succeed" in today's world. Narratives dramatically facilitate children's learning [23]. Although classroom instruction is the norm in many countries, there are many other learning opportunities available for children via individual and group play in and out of school. Mobile devices can potentially be designed to allow children to move about and play just the same way, but as they go along they could capture and create individual or collaborative narratives. The building of this common, public artifact – a story – fulfills an important requirement of constructionist learning theory. Such play is creative and educational, and the creation of a shared artifact enables reflection and encourages collaboration. Gene Chipman's thesis work at the University of Maryland

on technologies supporting fieldtrips has begun to address these issues. The system, Tangible Flags [83], was designed to allow children to create digital artifacts and link them to the real world via a “tangible flag” that had a radio frequency identification (RFID) tag inside. Although this system contains elements of mobility, constructionism and collaboration, it did not specifically address the mobile collaboration issues addressed herein. The context of the Tangible Flag research was different in that it was not one of creating narratives, but was more for tagging, labeling, or asking questions about individually flagged items. Another difference was that it did not look at different collocated collaborative interfaces other than being able to see the same interface or artifact creation page. It also only looked at creation, and did not investigate collaborative reading of previous and sharing.

By expanding the functionality of mobile phones from being used for communication, consumption, collecting and controlling to creative, constructive and collaborative processes, children can be empowered to leverage mobile devices for constructive learning purposes. The context used herein to explore mobile collaboration for young children (ages 6-11 years old) is collaboratively reading, constructing, modifying, and sharing stories. Mobile story authoring and sharing including collocated collaboration can yield social, interactive, exploratory, creative, constructive, mobile play and learning opportunities.

1.1 Research Questions

The following three research questions are addressed through the development and user evaluation of a system for mobile collaboration between children. The prototype system, *Mobile Stories*, was developed using *Cooperative Inquiry*, a

method for designing technologies with and for children. The techniques in Cooperative Inquiry enabled the development of an effective system. Using formative and evaluative studies mobile collaboration and collocated collaborative configurations were investigated further. The final study discussed in this research – which is referred to as the collaborative story study – has three parts where children read, create, and share collaborative narratives in a large, child-friendly lab environment using Mobile Stories.

1.1.1 How does the collaborative mobile technology Mobile Stories affect children’s collaboration and mobility?

This question seeks to explore to what extent collaborative mobile technologies – specifically Mobile Stories – promote, encourage and/or discourage collaboration and mobility. Corollary questions are: to what extent do children work with one another, and how effective is that collaboration; to what extent are children able to move around while using mobile devices to read, create, and share narratives. These questions were investigated via many formative and evaluative means including: an in context experience at Fort McHenry National Park (Section 3.4.1.2), an investigation using Mobile Stories 3.0 and a paper Mobile Stories system (Section 3.4.3), and the collaborative story study (Chapter 4).

1.1.2 What are some of the appropriate interfaces for collocated mobile collaboration with children?

There are many ways collaborative collocated mobile interfaces could be designed and configured. This question does not address a comparison of all possible interfaces as there is an infinite number. This question instead addresses some of the

possible configurations. In order to address this question, Cooperative Inquiry techniques were employed where I, along with other adults, partnered with children ages 6-11 to design appropriate collocated collaborative configurations. The design sessions started with a general, broad perspective and iteratively refining the design ideas (Section 3.4.1). From this process a prototype system, Mobile Stories (Section 3.4), was developed that used the collaborative configurations of: content splitting and space sharing (see Figure 1.2). In content splitting, each device shows different, parsed content within the same context. For example, one device could show the picture and the other the image from a page in a book (see Figure 1.2, *middle*; Figure 1.2). In space sharing, the interface is spread across both collaborative devices. For example, a picture or words could be spread across the collaborating phones (see see Figure 1.2, *right*; Figure 1.3). These are discussed further in Chapter 3 in Section 3.1. Allowing devices to come together can ameliorate the problem of limited screen space. The fact that there are two devices also increases the interactive possibilities. The designed system architecture handles not only sharing of screen space, but also the sharing of interactions made on each device to leverage the new, joint interactive opportunities.

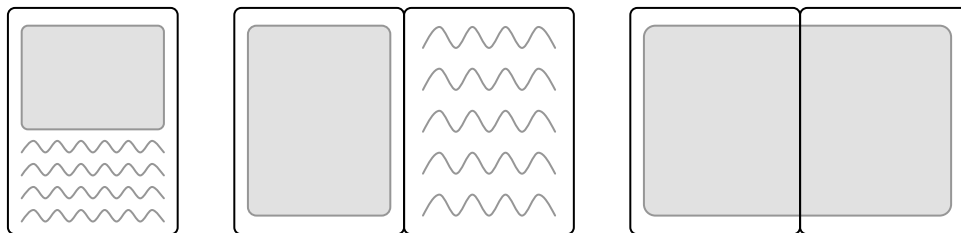


Figure 1.1 – Collaborative configurations *left*, a single page from a book with a picture and words; *middle: content splitting*, two devices showing the same page (one device shows the picture, the other the words); *right: space sharing*, two devices showing the same picture on a page (picture spread across both devices).

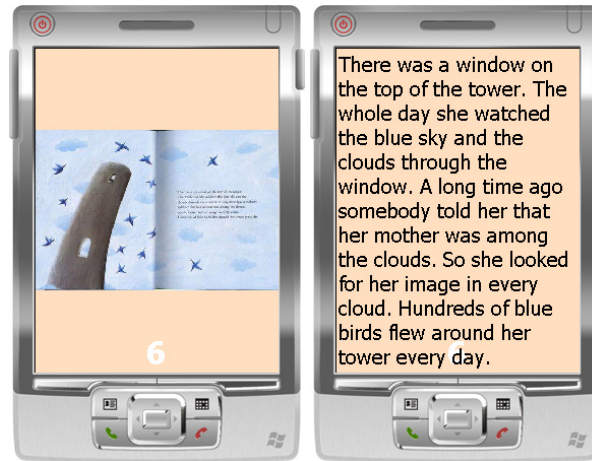


Figure 1.2 – Content Splitting, mobile collaboration using a page from the Blue Sky by Andrea Petrlik Huseinović published 2003, Kašmir Promet, Croatia, Available in the International Children’s Digital Library (ICDL) at www.chilrenslibrary.org.



Figure 1.3 – Space Sharing, mobile collaboration using a page from the same book as in Figure 1.2; *top*, an image; *bottom*, words spread across both devices.

1.1.3 When are the developed interfaces preferred and why?

The collocated workspace expansion addressed in the second research questions has not been widely explored or commercially leveraged within the mobile context. Building on the second research question, with this question, preferred usage patterns are investigated. When would children reportedly use these interfaces and when do they use them in practice. Also investigated is why they used these interfaces. This investigation is part of the collaborative story study discussed in Chapter 4. In summary, this research question is poised to investigate the relative advantages of the collocated collaborative configurations discussed above, as well as when and why they may be best employed.

1.2 Contributions

The contributions of this work include the design and development of a collaborative story telling application, Mobile Stories. The design, development, and evaluation of Mobile Stories addressed the above research questions – comprising the major contribution of this research. Through the use of Mobile Stories, mobile collaboration was investigated in its effectiveness for supporting collaboration and mobility. Mobile Stories’ interface was designed *with children* to be child-appropriate and support collocated mobile collaboration. While some have proposed collaborative interactions no detailed discussion of what happens when people come together with mobile devices has been proposed or analyzed. The collocated collaborative concepts of splitting content and sharing space, evaluations of their usage, and discussions of user preferences are all major contributions.

The following chapter, Chapter 2, discusses related work. Chapter 3 describes the design and development of Mobile Stories, including the collaborative concepts derived from the iterative design and development process. It also reports initial findings and considerations used to further the design at each stage of development. Chapter 4 reports on a three-part collaborative story study which was used to follow up on the initial findings and further address the research questions. The final chapter concludes this dissertation with a discussion of the contributions, implications for designers and developers, and research ideas that can build on this research.

Chapter 2: Related Work

The main focus of this research is mobile collaboration for young children. Figure 2.1 illustrates the intersection of these three areas which forms the basis for this research. The claim is that collaboration between children can be enhanced via mobile technologies. Collaboration is by definition to “work together, especially in a joint intellectual effort” [3]. The context for the “joint intellectual effort” used in this research, which is directed towards children, is constructing a narrative. Since the context is integral to understanding the overall context in which this research lies, work related to the context is also discussed in this chapter.

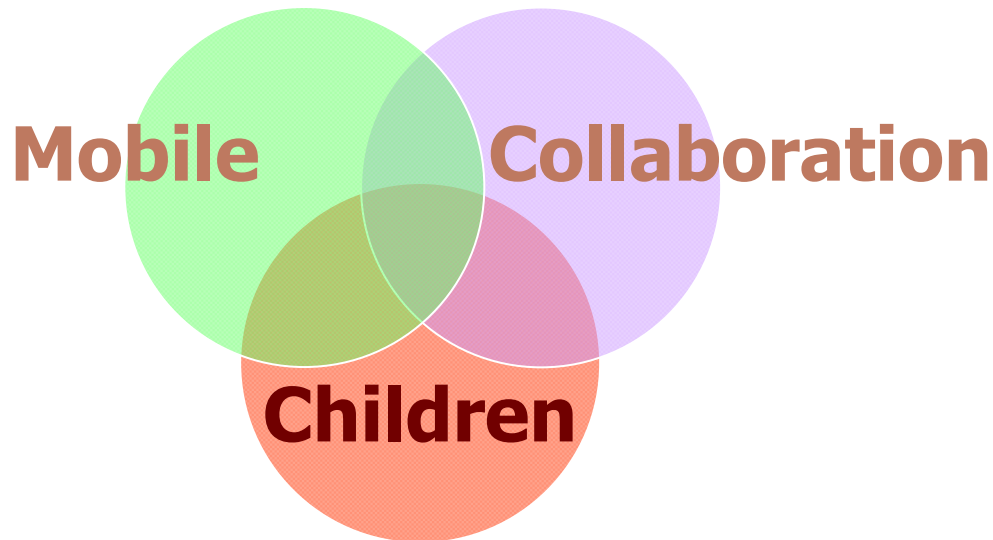


Figure 2.1 – Three main research areas: mobile collaboration for young children.

Including the context, there are five different research areas that intersect to inform my research on *collaboratively constructing children’s stories in mobile settings*. In Figure 2.2, an Edwards-Venn Diagram displays the power set of the five areas of research: mobile technologies/settings, collaboration, constructionism,

children and stories. The overall picture below helps contextualize the research. Based on this visualization, representative projects in the most relevant areas are described along with their specific relation to the project at hand. While there are broader implications within the full context of these five areas, the main contributions of this research are the particular attention to mobile collaboration for young children, the ability to seamlessly switch between individual and collaborative modes, and the intersection of all five of the aforementioned research areas – exploring how mobile collaboration can support narrative creation.

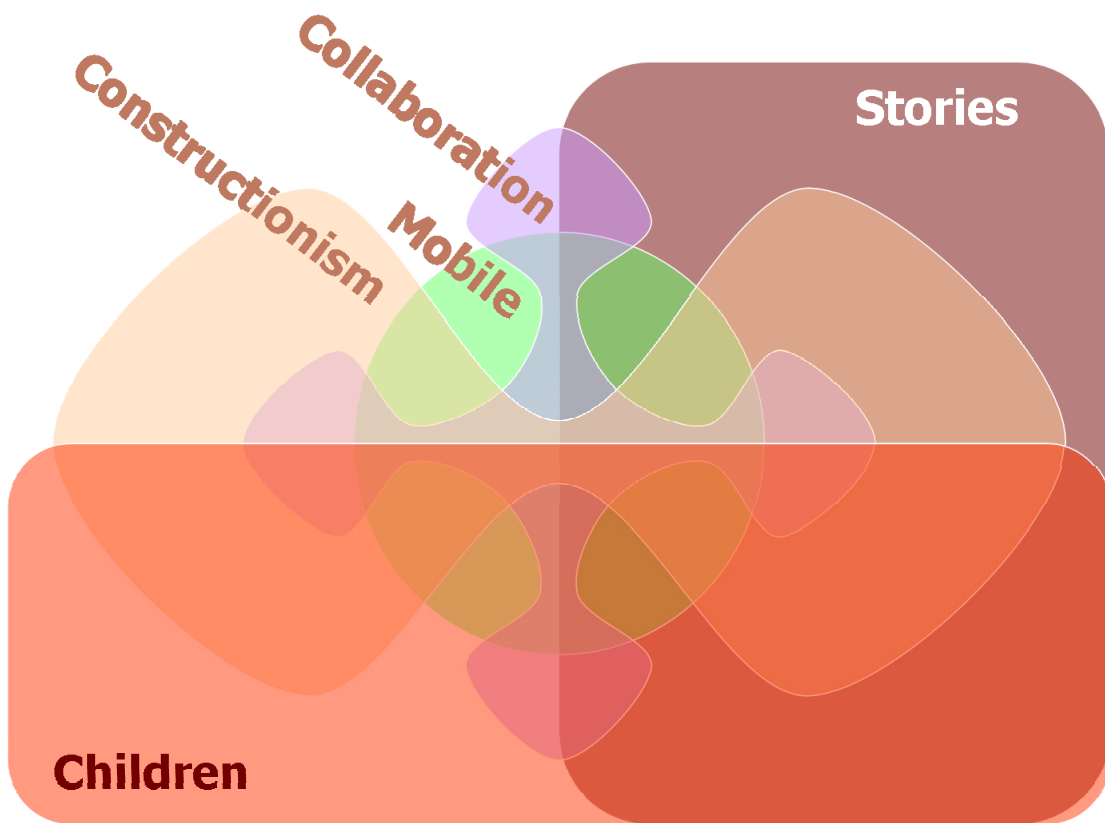


Figure 2.2 – Context of research: The power set of the five research areas addressed in this proposal: mobile technologies/settings, collaboration, constructionism, children and stories.

The chapter proceeds as follows. Section 2.1 discusses the educational approaches and learning theories associated with children. This gives context to the

specific application of Mobile Stories as well as giving context for the need of collaboration. Although collaboration is a subset of the concepts discussed in section 2.1, it is further developed in section 2.2 because of its central importance to this work. Section 2.3 brings together the concepts of children, stories and narrative systems illustrating examples of implementations following the concepts discussed in sections 2.1 and 2.2. Section 2.4 surveys various computational approaches and lays the framework for the need to use mobile devices. Section 2.5 continues this discussion broadening the foundation of mobile technologies. Section 2.6 then considers the important intersection of *mobile collaboration*.

2.1 Educational Approaches and Learning Theories

Recorded history documents peoples' yearning for education and the wide-ranging mechanisms to supply it. Plato [225], Aristotle [96], Locke [183], Rousseau [247], Dewey [102], Steiner [272], Skinner [263-265], Piaget [221], Papert [214, 215] all have theorized, promoted and implemented varying educational approaches and learning theories [97]. Due to the numerous theories, and the assorted opinions of each, educational practices vary widely. Despite the number of theories, there is a recognized need for improved education in the United States. Also, despite the numerous advances in technology, education has relatively maintained the status quo [13]. Even though the United States has a coveted system of higher education, there is a recognition that improvements need to be made even in this area [9, 196]. A call for improved education has been made concerning education in literacy [230], and for education in general [13]. And there are tough choices that need to be made in order to maintain and increase the ability of U.S. graduates to compete in an increasingly

competitive world [9, 26]. Among the many educational theories, the specific theories that most relate to my research are *constructionism* and *situated learning*.

Seymour Papert, a pioneer in developing new educational technologies for children, developed the theory of constructionism which builds on the work of Piaget and others. Piaget's theory of *constructivism* does not prescribe a fixed pedagogy, but describes how learning happens through the processes of accommodation and assimilation [221]. Through these processes, new knowledge is constructed from an individual's experiences and either accommodated through cognitive restructuring or assimilated into an already existing framework. Papert himself made the distinction between constructionism and constructivism as:

Constructionism — the *N* word as opposed to the *V* word — shares constructivism's view of learning as “building knowledge structures” through progressive internalization of actions ... It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe. [28, 215]

John Dewey, a predecessor of both Papert and Piaget, also affirms the importance of active construction — “education is not an affair of ‘telling’ and being told, but an *active* construction process is a principle almost as generally violated in practice as conceded in theory” [102]. Papert argues that it is through manipulation, experimentation, and personal experience that children learn and that learning that occurs through *constructing* a public artifact, which Papert calls a ‘public entity’ [215]. The creation of a representation is an important aspect of learning. Moving beyond recall and recognition, actively constructing or organizing knowledge gained from personal interactions and experiences in the real world enhances learning [215]. *Activity theory* also describes how people complete internal and external hierarchical

activities based upon their needs, culture and relationship with the physical world [179]. Activities are mediated through the use of tools. Bellamy suggests the application of activity theory to the design of educational technology by empowering children to create and share artifacts inspired by their experiences, culture and community [44]. Indeed, successful learning is a constructive process [62], and learning is most successful when the learner is in control and actively cycling between experimentation and reflection [171]. According to these theories, active creation is vital to learning.

As suggested by activity theory, context plays an important role in development, behavior, competence and impacts learning [116]. In fact, it has been shown that meaningful contexts influences children's memories [40]. *Situated learning* also emphasizes the importance of context, activity and culture as integral to the learning experience [178]. Jean Lave challenges traditional schools claiming they “decontextualize” knowledge, stating also that by virtue of presenting the information in schools, the context has been shifted to that of the school [178]. According to situated learning, context coupled with social interaction enables learners to form a “community of practice” further enabling unintentional instead of deliberate learning. Although context is often accepted to mean the cultural and social setting, spatial environment also plays a critical part in cognitive development [105]. Enabling children to construct artifacts in the context of a specific, physical learning space can enhance the learning experience [83].

In the last century, many have predicted how technology would revolutionize modern educational systems; however, these technologies have yet to realize this

dramatic impact [268]. To surpass the threshold digital technologies need to “go beyond telling stories and presenting information to support individuals and groups in doing activities” [268]. Mobile Stories can be a step in this direction by enabling children to explore real-world settings and encouraging collaborative construction of narratives.

2.2 Collaboration and Technology

There are many ways of collaborating with others. Generally collaboration is described as having two dimensions: time and space [104]. These dimensions are broken down into further differentiations namely temporal into synchronous (at the same time) and asynchronous (at different times), and spatial into collocated or collocated (in the same place) and distributed (different locations) [104]. In her book, Creative Collaboration [159], Vera John-Steiner, discusses four different classifications of collaboration differentiated by the roles of the collaborators, the extent the values and goals are shared, and how they work together. The continuum ranges from loosely connected to tightly integrated. The categories are: distributed, complementary, family, and integrative collaboration [159]. The Collaboration Handbook, describes three levels of interaction as cooperation, coordination, and collaboration [293]. Cooperation is characterized by short-term, informal relationships where there is limited shared information and there are separate goals, relationships and structures. Coordination is a longer-term project or task that involves planning, division of roles and some shared resources, rewards and risks. Collaboration is a durable, pervasive relationship where new structures are defined by a commitment to common goals and where all collaborators contribute resources,

share rewards and assume different leadership roles [293]. A recent framework for computer supported collaborative learning (CSCL) considers different permutations of child peer and adult facilitator configurations, as well as different interactive modalities (e.g. sounds, words, pictures) [231].

The numerous ways that collaboration can be conceptualized and performed poses a design question when it comes to crafting a child-appropriate interface. Mode switching has historically been a cognitively expensive task [233]. Allowing users to directly control and easily perceive what mode they are in is critical to efficient interactivity. According to Piaget, children in the target age of 6 to 10 are in the concrete operational stage, which is characterized by logical thinking about concrete events. Mode switching is an abstract principle which many adults struggle with [233]. Piaget theorizes that only around age 11 do children enter the formal operation stage and develop abstract reasoning [220]. With this in mind, designing an interface to ease collaborative mode switching for children is not trivial. The design could entail using one of many conceptualizations of collaboration, or devising a new one that is simple and concise. As discussed further in the following chapters, the concepts of content splitting and space sharing emerged as a simple way of describing different ways of collaborating (see Section 3.1).

It has been said that to bring education into the 21st century, a change in tactics is necessary to promote deeper, collaborative learning [288]. Computers are used in many collaborative settings; in fact there are large bodies of research that fall under the research area of Computer Supported Collaborative Work (CSCW) [128] and Computer Supported Collaborative Learning (CSCL) [172]. Although many hail

educational technologies for their abilities to personalize the learning experience, many feel that collaborative and cooperative approaches are one of best educational uses of computers [164].

Because of the broad importance of these approaches, recent strides have been taken in research and industry to echo the need to have collaborative software. Groupware systems have been built addressing concurrency control as well as collaborative interfaces [111, 130, 279]. Despite the numerous collaborative writing systems, a study conducted in 2004 reports that most respondents use “individual word processors and email as their main tools” [208]. Since then, other tools have been distributed. In 2006, Google released its *Google Docs & Spreadsheets* which allows users to work on the same digital document in real-time online [7]. In 2007, Microsoft is set to release its *Microsoft Office Groove 2007* – a suite of office products designed to simplify collaborative, business work flows [11]. In 2009, Google announced Google Wave, to be released in 2010, which is an HTML 5.0 compliant browser-based collaborative platform that intertwines and integrates various communication metaphors into one: a wave [8]. Google Wave incorporates multi-user concurrency and federation. Since it is browser-based, it can be used on mobile devices. These technologies have been designed to meet the collaborative needs of adults, and emphasize distributed collaboration, however “it is important that we do not limit computer-based collaboration to distributed settings” [152].

Researchers have found that social interaction and collaboration are important for child development [287]. Reflective interactions among children improve the cognitive process and facilitate learning [266]. Tools, such as the one developed

herein, provide a mechanism to collaboratively construct representations, providing a structure for elaboration [250]. Elaboration is indicative of effective knowledge restructuring which has been demonstrated to be related to the ability of retaining and relating information to other knowledge [266]. Young children have been shown to become capable of effective collaboration around the age range of 5-7 [296]. The desire to collaborate has been shown in other studies including one focused on children ages 7-11 who preferred to work in a group as well as to primarily consult a friend when confronted with a problem [257]. The children in the target range of this work (children ages 6-11 years-old) are able to collaborate. Collaborating and creating knowledge artifacts enriches the learning experience.

Collaborative systems can be characterized by those that *require* and those that *encourage* collaboration. Many technologies have considered both collocated and distributed collaboration experiences; however, much of the systems has required the children to collaborate. For one study, a collaborative math game was created where children were tethered to each other requiring each team member to climb the math mountain at a similar rate [254, 255]. There are many collaborative mobile systems that require collaboration, such as the many simulation activities, where to accomplish a goal, collaboration is necessary [4, 47, 99]. In *Silaba* (Syllable), children each have a syllable and they collaboratively sequence the order of the syllables to create a word [302]. Here again, collaboration is required. Some previous work has expanded the range of collocated collaboration by exploring how to encourage collaboration among children by giving incentives of richer opportunities, rather than requiring it. This work includes previous work done at the

University of Maryland sharing a single computer (Single Display Groupware [SDG]) with *KidPad* [45, 109], a collaborative storytelling application for a desktop computer, and also with *SearchKids* [241], a predecessor to the *International Children's Digital Library* (ICDL, www.childrenslibrary.org) [10]. This approach has recently been commercially released with Microsoft's *Multipoint technology* and has been used with youth in India [24]. In designing and studying those systems it was found that encouraging collaboration provides a lightweight interface approach to bringing people together – a very important aspect for children.

As collaboration is a large field of research a brief, general overview is given in this section and specific examples are embedded below in intersecting areas of interest (e.g. ubiquitous computing, other mobile systems). Before continuing, it is important to reemphasize the importance of collaboration with the aforementioned educational theories and learning approaches. Simply stated, constructing a digital artifact while interacting in physical space and collaborating with others is an effective learning strategy. At the creative level the goals are similar to those stated in *Tangible Flags*, namely “enabling children to collaborate on the construction of knowledge artifacts in the context of a physical learning space can bring together the learning benefits of construction, representation, collaboration and authentic context” [82].

2.3 Children, Stories and Narrative Systems

There is an Indian Proverb that says: *Tell me a fact and I'll learn. Tell me the truth and I'll believe. But tell me a story and it will live in my heart forever.* [126]

This proverb is supported by a The (U.S.) National Council of Teachers of English (NCTE) Guideline which states that teachers discovered children could easily recall whatever historical or scientific facts they learned through story [23]. Indeed, stories and narrative exploration, are excellent for learning and teaching [126, 127]. Stories herald lasting learning and educational impact for young children [126, 127] including many specific benefits such as language learning [153], construction of self-image [72] and more. Allowing children to assume the role of story maker facilitates the learning process as children learn to read, and supports socialization and language development [292].

Because stories are such a powerful teaching tool, many systems have been developed to foster story creation and sharing. The story creation adheres to the constructionist learning theory discussed in section 2.1, and the sharing correlates to the collaborative need as described in section 2.2. Despite the difficulties of supporting collaborative writing [277], there are many collaborative narrative systems including those designed for collocated [30, 45, 109, 197, 198, 270] or distributed [64, 193] settings. *MOOSE Crossing* [64] is an online community where children can construct stories individually or collaboratively. *MOOSE Crossing* is a MUD (Multi-user Dungeon/Dimension/Domain) that children can explore, expand and create people and spaces in a virtual world. Several other systems have been developed that enable exploration and modification of virtual worlds [76, 192, 193, 227].

In *SAGE* [52, 284], hospital patient children ages 7-16 interacted with a stuffed rabbit connected to a computer by typing. Children could essentially chat with a “wise” character (the computer) who would tell stories related to the

conversation and the patient's situation. The child could also create a character and add stories which in turn could be shared with other children. *Rosebud* [123] another research project by the same team at the MIT Media Lab links children's stories to their toys and tries to evoke emotional responses via narrative. This happens as a child can create a narrative and link it to a "keepsake object" (a stuffed animal). The object is used as an index to the story as well as a storage device as stories can be loaded onto the object.

PETS (A Personal Electronic Teller of Stories), developed at the University of Maryland [224] enables children to program a robot to mimic their actions creating a story in motion. *Triangles* [124, 125] another physical storytelling tool developed at the MIT Media Lab allowed children to create nonlinear stories putting together story pieces using triangular tiles. In *StoryBeads* [35], children could create a story necklace linking tiny computers (beads) that had story segments/images. These story pieces could be traded and swapped, enabling repurposing of images and image sequences in what the author entitled *transactional storytelling* [35].

Authoring tools also vary from those designed for professionals to those designed for young children. A professional digital storytelling environment was developed in [251], and was followed up with by the same author who created a tool to enable non-linear, digital story creation [252]. Such systems are geared for adults. *StoryMaker* [21] is a desktop application developed by Software Production Associates (SPA) which enables users to create actively "animated speaking and 'sounding' stories". This system claims that children 5 and under can enjoy stamping pictures, while those older up through adults can enjoy creating intricate animated

narratives. Stories can be shared and a viewer can be downloaded for free. Collaboration is not integrated, the development of the stories is quite advanced and in its current form is not amenable to use on mobile devices. One narrative system that allows limited collaboration in mobile settings is Sketchy [19] where children (grades K-12) can create drawings frame by frame and then animate them (like a thumb-flip animated picture book). Collaboration occurs as a child can share or send a frame to a peer by lining up the infrared ports and the two collaborators respectively selecting send/receive on the interface. This point-to-point sharing system does not enable any other collaborative modes, nor does it address the collocated mobile collaboration issue to the extent proposed and addressed herein. Sketchy's has a simpler concept and interface than StoryMaker and is therefore probably more suitable for the children targeted in this research, ages 6-11.

Although more will be discussed later, mobile devices have already started to emerge as a platform for collecting information that can later be used in a narrative. Several examples illustrate the use of mobile devices as collection or capturing devices. Recently video captured on cell phones has made headline news as people have recorded events relating to the Iraq war [73, 74]. WITNESS is a foundation that promotes and educates people on using mobile devices as a tool for social activism (www.witness.org) [25]. Mobile devices have been used to capture information in children-oriented research as well. The literacy field trip provided an environment that encouraged children to capture inspiration to later be used in the creation of a narrative once the children have returned to the classroom [137], . In *KidStory* [270], a multi-year research collaboration between the University of Nottingham, the Royal

Institute of Technology, Sweden, and the University of Maryland, children used mobile devices to collect parts of a story, and then collaboratively pieced them together on a large shared display. None of these systems offer collaborative mobile authoring and those that address collocated collaboration are not in the mobile realm or simply allow page sharing as the only mode of collaboration [21].

2.4 Computational Approaches

There are many different approaches to interacting with computers. The desktop computer is the most common; however, other methods include graspable and tangible, ubiquitous and pervasive, and mobile computing. These approaches are discussed in the following subsections. The concluding section discusses different collaborative spaces, as many have been proposed using combinations of these various approaches.

2.4.1 Graspable/tangible computing

Graspable or tangible computing involves physical manipulation of objects (*phicons*) that are coupled with a digital representation such as a physical brick or a triangle could be physically manipulated to modify a digital story [117, 118, 125]. *Bricks* [118] allowed a user to use small rectangular blocks (bricks) to interact and modify digital content. For example a block could be linked to a digital building and moving and rotating the physical block would translate and rotate the building in the three dimensional digital space. Scaling is performed using two blocks, where one is the anchor and the other is moved closer or further from the anchor block to respectively decrease or increase the size of the building. Many others have built on

the concept of tangible computing. In *Tangible Bits* [154], the *metaDESK*, *transBOARD*, and *ambientROOM* were developed combining interactive surfaces and the coupling of digital artifacts to graspable physical objects. More recently, *phidgets* [129] have been developed and commercialized (www.phidgets.com) to enable simple inclusion of physical interaction widgets in system development.

It is important for children to move and interact in three dimensional spaces, so physical computing is a particularly promising for young children [30, 197]. In fact several systems have been developed specifically for children including the *Programmable Brick* [239], *LEGO/Logo*[240], *StoryRooms* [30, 197], the *Hazard Room Game* [113], *Triangles* [124, 125], *Siftables* [195], and many more [32, 270]. *StoryRooms* is an example of a narrative system that used manipulatives to enable children to program digitally enhanced props to help illustrate stories [30, 197, 198]. The *Triangles* system is another example graspable computing narrative system where triangular tiles representing pieces of a story can be arranged to create a narrative [124, 125]. Although physical computing allows movement in three dimensional space, it has not allowed true mobility as the environments are fixed [125, 285]. Instead of embedding technology into the environment or using tangible props, this work equips children with mobile devices to enable true mobility.

In years past, researchers have explored physical and desktop environments as well as systems that try and bridge the gap between the two. In order to start to understand the nuances between the physical and the virtual, a comparison study was performed in [113]. The results of the study suggested several advantages of physical interactive environments for young children (ages 4-6), especially for young girls

[113]. Some systems that attempt to bridge the gap use a transitional figure like a stuffed animal like SAGE [52, 284] and Rosebud [123], which were discussed briefly in the previous section. The *PEBBLES*[™] project (Providing Education By Bringing Learning Environments to Students) uses a vicarious, child-sized robot to represent a child who cannot be present in the classroom due to hospitalization or long-term illness using “a unique video-conferencing system known as *telepresence*” [15]. This is similar to the *Chit Chat Club* [165], where users can informally meet people in a café-type setting while being geographically distributed. Other systems attempt to bridge the gap by using mobile computing devices such as in *KidStory* [85], *Ambient Wood* [245] and *Tangible Flags* [83]. This is the approach taken in this research, to use mobile devices to bridge the gap between physical and virtual interactive environments.

Physical devices via graspable and tangible computing or perceptual user interfaces have enabled new interactions. While these systems tout three-dimensional, physical characteristics many require short ranging sensing environments which are not mobile [117, 118, 154], therefore they do not allow wide-range access. These systems do not enable true mobility, at least not to the extent that mobile devices such as mobile phones may provide.

2.4.2 Ubiquitous & pervasive computing

Ubiquitous and pervasive computing technologies are technologies that are embedded and integrated into the environment. These technologies generally incorporate sensing technologies to enable user interaction. This is aptly described by Mark Weiser in his seminal paper *The Computer for the 21st Century* [291]. An

example of this is *Light Widgets*, where in a room instrumented with cameras, virtual widgets could be set up that could be manipulated using a hand [114]. For example, a virtual slider widget could be made along the casing of a doorway to adjust the temperature of the thermostat, or virtual button on a bedpost could turn the lights of a room on and off when a hand tapped it [114]. Although embedded technology is key characteristic of ubiquitous and pervasive computing implementations, it does not prevent the use of user-carried technological tools. In fact, in many instances, the instrumented environment is complemented by a user-carried computing device. This is the case in many context-aware systems.

Context-aware systems range from sensing systems that present information such as at a museum [63], to a cellular biology laboratory that takes measurements and records processes [31], to one that prompts students to investigate and collect items from a real-world environment [58, 137, 245], or something that allows interactive control of the surroundings through body movements [114, 174, 175]. Context-aware systems use a broad range of technologies for sensing as well, ranging from cameras, to global positioning systems (GPS), to close-proximity RFID [289], to controlled Bluetooth [60], to 802.11 access-point triangulation, and beyond. These systems afford many educational opportunities as context impacts learning as discussed previously in section 2.1 [40, 116, 148].

Two context-aware, ubiquitous computing projects of particular relevance to this dissertation research are *Ambient Wood* [245] and *The Literacy Field Trip* [137] developed by several collaborators in the United Kingdom. In *Ambient Wood*, users walked through fields and forested areas taking measurements and gathering

information. Context-aware sensors would trigger prerecorded content as well as various prompts designed to help users reflect on or further investigate the environment and the gathered information. Information could be shared with others in the environment. The literacy field trip was built upon the same architecture as Ambient Wood, however, the goal was to help users collect information that could be used in a narrative upon returning to the classroom. Despite the claims by some that context-aware applications “significantly enhance the utility of mobile applications” [138], this dissertation research is designed to allow children more freedom to *create their own* representations and not be guided by location-sensitive prompts.

Many ubiquitous systems have been developed to leverage the popular interest in games. A review of several pervasive games can be found in [185]. In *Human Pacman* [79], users play a real-life version of *Pacman*, eating cookies, getting power pellets, and running from and chasing ghosts who are fellow collaborators. Similar *Pacman* games have been developed in [55, 204]. In *Feeding Yoshi* [43], players would find Yoshis (which represented secure 802.11 access points) who had a seed of their favorite fruit. Fruits were cultivated and harvested from plantations (which represented insecure access points) and subsequently fed to Yoshis to receive points. In *Savannah* [47], collaborating players act out various lion missions. These systems have been relatively well received; however, they are fundamentally consumption-based systems. Although mobile collaboration for children includes aspects of consumption, by restricting it purely to consumption the collaboration is rigidly constrained. The focus in this research is to enable collaborative, *constructive* processes and not just support popularized consumption-based approaches.

Tools to create context-aware environments have also been created. *InStory* suggests allowing users to author content by changing/adding text and images in a location-aware system that senses where you are at and changes the content [91]. The same creators of *InStory* developed *InAuthoring* which is divided into *InAuthor* and *InContent* which allow a user to setup environments [34]. The system is inspired by *M-Views* [93] a system for creating and experiencing context-aware cinematic narratives and authoring is done with *M-Studio* [212, 213]. This system supports groups and could be used to build a system like *Ambient Woods* [245]. Another rapid authoring tool *Mediascapes* [147], was developed so non-programmers could create context-aware ubiquitous applications. Each of these despite claiming user friendly graphical user interfaces (GUIs) are not appropriate for young children nor do they facilitate authoring on a mobile computing platform but instead are designed for adults on desktop computers.

Although context-aware systems claim mobile characteristics, many also fixed to small geographic spaces as they generally require extensive instrumentation which is not available in many environments [114, 285]. Mobile devices enable true mobility. It is proposed that mobile devices can bridge between the physical and the virtual, and because of their more widespread dispersion than instrumented environments are more practical as a ubiquitous interactive tool.

2.4.3 Multimodal systems

Multimodal systems allow access to digital data via multiple input mechanisms or modes. For example a user could be seeing visual feedback of home security settings on a large-screen TV while modifying the settings using a phone.

Multiple such systems have been developed and explored [88, 201, 210, 246, 282]. *XWeb* [210], one such system, was an architecture for data synchronization what was used for multi-modal computing and included different components that allowed whiteboard, laser-pointer, desktop and RFID interactions, with various feedback mechanisms such as TVs, monitors, projectors, and *X10 products* (see www.x10.com) allowing control of home automation devices like lights, thermostats, etc. Pebbles also allows multimodal modification of digital data including input from mobile devices [201, 202]. While this work and others is applicable to mobile devices particularly as control devices, the work presented herein focuses specifically on how bringing together multiple devices one can elect to (not just when necessary) collaboratively use different modalities on various devices. Multimodal systems are also similar to this dissertation work because different devices could possibly have different interfaces while still accessing shared, synchronized session data, however in multimodal systems this is generally defined by the interface definition and not by user interactions such as bringing devices together for collaboration.

2.4.4 Collaborative spaces

Most of the remainder of collaborative technologies will be discussed in Section 2.6 on Mobile Collaboration; however, since collaborative spaces have emerged as another computational approach, a brief overview is given here to describe context for the mobile collaboration approach utilized herein. Various collaborative configurations have been proposed for varying numbers of collaborators, space configurations and public/private disclosure. These collaborative environments range from collaboration among single users across multiple devices

[150], to point to point or small group collaboration [99, 279], to larger collaborative groups [60, 155].

There are many characteristics that influence collocated collaboration including orientation of display, arrangement of users, size of display, proximity to display, privacy of the display, superimposition of display space on the input space, and the number of displays [189]. A major issue that is considered in collocated collaborative spaces is the notion of public versus private spaces. For example, *Connectables* [279] allows users to move tabletop computers around and join them. When joined, the computers form an interactive space where a large portion of the screen becomes a shared space, but private areas are reserved for personal interactions. Items can be moved from the personal space to the public space and vice versa. This notion of public/private space inspired on project to have a large public display and behind the public display was a smaller, collaborative interactive space where collaborators could jointly create the artifact to be displayed on the outer display [61]. Other privacy techniques have been proposed for various user roles such as a presenter and a passive audience where privacy could be ensured through techniques like blurring, salience and highlighting, spatial and temporal manipulations [50]. The notion of public and private spaces on mobile devices is pretty clear, as devices are brought in proximity the space is public, and when devices are held to oneself they are private. Orientation of the devices could change this dynamic, but for children this simplest of configurations is the approach taken herein. Even though devices are separated by space and therefore privately viewed the

collaborative link could still be maintained (e.g. the collaborators could still be working on a shared representation or artifact).

A recent related research trend has been called *multi-device environments* (MDEs) [54] or *distributed display environments* (DDEs) [149]. A framework for DDEs has been proposed to comprise: degree to which an interface supports replication, the usability of the distributed environment, and evaluation of the environments [149]. In [54], researchers investigated the impact of network representations on user understanding of the underlying network in MDEs and emphasized the necessity of awareness of other users' actions. Sharing or dividing the interface across multiple devices has been proposed by many [150, 222, 278]. In *Geney* [188], which was designed and used for children ages 10 to 13, the original intent was to share the interactive display of the devices however they found that the static formation and the borders of the PDAs to be distracting, so they opted for individual displays where only small information was shared between devices and where team leaders had an overview and could direct team members to accomplish the team goal. Mobile Stories supports their stated original intent and leverages what was reported as the best feature which was the ability to “beam fish to each other” [188]. *Opportunistic annexing* or *ad hoc* connecting of devices as well as interface sharing have been proposed in [222].

2.5 Mobile Technologies

During the last three decades, traditional desktop computing environments have proliferated worldwide. With the rise and proliferation of mobile devices [6, 275, 295], it has been said that mobile phones will become the primary personal

computing devices [36]. Indeed, mobile devices, more specifically phones, have become a part of everyday life to many who have seen it transform their function in their personal and work lives [2, 275]. Accompanying this trend, many mobile devices have been developed, marketed and deployed as well as many researchers have looked into the various opportunities the new technology affords. Although it is not all inclusive, much of what has been done with mobile devices can be categorized into three areas: porting old content to be accessible on the new technology (e.g. automated summarization and content adaptation), using mobile devices to control other devices (e.g. using a PDA to control a home automation system, a TV, or a computer), or using them as collecting devices (e.g. collecting pictures or video).

2.5.1 Porting “old” content to the new, mobile platform

In recent years, with the outbreak of mobile technologies, work quickly started on porting information traditionally available on desktop computers such as web pages and other digital documents to the new mobile platform. Automatic layout, recognition, translation and other morphing algorithms have been, and continue to be, developed to facilitate access of “desktop” information on smaller, portable devices. Early on in this research, guidelines for making web sites easier to use on small devices were stated to be to provide direct access via structured information and search, and also to reduce scrolling [162]. The *Power Browser* project at Stanford came out of the desire to support a digital library on handheld devices [67]. They pursued adaptive content on a PDA [184], accordion summarization for end-game browsing on PDAs and cellular phones [66], as well as efficient web browsing on handheld devices using page and form summarization [68].

Others have also pursued automatic summarization by directly manipulating the text [190], using hierarchical tables of contents for single [203] and multiple documents [75], generating and reorganizing indexes [80], fractal summarization of web pages [298], summary thumbnails which provide readable overviews of web pages [176]. Others still have used semantic bookmarks which use a combination of machine-learning and web-page segmentation to retrieve bookmarked content from web pages that share a previously described content domain [200]. This is similar to a server-side approach where an http proxy server dynamically re-authors web pages “using a heuristic planning algorithm and a set of structural page transformations to achieve the best looking document for a given display size” [53].

Research on portable books has continued to champion automatically changing the look to fit the smaller form factor [66-68], but has also begun to recognize the advantages of mobile devices. Mobile book readers leverage their mobility by echoing the centuries-old, portable book while adding some of the benefits of being digital; namely that the books are: replicable, more compact, searchable, etc. Despite recognizing some of the digital and mobile advantages, book reading devices have been almost exclusively developed to facilitate consumption. Although recognizing some of the benefits of mobile devices, the focus of porting information from an old platform to a new one has greatly touted mobility as a feature and has overlooked integrating mobility into its purpose. There are striking exceptions to this “feature” perspective on mobility, such as digital cameras where information is captured and collected. This integrates mobility into the purpose of the device because the picture can *only* be taken at the spot where it is created. Although

this integrates mobility into the purpose, taking a picture by itself is generally an individual (i.e. not collaborative) process and is limited to using the mobile device only for collecting, not really authoring or creating a personal representation.

2.5.2 Controlling the old with the new

Because of the mobility of mobile devices, many have suggested their use as control devices – a truly universal remote with an adaptable user interface depending on the device it is controlling [201, 202, 238, 244, 274]. Many multimodal systems have proposed the use of mobile devices [202, 210, 218, 246]. In [244], a platform enabling control of a TV with a PDA was described. Rajicon [274] is a system allowing remote access to a desktop computer's GUI operating system using a cell phone. The PEBBLES project at CMU focuses on adaptable user interfaces to control many different devices using a PDA [202]. The project has been a strong proponent of mobile devices as controlling devices and has researched this topic considerably in the last decade [201, 202]. Although the possibilities of using a mobile device as a universal controller is appealing and may be appreciated by young children, the focus in this research is to enable collaborative authoring in mobile settings to facilitate learning experiences.

2.5.3 Using the new as collection devices

Another purpose for which mobile devices have been put to use is collecting information. Movies have been designed and recorded using cell phones [18, 173]. Capturing video with cell phones has been recently brought to the forefront with cell phone video capturing activities in the war in Iraq which have later been posted on

the internet and in the news [73, 74]. Indeed, cell phone video capture has started to transform TV news [39]. A nonprofit organization, *WITNESS* (www.witness.org), is promoting the use of picture and video capture on cell phones and employing them in social activism [25]. Children also use the technology and have engaged in several collecting activities sometimes capturing individuals in compromising situations including teacher baiting where students taunt a teacher and video tape their reaction [256].

Specific systems have been designed to enable capture and creation of artifacts for young children. KidStory enabled children to collect parts of a story using PDAs and then the parts would be pieced together on a large screen [85, 270]. The *SENSE* project, designed for and used by children ages 10-14, enabled collecting of coordinated data for future collaborative [271]. The literacy field trip used a ubiquitous computing environment to encourage capture of a historical context [137]. The children, in Year 5 (between 9-10 years old), would then take their captured text and audio notes, as well as pictures back to the classroom and created individual narratives. This differs from the developed system, Mobile Stories, which enables collaborative authoring while in context. *Sketchy* [19], enables authoring on the go via allowing children to draw frame-by-frame an animation. Pages could be shared using a point-to-point transfer. Although this enables creation and collaboration, the creation is restricted to drawing and flip-style animations, and the collaboration is very limited. Sketchy does not specifically state age appropriateness however the company says it develops educational software for kids K-12.

2.5.4 Mobile devices for children

In recent years, researchers have been exploring the use of mobile devices for educational applications. From data collection by children for field research or inspiration [137, 231, 243, 245, 267], to participatory physical simulations [31, 46, 47, 86, 87, 99, 188], to use as mobile guides [27, 144], mobile devices have been supporting everything from science to social studies education. The majority of the devices used were PDAs of differing types. It is only recently that mobile phones have had features that rival those of PDAs such as large, clear screens, increased memory, advanced processing power and other functionality such as the ability to take text and audio notes as well as pictures.

With the rise in mobile devices and the reality that children are mobile beings, it is no surprise that mobile devices are increasingly being developed and marketed for children. There are numerous products available for kids that tout mobility as a feature. Many of the marketed devices are consumption based – allowing children to listen to music, watch videos or play games. Toys are integral in society, but there is not much longitudinal research performed on technological educational toys [48]. Beyond the “toy” mobile devices there are several other projects emerging striving to make mobile computers, laptops, specifically designed for kids. Some of the projects are the *One Laptop per Child* (OLPC), Intel’s *Classmate PC*, and *Mobilis* [290]. For mobile device educational toys and laptops, mobility is regarded as a feature not part of the integral purpose or activity. Although these entertaining devices can have some educational benefits depending on the content, one of the major differentiations of the approach suggested herein is activities performed on the mobile device can

range from entertaining to creative. There is a real need to enable and promote creative activities in a mobile environment.

Some have questioned the merit of children's use of technology and mobile devices. There has been an ongoing debate about role technology can and should play in the education of young children [90, 139, 158, 167, 180, 191]. Specifically in the domain of mobile phones, there are advocacy groups lobbying for investigations into the marketing of mobile phones raising concerns that the technologies could compromise young people's safety, privacy, education and health [253] and there are several studies questioning their safety [1, 121, 228]. Mobile phones for children have appeal to some parents as many phones marketed to children allow location tracking of their child as well as other calling limits as to who, how long and when calls can be made [226].

Despite the opposition, mobile devices afford many advantages besides widespread availability. The most straightforward advantage is that these devices are mobile and can be used independent of location. This coincides well with children – as they are mobile. Physical movement and play involve mobility and are inherent characteristics important for the social and cognitive development of young children [146, 161, 181, 199, 220, 221]. Not only are kids inherently mobile, but by allowing them the freedom to author content may help them better describe and relate to the world around them [72]. With mobile devices, children can access, create and share information with a friend, a class, or an online community anytime they wish. Also, by integrating mobility into the *purpose* for using the device (not merely a *feature* of the device), children user's ambulatory activities would increase countering one

complaint of technologies for young children – that technology encourages a sedentary lifestyle [38, 90]. Purposefully integrating mobility and education into playful fun may not only may help combat the growing problem of obesity [38, 90, 119, 157], but may also inspire the younger generation to be more creative in their problem solving which is essential for success in the future [26].

Wireless technologies such as telephony, *IrDA*, *802.11*, and others often appear in conjunction with mobile devices. The collaborative connection available via wireless communication is powerful, yet physical connections are more readily understood by children. Because of the inherent lack of physicality, wireless technologies are not simple concepts to grasp [46, 220, 221]. As such, an important aspect of this research is to emphasize the importance of collocated collaboration by “connecting” or linking multiple devices together. Physical connections are visible and tangible which enable young children to better understand the collaborative connections. While not directly addressed in the latest implementation of Mobile Stories, proximity or even a physical connection component could be added to the design of the phones. Once the cognitive bridge of how connections work is crossed via physical means, understanding wireless communication is facilitated.

The limitations of mobile devices go beyond understanding wireless technology and beyond the limited screen size and include the limited available interactions [163, 260]. Text entry is notoriously problematic on mobile devices [156, 261, 294]. Children are willing to be persistent as long as the interface is simple [205], and are willing to sacrifice some of the preciseness of adult interfaces

as long as interactivity is still possible [10]. The goal then is to have an interface simple and interactive enough to enable children to create content.

Besides categorizing mobile device research and development by porting old to new, controlling and collecting, many systems can also be delineated by those that are to be consumed, and those that promote constructive, creative processes. As previously discussed the learning theory of constructionism enables children to learn as they build a public artifact, this can be a collaborative process. Many consumption-based devices including those for video, music, gaming and multimedia alerts have been already mentioned. Some examples are handheld gaming systems, MP3 players, etc. Since many have already been discussed and since the focus of the proposed research is on devices that promote constructionism, the following subsection discusses these devices.

2.5.4.1 Consumption vs. Construction

A large majority of devices targeted for children that claim mobility as a feature are geared towards consumption; however, there are a few with creative characteristics. The simplest of devices are text chat devices and digital drawing tablets. There are several devices that allow children to chat with someone (who has an identical device). Such devices could support creative writing. The *Disney Classic Dream Sketcher* (www.amazon.com/Disney-Classic-Dream-Sketcher/dp/B0007YDBBY) and the *Fisher-Price Pixter* (www.fisher-price.com/fp.aspx?st=2280&e=hasflash) are representative of devices that allow simple creative drawing. This allows children to create their own representations; however, it only supports this simple interaction. *MIUCHIZ*TM (www.miuchiz.com)

is a device that lets a child wander a virtual neighborhood, encounter fun adventures, plug it into computer to enter an online community. The device features a color screen, touch screen, motion sensor, and an IR sensor for two player mode. The *Radica Digi-Makeover* (www.radicagames.com/digi-makeover.php) is designed for young girls. Users can take their own picture (or that of someone else) and drag different hair styles, and colors to give themselves a makeover. This is very similar to the digital drawing pads discussed earlier except the ability to personalize and capture any desired image affords many new possibilities.

In research there are many systems that have been developed with constructionism as a central tenet. *Syllable* [302] is a word building game for young children ages 6-7 years old. Children each have a PDA and they collaboratively construct syllable sequences to create a word, they must all agree it is a word before “submitting” it for approval. The system was shown to positively impact the children’s learning. Another system for children ages 9 to 11 promotes “life-long” learning by enabling them to capture images, notes, and sounds, to relate them to web-based learning resources, to organize them into a visual knowledge map, and to share them with other learners and teachers [257]. Although the capture capabilities are similar to that proposed in *Mobile Stories*, *Mobile Stories* enables collaborative narrative construction thus facilitating concept mapping in a less direct manner and accommodating younger children to cover the range of ages 6 to 10.

2.5.5 Mobile learning

The work proposed relates to an emerging field called *Mobile Learning* [283]. Many of the aforementioned mobile systems for children fall within the umbrella of

this new research area as they strive to enhance learning in mobile settings. Of mobile learning it has been said: “As wine fans claim ‘we cannot pour fresh wine in old bottles’, likewise, mobile learning too requires a new philosophical framework and new educational paradigms if it is to flourish” [177]. This echoes what has been described herein, that mobile devices cannot just be miniature desktops nor can they just be devices used for consumption or collection, but must be collaboratively used to construct and author representations thereby enabling learning experiences.

Mobile learning has also widely been investigated for college-age students. The ability to create personal narratives byway of journal keeping and creative diaries has been experimented with before with older users (second year college students) on tablet computers [51]. Such journaling is suggested to have many benefits including the ability to critically reflect on ones actions and work [122]. Journaling is similar to creating personal narratives and therefore relates to the context used in this research. Enabling collaboration facilitates understanding universal and other individual’s perspectives. Research with Japanese university students has shown mobile devices to be an effective educational medium [281]. Another study looked at using PDAs as a collaborative note taking tool, however users did not continue usage because the PowerPoint presentation slides used in classes were unreadable on the smaller devices [262].

2.6 Mobile Collaboration

Collaborating in mobile environments has been explored by many. As such there have been many different perspectives including those who have focused on social collaborative proximity, as well as more technical aspects including underlying

architectures, interactions, and systems that have been developed to support mobile collaboration. Collocated mobile collaboration and the ability to switch between collaborative modes in mobile situations have not previously been thoroughly addressed.

2.6.1 Proxemics

Proxemics is a term used to describe measurable distances between people as they interact [136]. There are different stages of proxemics, all of which have close and far delineations called phases (see Table 2.1). One of the major focuses of this work is on collocation, but collocation could mean several things depending on the granularity of its measurement or distinction. The collocated collaborative modes defined in Section 3.1 and addressed throughout this research were designed primarily for close interaction. To be more specific the personal if not intimate proxemic categories. This was targeted for several reasons. Foremost is that face-to-face collaboration has been identified in the literature as being particularly important to support and encourage for young children within the context of achieving collaborative learning [100, 160, 254]. Another reason is that it was noted to be insufficiently supported in the early prototype system, Mobile Stories 1.0, in some of the design sessions including the experience at Fort McHenry (see Section 3.4.1.2).

Table 2.1 – Proxemic categories and distances [136].

Proxemic category	Distance				
	Overall	Close Phase / Label		Far Phase / Label	
Intimate distance	0 – 18 inches	0 – 6 inches	1	6 – 18 inches	2
Personal distance	1.5 – 4 feet	1.5 – 2.5 feet	3	2.5 – 4 feet	4
Social distance	4 – 12 feet	4 – 7 feet	5	7 – 12 feet	6
Public distance	≥ 12 feet	12 – 25 feet	7	≥ 25 feet	8

2.6.2 Architectures

Many collaborative architectures have been designed as middle-ware; some mediating ad hoc networks while others include support for context-aware environments. Ad hoc collaboration in various settings is not a new idea, many scenarios have been proposed from groups attending a conference, to rescue teams, to military intelligence strike teams, security event staff, to a family visiting a national park [65]. Network architectures support services such as network configuration (e.g. devices being added and leaving the network), message delivery, publish/subscribe notifications, privacy, and security. Context-aware architectures support location tracking of the devices using various tracking means (e.g. global positioning system [GPS], 802.11 access point triangulation, etc.).

Network architectures support network configurations, message delivery and data synchronization. MoGrid is an example of a decentralized, ad hoc mobile network that enables novel grid applications in what they call mobile collaboration [182]. It adheres to a service-oriented grid approach similar to the Globus Toolkit [120]. YCab [65] supports asynchronous and multicast 802.11 communication and includes modules for message routing and managing communication, as well as client

programs and their state. YCab was used to implement several collaborative applications including a chat application, a shared whiteboard, image sharing (video conferencing) and file sharing. Message delivery is an important aspect of data synchronization. For data delivery many use a publish/subscribe mechanism where interested parties subscribe to receive updates and changes are made via publishing which notifies all subscribers. As race conditions and conflicts can still arise, many concurrency techniques have been proposed and implemented to help ensure data integrity [111, 130]. Because of the intricacies of concurrency control, it is suggested that user interface design takes into account awareness and varying levels of data granularity [130]. YACO (*Yet Another framework for Collaborative Work*) [70] uses a publish/subscribe mechanism for messaging and peer-to-peer artifact sharing and is based on SIENA [71] a distributed, content-based publish/subscribe communication infrastructure and on MobiKit [69] a mobility service toolkit based on proxies. MOTION (*MOBILE Teamwork Infrastructure for Organization Networking*) [168] uses PeerWare [94, 95] for messaging and artifact sharing, PeerWare uses publish/subscribe architecture for messaging and a P2P share for artifacts, MOTION also integrates DUMAS [115] an access control component to manage resource access rights. Other systems have included services for security [246] and sharing interactions [88]. Interactions will be looked at closer in the next section.

The *Situated Computing Framework* (SCF) [218] developed at Siemens incorporated two similar elements to those proposed in Mobile Stories – namely, media adaptation and collaborative support. The framework “facilitates nomadic users to access rich multimedia contents using small screen devices” [218]. Media

adaptation is similar to the approach proposed where different information can be displayed on various devices. Media adaptation depended on the available output devices and could be done via splitting (e.g. video split on a computer and sound on a telephone), conversion (e.g. text to speech), or filtering (e.g. only the audio of a video on a telephone). The infrastructure also defined interactive settings for abdlicative, cooperative and exclusive modes. In abdlicative mode the PDA would yield control to the output device; in cooperative mode both devices could be used; and in exclusive mode only the input device could be used. The prototype system they developed required only a web browser and used IR for short range detection and desktop computers for the various potential output devices [219]. In the multi-modal architecture presented in [246], a secure proxy architecture to enable filtering for security and privacy reasons. While the SCF work is instructive and similar to the proposed work, the proposed work builds upon it by building a working implementation on PDAs and developing collaborative interfaces that are appropriate for young children.

The integration of context-awareness, mobility, and grid computing has been proposed by the ISAM Project [297]. Some systems use a simple alert notification mechanism where multimedia alerts are received depending on location [34, 101, 245]. Many recent middleware architectures have added location awareness as a central focus to their architectures. *MoCA* [249] is a middleware architecture that supports the development of context-sensitive applications for mobile collaboration. They used their architecture to develop *NITA* (Notes in the Air) a context-aware chat program that would allow people to leave notes linked to a geographic location.

MoCA uses a similar decentralized architecture to *MoGrid* [182, 249]. ActiveCampus [131] has a similar architecture to MoCA, but is more centralized. *STEAM* [194] is an event-based middleware for collaborative applications where location plays a central role. The system is specially designed for ad hoc mobile networks and supports filtering of event notifications on the basis of both subject and proximity. Although context plays an important role for *in situ* learning, Mobile Stories focuses on the constructive aspect of collaborating in context. Context information could be automatically linked to the child-generated representations or narratives; however, pushing content to the users is not the approach taken herein.

2.6.3 Collaborative interaction styles

Collaboration has many interactive implications. This subsection discusses these different implications starting with various interaction styles that can be used for initial handshaking (i.e. agreeing to collaborate) or transfer of information, followed by discussions about sharing screen space and synchronized browsing and user interactions.

Research has illustrated how physical properties and affordances can be leveraged in the digital world such as bumping [140, 141], tossing [300], tilting [216], shaking [217], pointing [276, 301]. Others interactions include proximal interactions using radio frequency identification (RFID) [211, 237], synchronized tapping of buttons on devices [236], dragging an icon from one screen to another using a stylus [143, 170, 234], even synchronized tilting could be used [235]. These interactions have been proposed for use in transferring data or information from one device to another as well as authentication mechanisms. Although these interaction styles have

been proposed, many have not been used except, the frequently used, RFID proximal interaction.

Once devices are authenticated or connected, there are able to continue collaboration which can be done in many different ways. Opportunistic annexing [222], builds on join and capture [211], and describes opportunistic assemblies allowing devices to annex and therefore access the same personal information space. In [222], the authors discuss the question of how multiple displays should be treated – whether or not the spaces should be treated as single or separate spaces. They site examples where each approach has been employed and how a definitive answer is not clear. In Geney [99], the authors discuss how originally they were going to share screen space, however, in their design sessions it became apparent that they should not follow that approach, but instead used teams with leaders and individual interfaces. For reasons discussed in Chapter 1, and illustrated in Figure 1.1, a hybrid approach of using joined screens to display different information or parts of the interface is what is proposed in Mobile Stories.

With devices linked there is a need to share not only data, but also user interactions. This has also been recognized in the literature with various mechanisms to allow this sharing [78, 88, 145, 246]. Many multi-modal systems do not address this, as their approaches consider synchronized data to be sufficient [210]. In [88], uses a novel HTTP proxy with enhancements to XForms and XML Events to enable coordination of user interactions across client applications. Collaborative browsing has also been implemented which allows devices to work in tandem to view different parts of a document. For example a hierarchically summarized document using

multi-subject splitting [78] could appear on one device and selecting an item in the hierarchy could show the detail on the other device. Collaborative browsing techniques are incorporated into Mobile Stories as it is anticipated that users will likely want to keep synchronized as they navigate when jointly collaborating. Part of the research is to design and evaluate an interface for enabling users to control when they would or would not be collaboratively browsing. This directly relates to the second research question: what are the appropriate interfaces for collocated mobile collaboration with children.

In [142], a dual screen tablet computer called Codex is presented. The system allows the screens to be adjusted in different relative positions as well as detached from the dual screen encasing. It purports several single user and collaborative configurations which are mapped into a taxonomy where both devices are used in landscape or portrait layout and different configurations are touted for different proxemic distance of the users (e.g. intimate/private, personal, social). While this research correlates to the collocated collaborative configurations explored, their reported usability study was with four individuals and four pairs and only reports preferences after seeing a demo with some limited interaction. The collaborative story study reported in Chapters 5, is with twenty-six children (thirteen pairs), and looks at different use cases such as reading, creating, and sharing. Proxemic distances were noted in the coding of the data.

2.6.4 Systems

Mobile collaboration has been implemented in some systems. One system used technology to support collaborative learning in museums via a scavenger hunt

activity where kids answered questions and used walkie-talkies for communication [299]. *Syllable* [302] enables young children to collaboratively piece together words from syllables. Several simulation games such as *Savannah* [47], *Cooties* [4], and *Geney* [99] have been developed that exploit mobile collaboration. In these games, players act out different activities to reach a desired goal.

One project highlighting various aspects of mobile collaboration is the *eBag* system [60]. This system allows users to share captured materials across devices using a shared folder. Most authoring is done on a server (a desktop computer), but mobile devices are used as a collection tool. The tool supports various different platforms “to allow pupils to access their resources from anywhere” [60]. This system allows capture of material in a collaborative manner and also supports the use of mobile devices as capture devices. Mobile Stories extends beyond what eBag provides by enabling mobile authoring in context via mobile collaboration.

2.6.5 Interface design principles

The user interface design impacts the utility of the application, founding one basis for human-computer interaction (HCI). Beyond Jakob Nielsen’s guidelines and heuristics [206, 207], several research projects aid in the forming of the user interface experience for Mobile Stories. Some have suggested guidelines for developing on small devices. Early in mobile device research guidelines for making web sites easier to use on small devices were stated to be to provide direct access via structured information and search, and also to reduce scrolling [162]. Another study examining three different mobile systems made three suggestions: do not push too much information to the user, allow sharing of content, and provide awareness of the

actions of collaborators [85]. Other researchers have shown specific interface aspects to be important, such as using transparency especially for small devices [163], the importance of physical connections especially for young children [83, 113], as well as the trend for shorter content which caters well to younger children [41]. These aspects and others were considered in the development of Mobile Stories.

2.7 Summary

In this chapter a case was made for the power of narrative based upon principles of collaboration and constructionism. These principles have favorable developmental and learning implications. Several computational approaches were discussed and mobile technologies were presented as not only fitting within the parameters of the current societal usage of these devices, but also having benefits for young children – providing a tool for them while they are in various contexts. The combination of mobile technologies and collaboration were discussed as well as research that shaped the design and evaluation of Mobile Stories.

Chapter 3: System Design, Development and Initial Findings

This chapter addresses the key concepts, the methods used, some of the preliminary explorations, the design and development of the prototypes, as well as observations made during each prototypes usage. This chapter presents the key collocated collaboration concepts in Section 3.1. Section 3.2 discusses the design methods used to arrive at those concepts, as well as those used in sections 3.3, 3.4 in the preliminary explorations and design of the prototypes. Section 3.4 presents various versions of the prototypes and observations or lessons learned from each.

3.1 Collocated Collaboration Concepts

Discovering an appropriate interface for collocated mobile collaboration for children could dramatically foster physical activity for young children and also have an impact on educational and social development for young children. It is anticipated that lessons learned in the development of interfaces for young children will also inspire improvements that for adult interfaces.

Several factors influence collocated collaboration including: angle, size, and number of devices, user arrangement, privacy of information, and the mapping of display space to input space [151, 189, 273]. Collaborative spaces generally have private and public spaces – spaces where individuals can work alone (and others cannot see), and open spaces, where all is shared [189]. On mobile devices the screens are so small that the only distinction we make is connected or not connected. When devices are connected all is shared; when disconnected, each has their own

view. During design sessions with adult and children design partners using Cooperative Inquiry methods [106] (see Section 3.2.1 for more details), designers were informed of these considerations suggested by the literature. From the design sessions, three collaborative configurations were suggested that support collaboration when in a special collaborative mode, termed “connected”. The three collocated collaborative modes that emerged from these design experiences were: content splitting, space sharing and automatic mode switching (AutoSwitch) (see Figure 3.1 and Figure 3.2). The underlying data is synchronized for each of these configurations.

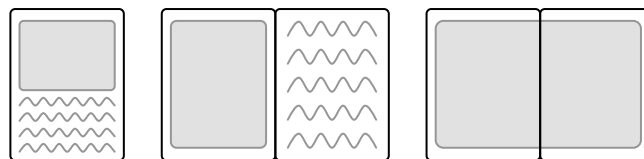


Figure 3.1 – Collaborative configurations; *left*, a single page from a book with a picture and words on one device; *middle*: content splitting, two devices showing the same page (one device shows the picture, the other, the words); *right*: space sharing, two devices showing the same picture on a page (picture spread across both devices).

3.1.1 Content splitting

Content splitting is the notion of parsing out different content, such as words and text, to each device (see Figure 3.1, *middle*). While picture and words make for a simple delineation of content, we have noticed, especially through our co-design sessions, that the concept of role assignment is not only appropriate, but an integral part of the collaborative process. Parsing content can be synonymous with role assignment as each collaborator can take ownership and responsibility for her segment. This division of roles can also allow collaborators to continue to work together even when they are not collocated.

Researchers have parsed web pages and other documents to organize the data representation in efforts to better utilize the limited visual space on mobile devices [75, 78]. Others have expanded on this idea in coordinating overview and detail displays [142, 145], enabling a staged collaborative browsing interaction. This research, however, has not really been viewed as a multi-user collaborative technique nor viewed as an effective means of role assignment.

3.1.2 Space sharing

The notion of *space sharing* suggests combining the visual space of multiple devices (see Figure 3.1, *right*). Expanding an environment to multiple displays is an area of active research [54, 258, 279]. Other systems support opportunistic annexing [209, 222] where users can easily expand their interface to other devices. Dual display devices also could also support space-sharing as well as content splitting [77]. While this research is applicable, it has a fundamental difference in that these devices are directed primarily for a single user looking to expand their interactive space. The focus here is to allow multiple users to expand their interactive space together.

3.1.3 Automatic Mode Switching (AutoSwitch)

Automatic mode switching (AutoSwitch) presents different collaborative modes at different zoom levels. The reason for this approach is to allow a seamless (modeless) transition between content splitting and space sharing, since modes can be confusing [232]. Table 3.1 illustrates how AutoSwitch could work for different zoom levels of a book; Figure 3.2 shows an example. AutoSwitch enables seamless mode switching between the split content and share space configurations when zooming to

different levels. For example, when two phones were connected at the highest level zoom level, the pages of the book would be laid out across both of the phones – thus utilizing all of the space on both phones (the share space configuration). Users could then zoom in to a two-page spread, with one page on each phone by touching one of the pages (still the share space configuration). Zooming in further to a single page, the picture would appear on one phone and the words on the other (automatically changing to the split content configuration). Zooming in further, either the words or the picture would be spread across both devices (the share space configuration).

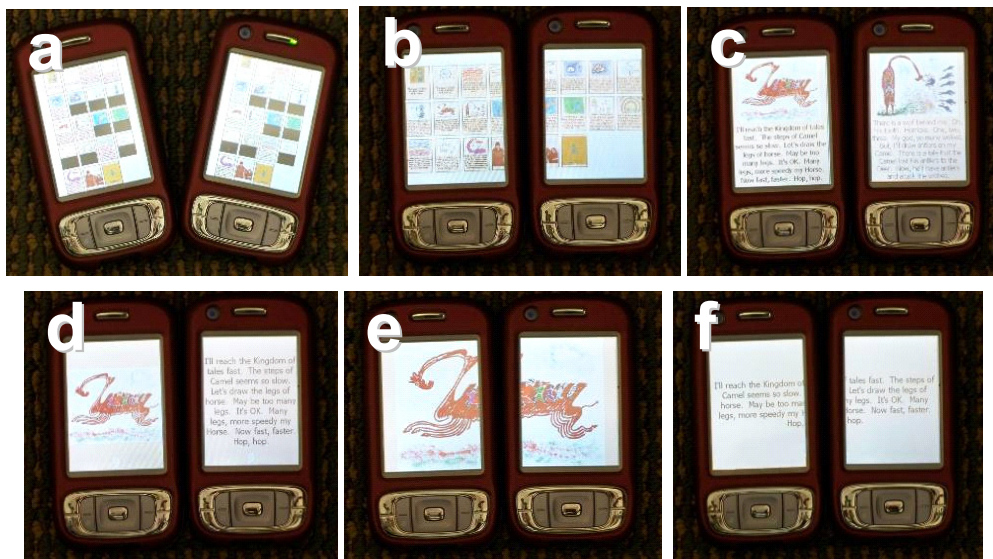

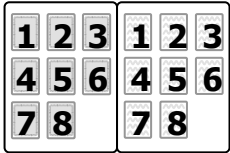
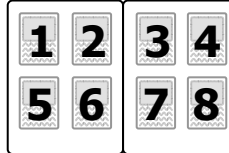
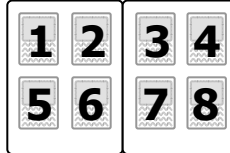
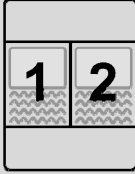

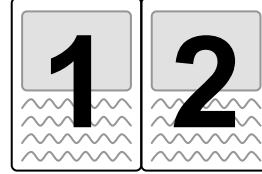
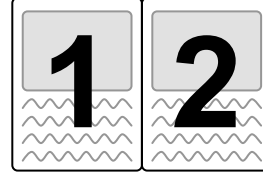

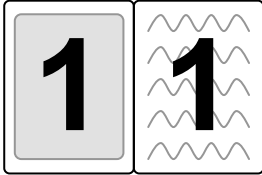
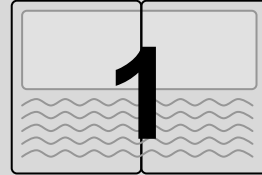
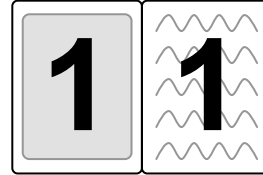


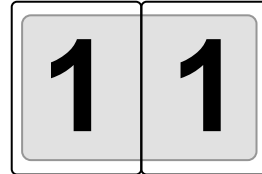
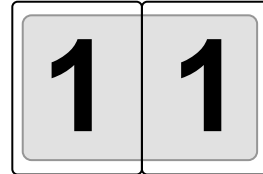
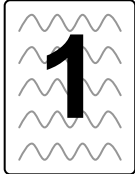
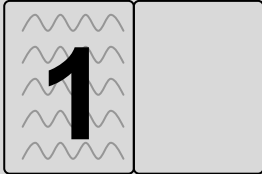
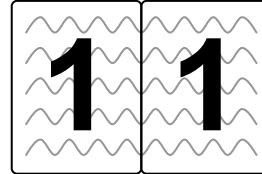
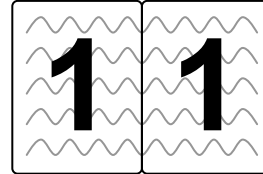
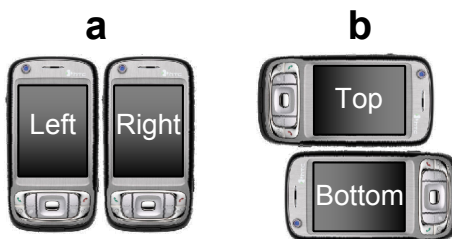


Figure 3.2 – Automatic Mode Switching (AutoSwitch) example using Mobile Stories 3.0 (discussed in Section 3.4.3) and pages from the book *The camel with seven humps* by Jambyn Dashdondog from www.childrenslibrary.org.
a, disconnected, each device displays the full story independently while data is synchronized;
b, connected, the pages of the story are distributed across both devices;
c, previous and next pages;
d, split content, one device shows picture, the other words of the same page;
e & f, share space, showing just the picture and words of a page, respectively.

**Table 3.1 – Zoom levels of a book for different collaborative configurations: synchronized data, content splitting, space sharing and AutoSwitch.
(Shaded cells were not implemented in Mobile Stories.)**

Zoom Levels	Disconnected	Connected (Two Devices)		
	Synchronized Data	Content Splitting	Space Sharing	AutoSwitch
Story				
Previous/Next				
Page				
Page Part				
				

It is important to note that Table 3.1 shows all of the devices as if they were held in a portrait aspect ratio position. It also shows images with aspect ratios that vary to fill the space – showing whatever would fit and look best. Aspect ratios of pictures will not always fit and fill the full amount of space as illustrated above. For the split content configuration this does not necessarily present a problem, as the image could automatically rotate to landscape if it would better show the picture (i.e. the picture would be larger). For the share space configuration, symmetrical relative positioning of the devices is necessary. However, as illustrated in Figure 3.3, net landscape and portrait aspect ratios can be accommodated.



**Figure 3.3 – Relative positioning of collaborating devices:
a, net landscape aspect ratio; b, net portrait landscape aspect ratio.**

3.2 *Methods*

In order to address the research questions (which can be reviewed in Table 3.2) I used various design and evaluation methods. The general methods that were used are discussed in this section. As the methods slightly vary for each of the stages of development and for the final collaborative story study (discussed in Chapters 4-6), more details on protocol, collected data, and data analysis are addressed within the context of each of those stages or studies. In general, Table 3.2 displays how each of the methods described below in Sections 3.2.1 and 3.2.2 are used to address the main research questions.

Table 3.2 – Research questions and the methods used to address each.

#	Research Question	Cooperative Inquiry	Formative Studies	Evaluation Methods
1	How does the collaborative mobile technology Mobile Stories affect children’s collaboration and mobility?		X	X
2	What are some of the appropriate interfaces for collocated mobile collaboration with children?	X	X	X
3	When are the developed interfaces preferred and why?			X

3.2.1 Design Methods – Cooperative Inquiry and Kidsteam

The design methodology that used to develop concepts and interfaces is *Cooperative Inquiry* which adapts ideas from contextual inquiry and cooperative or participatory design to form a methodology that effectively gives children a voice in the design process [106]. In Cooperative Inquiry, the brainstorming process involves sketching ideas to create low-tech prototypes using child-friendly art supplies. Child and adult team members also observe technology use and capture activity patterns, using sticky notes, drawing or writing in journals [106, 108]. Typically, methods which involve children in the design process primarily involve the target age children in consulting or participatory roles. Cooperative Inquiry goes beyond just getting children’s advice [242], and instead integrates children and adults into an unified design team – where each are design partners. Cooperative inquiry is a methodology that has been used and adapted in several projects [82, 113, 133, 197]. It specifically caters to designing for young children and broadens the scope of participatory design.

Here at the University of Maryland, an intergenerational design team has been directed by Associate Professor, Allison Druin for the last eleven years. *Kidsteam*, as the team is called, includes young children ages 6 to 11 years old and several adult

researchers who work with them. Each year, before the school year starts the team comes together every day for two weeks where the team builds unity as well as learns the various design methodologies. Since some children continue on from year to year, there is also a mentoring process that occurs between the more experienced and less experienced designers. During the school year, the team meets twice a week working on various projects ranging from initial design ideation, to prototype design, to new approaches for previously created prototypes, to incremental improvements. Many projects evolve from initial design to low- and medium-level prototypes. In this process both children and adults actively influence one another as they are co-designers. I have participated in Kidsteam for the last six years and taken on central roles in planning, executing and directing various aspects of the team. Having been involved in various research projects [82, 113] including many corporate partnerships (e.g. National Park Service, Microsoft, Discovery, etc.) and in design adaptations [133, 134], I am familiar with the methodologies as well as all members of the Kidsteam. Over the last several years I have worked with Kidsteam using *Cooperative Inquiry* to design, and iteratively improve the concepts and prototypes employed by Mobile Stories. While not directly part of Cooperative Inquiry, at different stages of the development, formative studies were performed to provide direction for the design and development as well as to get data points with respect to the research questions.

3.2.2 Evaluation Methods

The research shows there are many different ways to evaluate collaborative technologies. Preece suggests five different approaches: reviews, surveys,

observation, controlled experiments and data logging [229]. Reviews involve one or more reviewers who comment on the software and collaborative merits. Reviewers can be experts or members of the user community. Oftentimes heuristics are used to guide reviews. Specific heuristics and guidelines have been suggested for collaborative or groupware systems [33, 135, 223, 229]. Surveys can be administered via questionnaires or interviews and can be guided by heuristic criteria. Observation consists of watching and monitoring users while they use the system. Controlled experiments follow scientific procedures where hypotheses are tested under controlled conditions. Controlled experiments for collaborative technologies have been proposed [89]. Many systems are often designed to log data and other metrics for later analysis. Collected information can be used for quantitative, statistical analysis or can be analyzed qualitatively [229]. It has been suggested to use physiological measures to “determine” emotion and therefore capture usability and playability metrics relevant to the experience [186, 187]; however these can be intrusive, especially for young children in mobile situations. While each of the suggested five approaches has value, it has been said that “evaluations of collaborative technology are done best through field studies because they can, among other things, be used to assess social psychological and anthropological effects of the technology” [132]. There are also shortcomings of field studies, in that they require a fairly robust system, an appropriately equipped environment, and the time required for observation and analysis [98].

The various heuristic methods include collaborative frameworks for evaluation. In [135], the authors argue that usability problems are not necessarily

ted to the social context, but are the result of poor support for basic collaborative activities including: communication, coordination, planning, monitoring, assistance and protection. It is suggested that each of these tasks be analyzed according to their effectiveness, efficiency and satisfaction. Others have proposed task analysis techniques for studying teamwork such as in Collaboration Usability Analysis (CUA) [223]. CUA consolidates the important activities to just communication and coordination while detailing the important aspects of each. According to CUA, one must look at the explicit communication and information gathering to evaluate communication and shared access and transferring of materials for coordination [223]. Another controlled laboratory experiment for collaborative systems focused on activity awareness [89]. Because of the importance of user awareness in collaborative systems [54, 89], this important aspect was investigated in the collaborative story study (see Chapter 4).

In [110], a methodology for the evaluation of collaborative systems included a discussion of various metrics including countables (e.g. turns, moves, trials, ideas generated, responses, button presses), length of turn (e.g. length of utterances, messages or story), task completion, time (e.g. time alone, time collaborating, repair activities time), preparation cost, expert judgments (e.g. scalability, security, interoperability, communication, usability, product quality, etc.), user ratings, tool usage, turn overlap, repair activities, and conversational constructs. These metrics provide a rich resource for analysis and specific measures taken to incorporate these metrics into the analysis are discussed in section 4.3.2, Data Collection Methods. The evaluation methods used incorporate these metrics and follow the general outline for

qualitative research design proposed by Creswell [92], which details the common components of various traditional approaches to qualitative inquiry.

3.3 Preliminary Explorations

My dissertation focus came out of three years of initial investigations which included:

- A comparison between desktop and physical interactive environments [113] providing direction towards mobile computing environments that can bridge the virtual-physical gap,
- Collaboration with Tangible Flags [82] which emphasized the importance of collaborating in context, and
- And design sessions with young children in *Kidsteam* (discussed more in Section 3.2.1) focused on collections, guiding the direction of this research from explicit support for collections (collecting, organizing, sharing), to a narrative approach which implicitly supports these activities.

Specific preliminary explorations related to this work, are discussed in the following subsections. These are: a comparison of physical and desktop computing environments, initial investigations for a tool supporting collection management, and Tangible Flags.

3.3.1 Physical versus Desktop Comparison

In conjunction with The Children's Environmental Health Network (CEHN), which promotes health awareness for young children, the *Hazard Room Game* was developed at the University of Maryland. The Hazard Room Game uses stories as a

teaching mechanism in directed or pre-scripted manner, what are called *content-infused story games* [113]. The object of the game was to demonstrate understanding about what to do when confronted with various health hazards by finding and sequencing props to create a safe outcome. For example: “You get an apple / You wash the apple because the apple can have pesticides on it. Pesticides make you sick / You eat the apple”. In this story, the potential hazard is pesticides. Three props are used to help tell the story: an apple, a sink, and a mouth. Each prop corresponds to a sound segment as delineated by the ‘/’ above.

In an attempt to better understand the distinctions between physical and desktop computing environments, the Hazard Room Game was developed in both environments and a study was conducted to consider the merits of each environment for young children (4-6 years old), by comparing the same content-infused game in both contexts. Both quantitative and qualitative methods are used for data collection and analysis. Pictures of both environments can be seen in Figure 3.4. Figure 3.5 shows the apple story sequence partially completed. My contributions to this project included: taking an active role in all of the design sessions for this project, coordinating with the adults who implemented the physical game, developing the desktop user interface, and taking the primary role in creating the evaluation scheme and forms, and collecting, analyzing and reporting the results [113].

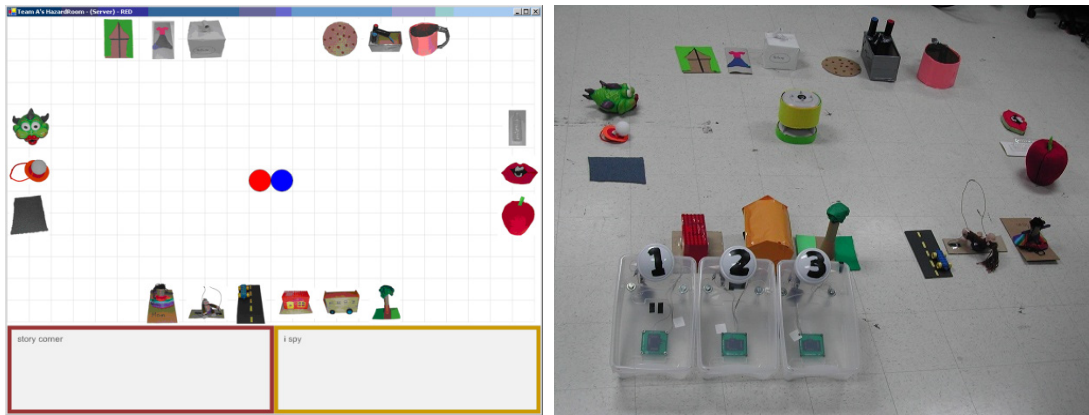


Figure 3.4 – The Hazard Room Game desktop (left) and physical (right) interactive computing environments.

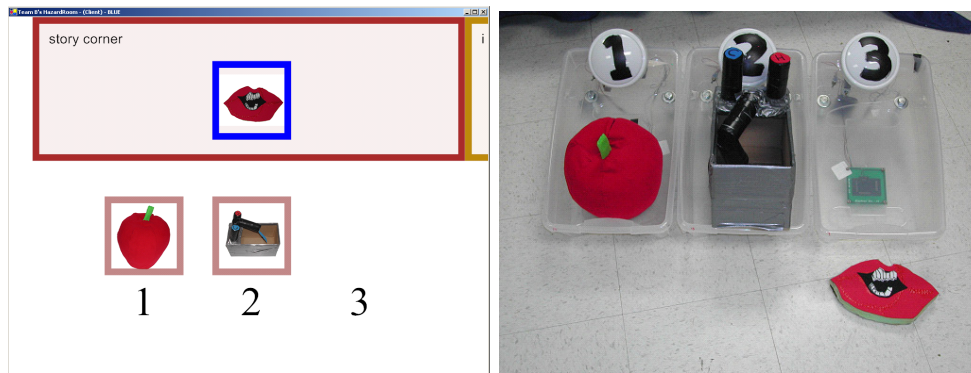


Figure 3.5 – Sequencing props in the Hazard Room Game – apple, sink, mouth.

The same props (or pictures of the same props), the same hazards, and the same stories are used in both desktop and physical implementations of the Hazard Room Game. In both implementations, the props were located in the same manner around the periphery of the space, real or virtual. The placement of the props was designed to encourage children to explore the whole area during each turn.

The study analysis included both qualitative and quantitative measures. The quantitative metrics were measured via identical pre and post tests administered before and after each session. The qualitative analysis is based on notes and video coding of questions asked by adult researchers after each, correct story sequencing. Adult researchers used two prompts to initiate discussion:

- “Tell me the story in your own words.”, and
- “What did the story teach you?”

After reviewing notes and video of these qualitative discussions, a coding scheme was developed. The coding scheme for each story included the number of times adults verbally prompted the children for a response for each of the above discussion prompts, as well as coding behaviors of each child throughout the discussion. A prompt consisted of an additional question or comment from an adult facilitator that had the intention of eliciting a response from a child participant. Each prompt was separated either by a response from the children or a pause of 5 or more seconds. For each child within a story, video evaluators made five observations:

- Whether or not the child gave a verbal response
- How many times the child communicated “I don’t know” either verbally or non-verbally (e.g. such as shrugging their shoulders)
- The depth of response as defined by:
 1. Incorrect or no response
 2. Rote or slightly reworded, or just identifying the sequence of props
 3. Processed or mostly reworded
 4. A processed response including the causal effect (e.g. “You should wash the apple before you eat it because it might have pesticide on, which could make you sick.)
- A frequency of the interaction types (pointing or touching of props) to identify which happened most frequently
- A subjective interest level for the child on a scale of one to five, where one is very disinterested, and five, very interested

Table 3.3 contains a summary of the video coding. For more details please see the results presented in [113]. The results of the coding yielded several advantages for the physical environments over the desktop environments. Specifically, there are four measures that indicate advantages for the physical environments (as can be seen in Table 3.3). First, the number of prompts necessitated by the facilitators was fewer in the physical environment. Second, the answer depth

increased in the physical. Third, the number of “I don’t know” responses was reduced. Fourth, the average subjective interest was higher in the physical than it was in the desktop case. These four measures collectively suggest that these children may have been more engaged and that they qualitatively learned more in the physical environment than in the desktop environment. Table 3.3, shows all of the results, the first three measurements (# prompts, # responded and # don’t know) seem to be correlated as do the last three (answer depth, interaction, and subjective interest). If there were no disparity between the desktop and physical environments, then the first three would be correlated with the last three, but instead they are negatively correlated, meaning that more prompts yielded more “I don’t know”s than good answers in the desktop environment. These qualitative results agree with the descriptive quantitative statistics where the mean score differential between pre and post tests was greater in the physical (3.63) than in the desktop application type (2.69).

Table 3.3 – Summary of the qualitative coding averages.

	Desktop	Physical	Winner
# Prompts	3.58	2.75	Physical
Story	1.96	1.67	
Learn	1.63	1.08	
# Responded	0.86	0.75	NA
# Don’t Know			Physical
By person	0.30	0.23	
Total	0.39	0.28	
Answer Depth	1.87	2.25	Physical
Interaction (# Point; # Touch)	8; 0	3; 11	NA
Subj. Interest	2.66	3.09	Physical

Some gender differences were apparent in our overall findings. The most marked gender distinction was manifest in the type of responses given by girls and

boys. Boys tended to respond with rote responses, mimicking the stories almost word for word, but leaving out the causal effects. This was witnessed in observing many segments where the boys simply stated the ordering, but the girls would reword the story when prompted to tell the story in their own words. The qualitative results dramatically illustrate this finding as the boys received rote depth ratings (code number two above) almost four times more than the girls did (15:4). Conversely, girls tended to respond with full causal depth (code number four above) twice as much as the boys did (15:8).

Gender differences were also evident when analyzing the data by environment. The girls verbalized more, as the boys pointed and touched the props considerably more both in the physical and desktop environments. The aggregate ratio of male to female point and touch interactions was 9:2. Not surprisingly touching the props occurred more in the physical environment, although some children did point at the computer screens as they explained the stories in the desktop environment. In the physical environment, the ratio of touching the props again favored the boys, echoing the overall ratio of 9:2.

The quantitative descriptive statistics also pointed to a gender difference, which was not distinguished in the qualitative analysis. Comparing the difference between pre and post tests, the girls performed better on the physical (4.63) than on the desktop (2.19), whereas the boys were about the same on both physical (2.63) and desktop environments (3.19). This difference was not observed as strikingly in the qualitative results. Only minimal benefits (less than 10% improvement) were

observed in average depth and average engagement (using average interaction and subjective interest).

This research experience, strongly suggested to me that mobile devices can provide many of the advantages of computers in physical, real-world scenarios. In Mobile Stories, mobile devices are used to bridge the gap between physical and virtual environments and enable artifact creation, modification and collaboration *in situ*, or rather in the original context of the artifact being represented.

3.3.2 Tangible Flags

The research of *Tangible Flags* also influenced this research direction. It is the doctoral research of Gene Chipman at the University of Maryland [82, 83]. It is cited here as a preliminary exploration because of my collaboration on this project. I was an active adult facilitator and participant in all of the preliminary design sessions, developed the initial user interface, and acted as a facilitator in most of the evaluation sessions. In Tangible Flags, children can create artifacts and link them to the physical world via flags. The flags are equipped with radio-frequency identification (RFID) cards, that when scanned bring up a shared drawing space where all who have a device can add annotations. The system creates a direct link between the physical and the virtual by way of the flags that are left in the environment identifying what has been represented or what inspired an annotation. The flag acts as a signal to other teams that there is an annotation they can look at and add to if they so desire. Figure 3.6 shows two children using Tangible Flags.



Figure 3.6 – Children using Tangible Flags, the bulls-eye is an RFID reader, the blue flag has an RFID card inside; the children are both adding annotations to the same flag.

In Tangible Flags, the focus is on relating artifacts to the real-world. While this relationship is also integral to the proposed work, Tangible Flags does not address several issues addressed herein. Tangible flags presented all flag information in a flat manner as all flags were visible in thumbnail form (see Figure 3.7). A flag became the focus when it was scanned or the thumbnail was selected. This flat representation did not address organization of collections of artifacts. The proposed work enables a level of organization by piecing words, pictures, and audio together in a narrative. Cognitively this could enable the “stepping back” essential to development and learning [28, 166]. To an extent Mobile Stories is an extension of Tangible Flags enabling organization of artifacts, there is also increased attention given to mobile collaboration for young children. Three promising areas of future research emerged from this work, more direct support for face-to-face, various modes of mobile collaboration and providing organizational support for collected artifacts. Tangible Flags also reinforced the decision to use mobile devices. The feedback from

the children in the studies suggested that a lighter, smaller device might be more appropriate for young children.

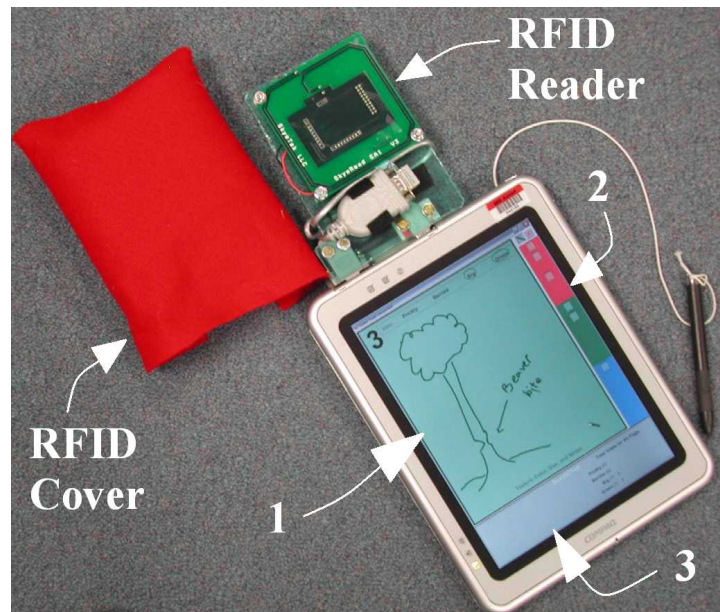


Figure 3.7 – Tablet PC with RFID reader and cover, showing the GUI interface; (1) active flag working area, (2) thumbnails for every scanned flag, (3) ScratChat area for communication.

3.3.3 Collections

Work with *Tangible Flags* and the *Hazard Room Game* led me to explore the notion of *collections*. Oftentimes collections are physical representations that trigger narratives. For example, if you ask a philatelist (a stamp collector) about a stamp in their collection it might trigger a narrative about the importance or history of the individual stamp, a commentary on the set, or even a narrative about how s/he started collecting. Collections are an important part of our lives and include sentimental memoirs, figurines, tools, relationships, friends, beliefs, opinions. At the abstract level, we are constantly collecting, organizing, sharing and utilizing information. Children especially enjoy building, sharing, and trading collections. Throughout my four years working with the Kidsteam children, collections in various forms have

been emerged and approached including collections of various representations created by the children. This research initially was focused on capitalizing on this culture of collecting, specifically on how to support collection building, organizing and sharing.

In April 2006, members of Kidsteam were invited to bring in a collection to share with the group (see Figure 3.8). Many brought in physical collections, a few supplied photographs of their collections. The collections included: shell and rock collections, animal glass figurines, baseball cards, books, rubber bracelets, and medieval armor and weapons. The object of this activity was not just to see the collections, but to use them as a bridge to discuss several questions. The questions and some of the answers follow:

- What makes a collection a collection? – have a hobby; have a lot of them; the collection has to be something you like – “it has to come to you”
- How do you trade/share items in your collection? – “just do”; “don’t trade because others don’t”
- How do you find things in your collection? – “keep in room on a shelf”
- How do you organize your collection? – don’t organize; baseball cards sort by teams and alphabetical order
- How would that change if you had hundreds or thousands of things in your collection? – nothing

These responses as well as other observations made throughout the session informed the research direction. There was a distinct sense of individual ownership (e.g. “don’t touch [my collection]”). There was also a sense of collaboration and social interaction (e.g. “What should I name this hippo?”). Also noted was that all of the girls carefully set out their collections for display. As the children explained their collections it was evident that there were narratives tied to them. One child explained “these sea shells are from ‘Poppy’s’ beach house, I started with 4 or 5 in a pale, but then it grew”. Another child explained: “I collect from lots of different places, but

most of my collection comes from Maine. We used to go every summer. Now we go in October on Columbus Day, some are from Grandma Wanda’s collection.” Another boy showed his collection of 403 cards showing his favorites and pointed out the empty spots were because he traded cards. Another girl mentioned she was not able to share and trade because no one else she knew had glass animals, but expressed that she would trade if she knew someone who had some. These examples emphasize the link between collections and stories as well as the importance for awareness of other’s collections, collaboration and personalization.



Figure 3.8 – Children’s collections: rocks, sea shells, figurines, baseball cards, weapons. Children shared their collections; they set them out for display, labeled them, talked about them.

In another session, the children and adults designed a collection tool to facilitate gathering, building, creating, organizing a collection as well as one that

supported searching and finding within the collection. The team used “bags of stuff”, a low-tech prototyping technique in *Cooperative Inquiry* where art supplies are used to build models of what could be created [106]. The “big ideas” from the design session included physical indicators of the size of the collection (e.g. tool grows as collection gets bigger like a bag gets bigger as you put more in it), capturing the collection (e.g. cameras, handheld pen scanner), a virtual-physical connection (e.g. once scanned, can display with a tactile hologram or atom duplicator). Enabling various forms of collecting therefore is important in the design of Mobile Stories.

The most salient outcome of this initial research was that according to the children organization should be automatic – the children should not have to do the organization. There are however many learning reasons to encourage “stepping back” and looking at and organizing the collection [28]. According to Kidsteam, kids do not want to directly organize the collected items as is supported in [257] which allows users to create concept maps of collected items. Incorporating artifacts into a narrative implicitly structures and organizes them by building relationships between narrative elements (e.g. the words on the page often relate to the picture on the same page). The use of narratives is also supported by the observation that collected items often triggered narratives. Children also expressed a desire to share, trade and asking other’s for their opinions (e.g. “What should I name this dolphin [figurine]?”). These suggested interactions imply that mobile collaboration should be supported.

This formative research led most directly to the context for exploration of mobile collaboration, namely narrative creation which enables implicit organization of collections. The approach Mobile Stories takes is to support organization of the

collection via inclusion of collected artifacts in a narrative. By using a narrative approach Mobile Stories seeks to implicitly integrate collection organization and therefore support the educational benefits touted in [257], while making the activity fun and natural. Children also have the opportunity to share these narratives with others.

3.4 Mobile Stories

Mobile Stories, explores mobile collaboration for children within the context of reading and creating stories. Mobile Stories has a flexible architecture that enables structured, to semi-structured, to unstructured activities. This ranges from rigorously structured activities as in many consumer products that have a consumption-based approach, to more constructive activities that enable the creation and sharing of personal or shared narratives. Children are able to add various multi-media segments such as pictures, words, and audio, to pages within a story or narrative.

The ability to distribute and share screen space, sharing individual contents such as the text of a book on one screen and the picture on the other has broad implications. Systems that support these configurations could help overcome many usability challenges faced by mobile devices – foremost being their small screen size. By bringing multiple mobile devices together many usability challenges can be mitigated and many new interactive opportunities can be made possible. Collaborative relationships such as the collocated situation previously described can be enhanced via supporting technology. There were several investigations that I undertook that enabled this level of interactivity to be possible. The following subsections present each of the versions of Mobile Stories, the findings at that stage

of its evolution, and what was investigated or evaluated to improve the next stage of development. Table 3.4 provides a summary of the different versions.

Table 3.4 – Mobile Stories version summary listing features and studies.

Versions	Supported Features	Studies	See
1.0	Collaborative story creation Client-server architecture	Kidsteam design sessions Fort McHenry experience	Section 3.4.1
2.0	Collaborative reading and sharing of stories Peer-to-peer architecture	Informal demonstration at Kids Mobile Workshop	Section 3.4.2
3.0	Collaborative story creation Collaborative reading and sharing of stories (automatic mode switching – AutoSwitch) See-through menus	Kidsteam comparison between paper and mobile devices	Section 3.4.3
3.1	Collaborative mode switching (synchronized data, split content, share space) Collaborative story creation Collaborative reading and sharing of stories	Collaborative story study <ul style="list-style-type: none"> • Reading • Creating • Sharing 	Section 3.4.4

3.4.1 Version 1.0

During the summer of 2006 a prototype system for collaborative constructing mobile narratives was implemented: Mobile Stories 1.0. Mobile Stories 1.0 supported the addition and editing of multimedia to scenes/pages in a narrative/story. The supported multimedia included sound, pictures, and words. The opening situation at the beginning of Chapter 1 is a description of some of the interactions observed. The design of the Mobile Stories 1.0 using Cooperative Inquiry, and the observations from this initial in-field experience have formed many of the core ideas of this work. The initial explorations, prototype, and observations are discussed in the following sections.

The system was developed in C# using Visual Studio .NET and the .NET compact framework for PocketPCs. The Piccolo Toolkit [16] was used to facilitate

zooming and animation. Architecturally the system uses a client-server model and leverages the *Observer* and *Command* software design patterns [37]. The *Observer* pattern is a publish/subscribe mechanism, in this architecture devices subscribe to data on the server. All client devices publish any changes made by the user to the server, which in turn notifies all subscribers (connected clients). For communication purposes, TCP/IP sockets are used over 802.11. Messages are commands as described by the *Command* design pattern. This pattern is a software code design pattern where modifications to data and view are defined by a command which has methods *execute* and *undo* and the information necessary to process these methods. It is generally used to implement undo functionality in programs, but also has other beneficial properties. In this architecture, it simplifies messaging because the commands can just be sent across the network. Commands also facilitate synchronization because each has the information to execute and undo if necessary which is helpful for conflict resolution. Originally data and commands were delivered using a multi-threaded approach similar to file transfer protocol (FTP); however, the numerous threads were not handled well on the small mobile devices, therefore the architecture was changed to use dedicated background thread for sending and receiving data and messages using queues.

The initial architecture enabled devices to log onto a server identifying itself as well as its capabilities. The server would receive all device connection requests and through the use of a role manager would assign each device a role. My goal was to allow the server to dictate the various roles a device could fill. Roles could include only showing the text, picture or audio. Roles could also define regions of the

interactive space that the device should display and control thus enabling expanding the interactive space across devices. Roles could also be different for content creation and content playback. Roles could also be used to construct different parts of stories from different perspectives (e.g. different characters). Role management was never fully implemented or tested, and in subsequent research will have to be redesigned to enable more user control and explored more fully. The architecture as described is displayed below in Figure 3.5.

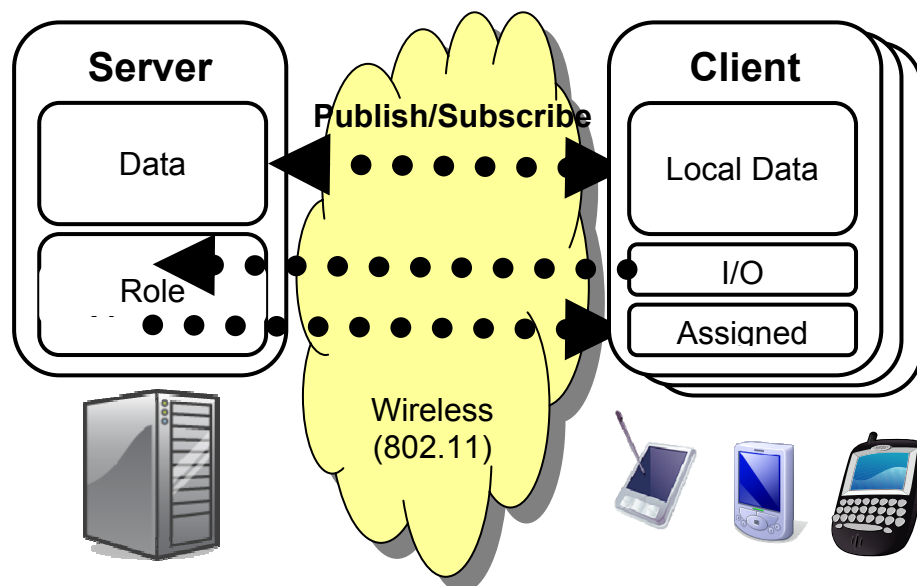


Figure 3.9 – Mobile Stories 1.0 architecture design.

Functionally, the system enabled users to create a story with various pages or scenes. Each scene could contain multiple sub-scenes which for Mobile Stories 1.0 were simple media elements: pictures, audio, and text. Users could add or modify these elements to each scene. Users could view the full story by zooming out and seeing all of the scenes (see Figure 3.6, left) or could zoom in to a particular page (Figure 3.6, right). Tapping on the media piece would enable editing. For example tapping on the text would open a textbox and the onscreen keyboard to enable text

editing. In Mobile Stories 1.0 users could only change pictures to those that were on the device, but it was hoped that for future implementations onboard cameras would enable capture of images in context. Mobile Stories 1.0 allowed creation of new audio. Another feature included in the prototype was the ability to “play” a story. This feature would zoom in to the first page and animate to each scene playing the audio clip associated with that scene. Durations for pausing on each scene was calculated by a PlayGenerator. This feature was well-liked by the children, however some modifications of the architecture and collaborative interactions will need to be adjusted. One possibility is to use the collaborative physical configuration to control story play.



Figure 3.10 – Mobile Stories 1.0 interface displaying the book Axle the Freeway Cat by Thacher Hurd; *left*, zoomed out to show the full story, *right*, zoomed in showing the title page.

I also developed a desktop client for testing purposes. In addition, I developed a desktop client that incorporated a slider which could be adjusted to

display the story at any given time during a collaborative session. Logged data from the interactive sessions enabled this history to be captured and displayed by the historical viewer which showed the evolution of the collaborative story.

3.4.1.1 Kidsteam Sessions with the Mobile Stories 1.0

Mobile Stories 1.0 was presented to Kidsteam and several sessions were devoted to playing with it, making suggestions for improvement, design ideas for the next iteration, and helping to focus the direction for research. The prototype systems had some stories from the ICDL preloaded onto them. Initially I introduced Mobile Stories 1.0 to the children by asking them to read as many books as they would like from the four that were preloaded onto the devices (from the server application). I also introduced the play feature. All of the initial books shown had pictures, text and audio (which was the narrated text). Figure 3.11 shows the various PDAs that were used in these design sessions. All devices were Pocket PCs supporting Pocket PC 2002 (the predecessor to Windows Mobile). They each had varying processing power (~200-400 MHz) and memory capabilities (~64-128MB). They all had QVGA (240x320) touchscreens, supported audio capture and playback, and had 802.11b (Wi-Fi) capability.



Figure 3.11 – Devices used for early prototype sessions.

While reading the books children mentioned changing some of the words to fit what they thought the words should be. This occurred while reading the book *An Apple Pie* (see www.childrenslibrary.org). One child expressed that “S Sang For It” (the *it* in the picture being a tasty looking pie), should be changed to “S Snatched It”. Another child thought it would be cool to be able to write their own story. This directly pointed to enabling children to edit stories as well as to create their own. Since the activity was reading, the children who felt less comfortable reading did not remain as engaged throughout this initial session. Some children started to read in unison. Other children also used the play function in synchronization so that two devices could be playing at the same time (see Figure 3.12). This suggested to me that bringing devices together should enable synchronous activities. At the end of this session the children gave suggestions for improvement which included changing the menus, focusing on just picture or text, adding an ending page to each book, adding fast-forward and stop to the play story, and having a page at the end of the book. Observed issues and many of the previously mentioned changes were quickly made for the session at Fort McHenry (discussed in the next section, Section 3.4).



Figure 3.12 – Synchronized playing of the story using Mobile Stories 1.0.

In another session, the children were given Mobile Stories 1.0 which had a story starter preloaded onto it. The story starter contained pictures of objects inside the building where Kidsteam was conducted. The children were asked to create stories using those pictures. They could add text, add audio, and reorder the pages. Most children added text or audio stating what the item was and/or describing its context – in other words it became more of a scavenger hunt. The children did not understand that they were working on the same story, so the collaborative interface needed revision to enhance awareness and understanding. Upon completing the activity children shared their thoughts of the Mobile Stories 1.0. Some liked entering words, others liked recording audio, but all liked the ability to add to the story. Interestingly, even though text entry is generally regarded as less effective on mobile devices [156, 260, 261], none of the children complained about this difficulty even though they did experience typing errors. Some children preferred to type, even though it took them a long time to do so. The only complaints were some bugs found in the prototype system. The children also stated that it would be better if each child had their own device (since some children were in pairs due to the number of devices available). An additional improvement that was mentioned would be to add the ability to take pictures (with an integrated camera) and to be able to draw pictures. This directly related to the preliminary investigations on collections which suggested

providing multiple mechanisms to capture or create representations. Finding the difficult objects on the scavenger hunt list and being able to move around with the technology were cited as the salient characteristics making the activity fun. The positive response to being mobile supports previous discussions and cited works (see Chapters 1 and 2).

The next Kidsteam design session was devoted to low-tech prototypes (“bags of stuff”) [106] a redesigned Mobile Stories prototype. The “big ideas” from this session focused on various forms of collaborating and sharing. The most frequently suggested idea was an explicit connection between devices (e.g. snapping them together, connecting with a rod or wire, drawing a line between them). Making sharing an obvious interaction via a specific button was noted by several children, but how sharing occurs sometimes did not have to be so explicit as kids thought it might be fun to “randomly” join stories and parts of stories. Although not in such technical jargon, the children in Kidsteam expressed different modes of collaboration: *giving* (simply transferring from one person to another), *combining* (joining stories), *sharing* (working on the same story). Other children had a democratic view that when devices were brought together, the most common story should become the story of focus for all parties. Another idea that emerged from our design session was that each device could represent different characters in the story and each device could be used to control that character. As screens were brought together more of the story could be revealed. This could be supported via the role mechanism previously described. All these suggestions have application to mobile collaboration and were used to redesign and improve Mobile Stories.

3.4.1.2 Fort McHenry Field Trip with Mobile Stories 1.0

August 10, 2006 the Kidsteam visited Fort McHenry (see Figure 3.13). After receiving a tour of the fort, the kids participated in two activities using Mobile Stories 1.0: the first, collaborating on a narrative describing their experience; the second, a scavenger hunt where children found answers to various questions (this was modeled after an activity used by the park for their Junior Ranger Program). For the second activity only two children participated and each had their own device. In the first activity six children were paired, so that there were two children to a device. Each group also had two adults one to take notes and another to videotape. For this activity the children were given a story starter which is displayed in Figure 3.14. The story at the end of the collaborative session is shown in Figure 3.15. An example of the evolution of a scene is shown in Figure 3.16. This example shows how changes were made over time by various collaborators. This section presents several observations I made regarding this session.



Figure 3.13 – Fort McHenry National Park, inspiration for the U.S. National Anthem and site of formative study experience using Mobile Stories 1.0.



Figure 3.14 – Story starter for collaborative narrative of Fort McHenry, the Anthem page had an orchestral arrangement of the national anthem.



Figure 3.15 – Collaborative narrative at the end of the session at Fort McHenry.

<p>What do you think?</p> 	<p>What do you think?</p>  <p>Fort mchenry is a park of history</p>	<p>What do you think?</p>  <p>Fort mchenry is a park of history</p>
<p>What do you think?</p>  <p>Fort mchenry is a park of history that survived war.</p>	<p>What do you think?</p>  <p>Fort mchenry is a park of history that survived war.</p>	<p>What do you think?</p>  <p>Fort mchenry is a park of history that survived war.</p>
<p>What do you think?</p>  <p>Fort mchenry is a park of history that survived war.</p>	<p>What do you think?</p>  <p>Fort mchenry is a park of history that survived war.</p>	<p>What do you think?</p>  <p>Fort mchenry is a park of history that survived war.</p>

Figure 3.16 – Evolution of a scene throughout a collaborative session (left-to-right and top-to-bottom), the scene started as an empty frame with “What do you think?” (see Figure 3.14).

While one primary reasons for mobile collaboration is to enhance creation, Mobile Stories should support a broad spectrum of interactions including consumption (reading, viewing, hearing), collection (adding words, pictures, sounds), and creation of a story or narrative *in situ* (while in the original context of the object which inspired the representation). An example of this is pictured in Figure 3.17 where children were next to the magazine and decided to capture the placard information by reading and recording it on the PDA. Although this example showed only collection of information, it illustrated how having a device and creating a narrative may trigger more in-depth exploration of a setting. From this work, I later considered whether or not the children would have stopped to read the placard if they

were not adding it to their personal narrative about the setting which in this case was Fort McHenry.

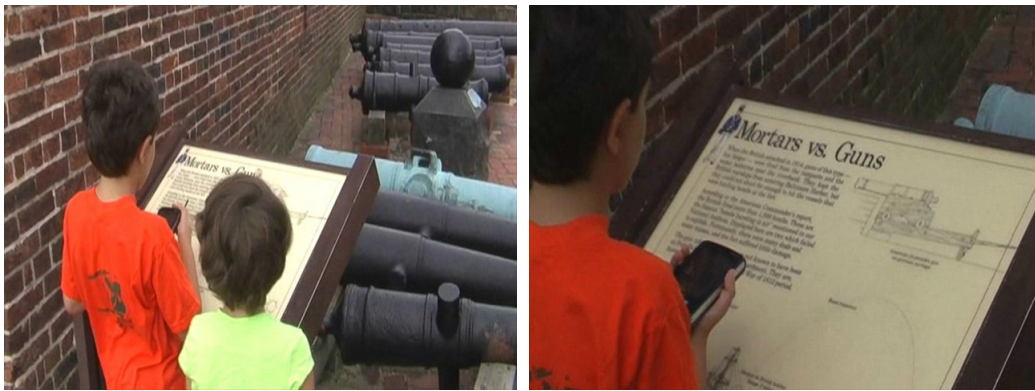


Figure 3.17 – Data collection example, child created an audio clip of reading Mortars vs. Guns placard.

Although collection was supported as shown above creation or construction was also supported. For example, the above collected audio clip was reviewed again (consumed), shared (consumed), and reformulated (recreated). After previously recording himself reading the full placard explanation of the powder magazine, in sharing it with others he decided it was too long of an explanation, so he returned and simplified the description. The new recording reformulated and stated in his own words was:

Uh, the powder magazine was where they kept the gun powder. If it had been hit in the defense of Fort McHenry, then the entire place would have crumbled. Only one bomb hit it, but that bomb was a dud and so it did not destroy the entire fort. — 10 year-old boy

This example illustrates not only collection of information, but a reprocessing as the child puts the historical importance of the magazine in his own words.

Another example of creation was a child added the words of the national anthem to the Anthem page which also had an orchestral arrangement of the anthem (see Figure 3.18).



Figure 3.18 – Construction example, entering the text for the National Anthem.

Various types of collaboration were also observed. Figure 3.19 captures a representative collaborative interaction where a child wanted to show a part of the story to a collaborator and so they walked over to meet one another to share information. The child not only showed the other child, but both took turns interacting and adding to the narrative. This face-to-face collaboration illustrated the importance of physically supporting mobile face-to-face collaboration for young children. Understanding how different collaborative configurations can support collocated situations (e.g. face-to-face, shoulder-to-shoulder, etc.) is an important aspect of this research.



Figure 3.19 – Sharing and collaborating with mobile devices.

Collaborative relationships such as the collocated situation previously described can be enhanced via supporting technology.

By initially testing Mobile Stories 1.0 in a real-world setting such as Fort McHenry National Park, I made several observations which illustrated the types of collaborative and constructive interactions that were currently supported in Mobile Stories as well as those that were desired by the children and needed better support. One thing that became fairly obvious was that each child needed their own small device. As illustrated in Figure 3.15, this does not mean children will not collaborate. It is proposed that by better supporting mobile collaboration, especially face-to-face collaboration, collaboration between young children can be enhanced.

3.4.1.3 Next Steps

Based on the observed need to better support collocated collaboration, further Kidsteam design sessions investigated how both devices could better support this scenario using paper prototypes. The concepts of content splitting and space sharing came out of these design sessions. Figure 3.20 shows the low-fidelity version of the mobile device used in low-tech and paper prototyping sessions. Figure 3.21 shows a low-tech prototype illustrating the concept of content splitting, made during one of the design partnering sessions.



Figure 3.20 – Low-fidelity version of mobile device, used in low-tech and paper prototyping sessions



Figure 3.21 – Low-tech prototype of content splitting, where a story’s images were shown on one device and the words on the other; navigation was a vertical scrolling mechanism.

3.4.2 Version 2.0

Mobile Stories 2.0 was created to explore the potential collaborative benefits mobile devices could provide to reading. This new version supported the content splitting and space sharing as discussed in Section 3.1. This version did not enable

story creation, but only collaborative reading. (Collaborative reading by itself, in its many forms, has also been shown to have benefits [286].) In this version, a user could view a story on a single device (see Figure 3.22, a), or could use the split content or share space collaborative configurations using the relative positions illustrated in Figure 3.22, b & c. The relative positions shown in Figure 3.22 b & c were deemed best by Kidsteam members. Kidsteam members noted this was because users could not only share space visually, but using these relative positions, users could still interact with their device via screen input and physical buttons. Looking at other possible relative positions, this input is not possible (see Figure 3.23). Thus, the interface enabled users to take advantage of the increased physical space, and both users could still interact with their device to change the overall state.

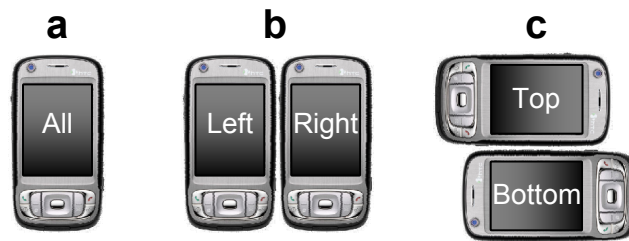


Figure 3.22 – Relative position of collaborating devices; a, a single device, all information is displayed; b & c, two devices share space with illustrated relative positions. (Note: collaborators can use most hardware buttons while connected.)

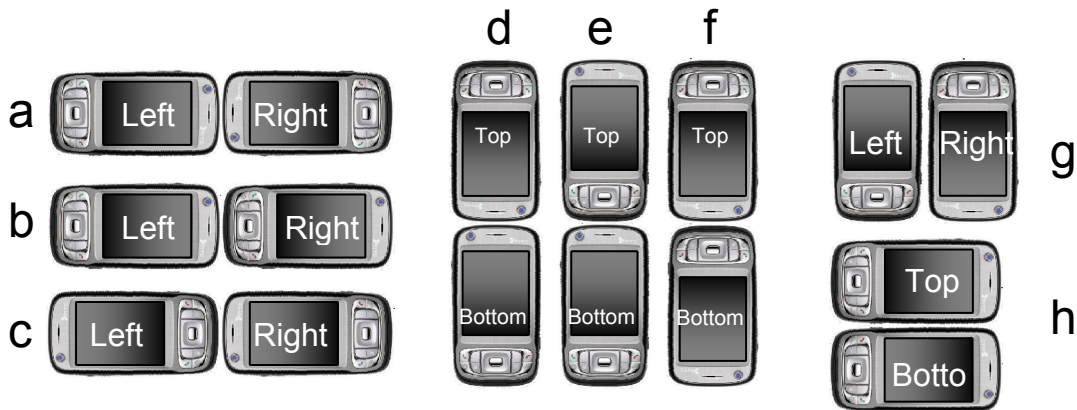


Figure 3.23 – Some of the possible relative positions of two collaborating devices.

The underlying architecture of Mobile Stories 2.0 is fundamentally different than that of Version 1.0 in that it utilizes a peer-to-peer (P2P) architecture (see Figure 3.24). Mobile Stories 1.0 used a client-server model (as described in Section 3.4.1). This previous architecture resulted in problems if one of two people was experiencing networking difficulties, even if the two devices were next to each other. For example, if one device was not *connected* the other would not receive any updates made by the other even if the other was sending the update to the server. The disconnected device also would not be able to send any other updates to any others who were collaborating on the same narrative – even if the two collaborators were close together. The P2P architecture allows close collaborators to work together without having to have an intervening server, thus enabling more mobility and interaction.

This version, and all subsequent versions reported herein, was developed for Windows Mobile 6.0 Professional devices using C# .NET. A desktop client was created that enables reviewing the historical changes of the story. The P2P architecture uses two communication connections – a high-priority connection for interactions, and a medium-priority connection for exchanging data updates. This allows interactions to be relayed faster, and be less likely to be slowed by a large data transfer (e.g. transferring an image).

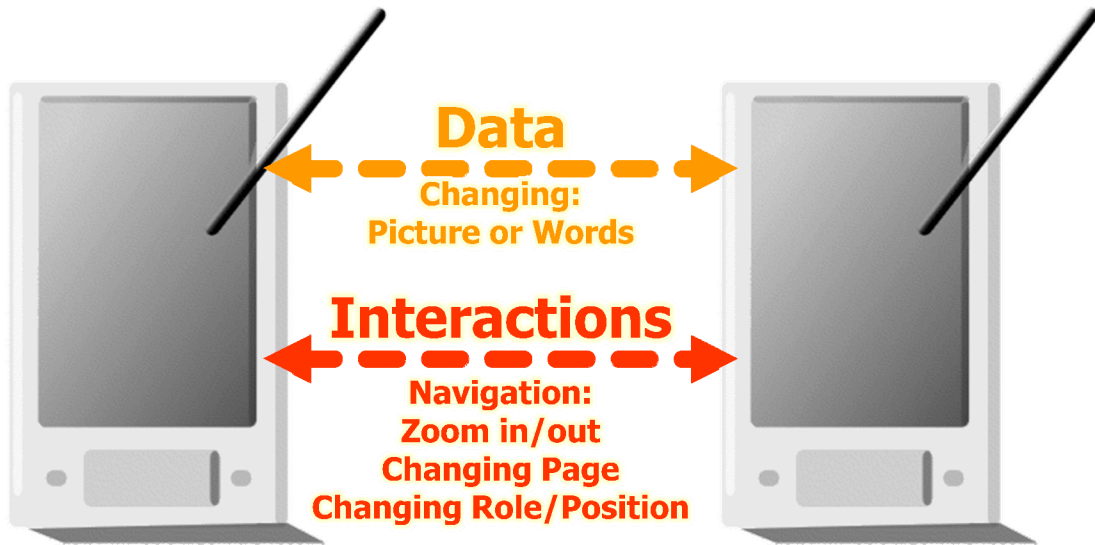


Figure 3.24 – Peer-to-peer connection; a medium-priority connection for exchanging data and a high-priority one for interactions.

Version 2.0 also enabled mode changes so one device could just view the picture, and another, the text. Since the books were from the International Children’s Digital Library (www.childrenslibrary.org), the books could be in different languages. One user could view the text in English, while the other could view the words in Mongolian, for instance. Or one could be showing the pictures while the other viewed the words in English. Both devices synchronized their interactions, so going to the next page on one would change the page on the other.

This system was demonstrated at an NSF sponsored workshop on mobile devices for children [112], and to our design partner children in the lab. While this interface was not formally evaluated, the overall response was positive through discussions with participating researchers. Users appreciated the ability to come together and expand the visual and interactive space. They noted how, by expand the interface across two devices – both using content splitting and space sharing – it made

it possible to read the words from the book, whereas in some cases the text was illegible when shown on only one device.

3.4.3 Version 3.0

The third version of the system enabled story creation as well as reading. The purpose of this iteration was to combine the in situ constructionist principles of Version 1.0 with the collocated collaboration interfaces of Version 2.0. It featured automatic mode switching (AutoSwitch, see Section 3.1.3) allowing children to seamlessly zoom in and out of different stages of collaboration – effectively switching between content splitting and space sharing (see Figure 3.1 and Table 3.1). Version 3.0 featured “see-through” menus (for more see Section 3.4.4.2). In Version 3.0 gesture navigation was also added so users could drag pages to move to the previous or next page. Swiping your finger in an upward motion would zoom out one level. These were added because of the notable difficulty children had using the physical, directional pad to change the page. A summary of usability updates are listed in Table 3.5.

Table 3.5 – Mobile Stories 3.0 usability updates from Version 1.0.

Mobile Stories 1.0	Mobile Stories 3.0
Client/server delays when far from server/router	P2P networking devices only need be close
From story view tapping zooms to page; when viewing a page it edits picture, sound, or words	Tapping only zooms; must use menu to edit picture, sound, or words
Generic WM menu and accompanying issues	Menus “see through” (opened/closed by a single button – the center button on the d-pad)
	Added gestures to navigate: <ul style="list-style-type: none"> • Dragging page left moves to next page • Dragging page right moves to previous page • Swiping up zooms out

3.4.3.1 System in Action: Paper vs. Mobile Devices

The system was used by child co-design partners during a summer program where children came to our lab every day for two weeks to work on technology design. The system was introduced the first week, allowing them to create a story within the lab; effectively introducing them to and familiarizing with the usage of the technology to read and create a story. A week later, two mornings were set aside for story creation. Children were paired into four teams, two of which used technology the first day and paper notebooks the second; while the other two groups used paper notebooks the first day and Mobile Stories 3.0 the second day. Using the paper notebook children could add words and pictures (drawings); with the technology they could add words, pictures, and audio recordings. The pictures and audio recordings available for the technology instance leveraged the embedded camera and microphone in the mobile device. The task for all sessions, paper or technology, was to create a story. Since only six children of the target age group were available those two days, three of the teams were composed of children ages 7-10 and the fourth team was two teenage alumni design partners the first day and a boy in the target age range with an alumna partner the second day. Both the technology and paper stories were limited to six pages.

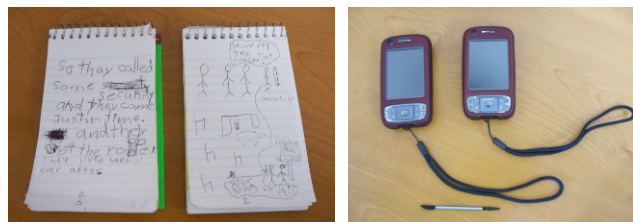


Figure 3.25 – Mobile stories implementations: *left*, paper (small handheld notebooks); *right*, mobile devices (HTC TyTN II).

The purpose of this activity was primarily to see how the children interacted with the technology while creating a story in a new space, as well as to note any differences in how the children collaborated while using the technology and the paper. Also of interest was looking at how they shared their stories. Before starting, teams were instructed that each member had to add something to each page in the story. The teams using the technology were given a review of how the technology worked, namely, how to zoom in and out to different parts of the story, how to connect or disconnect from their partner, and how to add or change various aspects of a page (e.g., how to change the picture, words, or audio). The teams were given approximately 45 minutes to create a story. At the end of each session, each team shared their stories. This formative evaluation which compared Mobile Stories and a paper version showed the relative advantages of the digital which confirmed more formal previous studies [81]. The specifics of these findings are discussed in the next section.

3.4.3.2 Observations and Discussion

The observations discussed in this section are based on interaction logs from the mobile devices, adult researchers' observations (both written and discussed verbally), pictures and video of children's interactions with the technology and each other, the stories the children created, and notes from discussions with the children after each session. This section addresses three main issues: how the children collaborated while using the technology (i.e., how the technology supported collaboration), the differences between creating stories on paper and the mobile devices, and overall preferences.

3.4.3.2.1 Differences between Technology and Paper

The story creation experiences using paper and technology differed in story content, how the children collaborated, and how they exchanged devices. Stories differed when using paper and technology. Figure 3.26 shows examples of digital stories; Figure 3.27, paper. The groups who used technology the first day may have been affected by first participating in the technological storytelling experience, as when they transitioned to paper, they used more of the pages and divided roles – one child wrote and the other drew. They also used more pages (see shading of Table 3.6 for mobile device, and Table 3.7 for paper). Those who used the paper first, their paper stories only utilized two pages. In general, the stories created on the mobile devices used more pages. While using the mobile devices, one child expressed they wanted to make the story “look full”. This was perhaps because the children could zoom out and see the full story. We feel the ability to get an overview of the story in this manner encouraged the children to continue to add to the story.



Figure 3.26 – Digital stories: *left, C5 & C6; right, C7 & C8.*

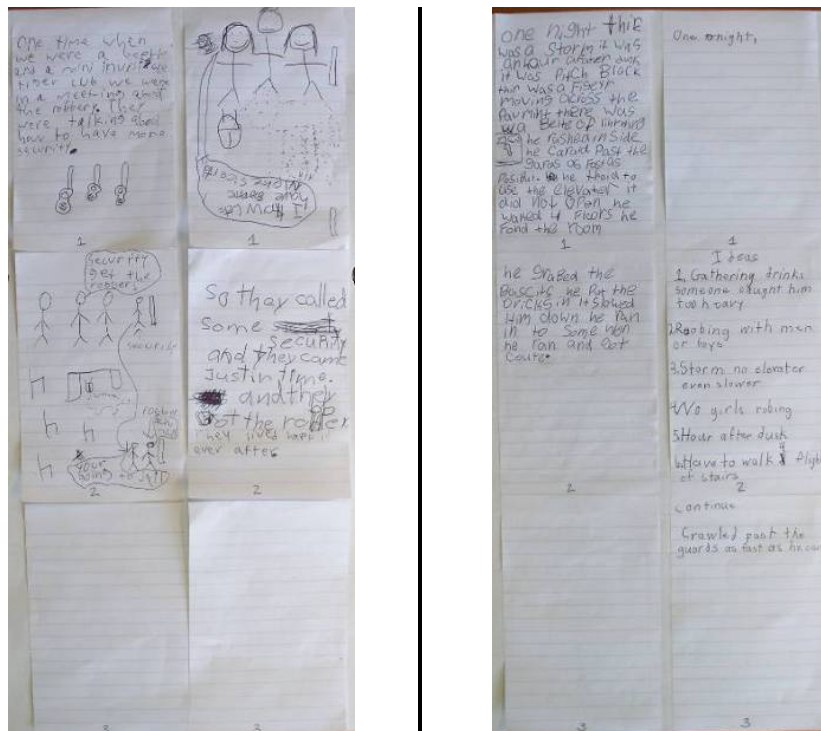


Figure 3.27 – Paper stories: *left, C5 & C6, right, C7 & C8.*

Table 3.6 – Mobile device story collaboration: number of media (picture, text, audio) changed by each child (C) on each page. (shaded = contribution; *teenage children; †partial data loss)

Page #	Day 1				Day 2			
	C1*	C2*†	C3	C4	C5	C6	C7	C8
1	2	1	2	1			2	2
2	2	1	1	2	1	1	1	2
3	2	1	2	1	3	1	1	1
4	2	1	1	2	2	1	1	2
5	2	1	3		1	3	1	
6	2	1	1	3	2		2	

Table 3.7 – Paper story collaboration: number of media types (picture and/or text) changed by each child (C) on each page. (shaded = contribution; *teenage children)

Page #	Day 1				Day 2			
	C5	C6	C7	C8	C1*	C2*	C3	C4
1	2	2	1	1	1	1	1	1
2	1	2	1	1	1	1	1	1
3				1	1	1	1	1
4					1	1	1	
5					1	1		1
6					1	1		1

Another observed difference was how they collaborated with one another. When creating paper stories, children would sit close to each other, and discuss, but had limited interaction, only sometimes looking over each other’s shoulders. With the mobile devices, children also generally stayed close to each other, but they did roam a little further from each other, seemingly demonstrating a bit more independence. While roaming, they continued to discuss what they were doing and occasionally came together to see what the other was doing on their device.

Looking closer at the number of media types changed per page, per child, revealed that children added more types of media to their stories using the mobile devices (note Table 3.6 is more shaded than Table 3.7). These additions resulted in

overlaps, meaning they often changed, enhanced, or elaborated on one another's work.

While using the technology, children would trade devices, while the children using paper did not trade notebooks, unless explicitly asked to – and even then under duress. The same pairs of children were working together (except for the teenage group which included C1 & C2) – so individual differences in collaboration style cannot explain this discrepancy. This is counter to most research that states mobile devices are very personal [22]. Our research does not necessarily refute this, because there are other complexities such as the devices not really belonging to the children in a personal sense, and the devices being exactly the same amongst the pairs; however it is curious as it was unexpected. Finally, even though with the technology paired children (and devices) had the same abilities to see, create, and edit all aspects of the story, trading occurred. It seemed that although the capability was there, the immediacy of transferring the current state by trading devices was desirable.

3.4.3.2.2 Collaboration with Mobile Stories 3.0

There were three key ideas which emerged from my work with children using Mobile Stories 3.0. First, the children made more additions using the technology than paper. Second, AutoSwitch seemed confusing. Third, while using the technology, children connected most when sharing their stories. The first was discussed in the previous section; the other two are discussed below.

Despite having interacted with the technology for approximately thirty minutes the first week and having had a review of the use of the interface before using it the second week, the children did not seem particularly comfortable using the

technology to navigate their stories using the AutoSwitch configurations as described in Section 3.1.3 and Table 3.1. It seemed as though they did not understand how the zooming could change how they collaborated. One child opted to always zoom out to the story level and then zoom into a page, rarely zooming in further. Most would simply use the page level and communicate verbally or showing/looking at each other's devices. The percentage of time spent in each of the zoom levels for each child is shown in Figure 3.28 (as determined by interaction logs). The figure reveals how the various levels were used, including the dominance of the page level (previous/next) zoom level. This implies that AutoSwitch may not be the best approach for children, or that the interface needs to better situate the children as they zoom in and change the collaborative configuration. Having had little success with automatic mode switching in our formative study the focus here was to compare content splitting and space sharing collocated collaborative configurations

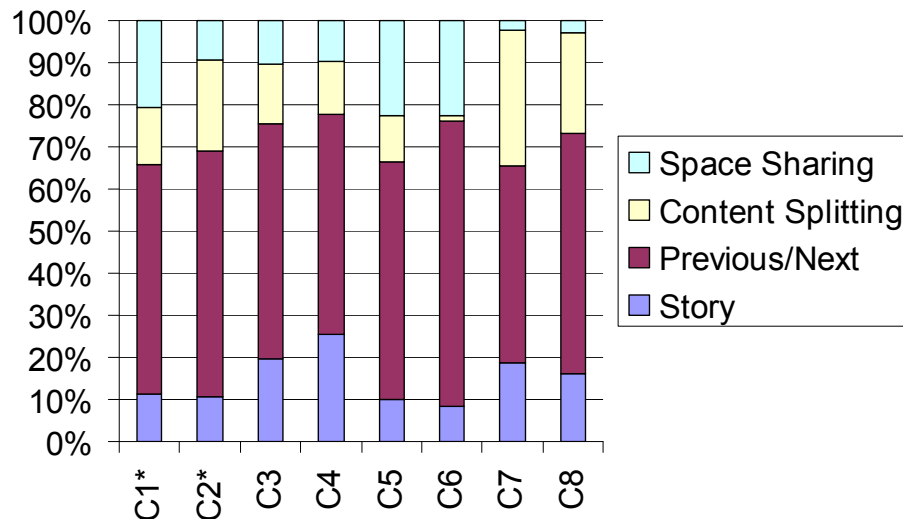


Figure 3.28 – Average interaction time (percentage) of the total time spent in each zoom level, by each participant.

Children connected more near the end of the session when they were showing the other group their story. On average, the children were connected about 10-15 minutes which accounted for approximately 25-32% of the time they were working together. Connecting to one another almost exclusively occurred at the end of each session when sharing their stories. This emphasized the need to support connectedness principally when sharing and/or reading. The few instances where users chose to “connect” during the story creation period seemed intermittent, and occurred mostly at the beginning when the children were experimenting with the interface. The dominance of the page level view, which in the connected state showed previous and next pages, persisted even while sharing.

3.4.3.2.3 Overall Preferences

After each story creation session, the children were asked what was easy, and what was hard about the system that they used. After the second day, children were asked which they liked better, and which system was easier to use to make a good story (or which produced better stories) in their opinions. When asked which they liked better, the overwhelming response was: cell phones. Many stated this was because cell phones were “cool” or that it was simply more fun. One child indicated it as because he liked to type. Another interesting statement made by a child while creating a story on the cell phone after adding her picture to the story was: “Now I’m in a story. I’ve never been in a ‘real’ story before.” This overwhelming preference could be partially due to the novelty factor which was even mentioned as a possibility by one of the child design partners. With the continued proliferation of technology, especially mobile devices [12], it is expected this novelty factor will quickly become

a non-issue. When asked which they thought supported a better story, the response was about equal, with a slight advantage to paper (due to three ties, two pro technology and three pro paper). When asked why they preferred the cell phones, the children said it was easier to get started using the technology. Although this was not observed as a difference by the adult partners, it was a perceived difference by the children. When asked why they preferred paper, the most frequent reply was because they were unfamiliar with the cell phone keyboard and so it slowed down their writing.

3.4.4 Mobile Stories 3.1

Mobile Stories 3.1 was developed in C# .NET for the Windows Mobile 6.0 Professional platform – specifically for the HTC TyTN II. The HTC TyTN II is a Windows Mobile 6.1 Professional device with a 400 MHz processor, a QVGA (240x320 pixel) display, and 128MB RAM and 256 ROM. It has a 3.1 megapixel camera, and supports audio capture and playback. It also supports 802.11b/g (Wi-Fi) and Bluetooth, although the Wi-Fi connection is the only one used for communication in Mobile Stories. A desktop client and a historical story browser were also developed. The code base consists of approximately 24,000 lines of code much of which is inherited from previous versions of Mobile Stories. Additional libraries that were used were not counted. The additional libraries used were Piccolo and OpenNETCF. Piccolo is a toolkit for zooming and animation [42]. OpenNETCF is used for its sound playback and recording application programming interface (API) [20].

Mobile Stories 3.1 uses some of the enhancements from previous prototypes, but adds the addition of allowing the user to explicitly switch between different collaborative modes. As this is the most current version of Mobile Stories, it is discussed in more detail. Some of the enhancements that appeared in previous versions, but were not mentioned previously. If this is the case a note will be amended to indicate when the feature or enhancement was added.

3.4.4.1 Architecture

Version 3.1 uses the same P2P architecture described in Section 3.4.2 (see Figure 3.24 on page 94). Story data was stored on each device. Data updates were numbered and time-stamped. Upon starting up a story, both devices would first synchronize their data and clocks before allowing collaborators to work on a shared story. Storing all data and log data locally provided a more robust capture mechanism over the client-server architecture of Mobile Stories 1.0.

Even though mobile devices increasingly have more processing power, considerations were made to decrease computation and multi-threading. In order to decrease threading two data connections were established and maintained throughout a session – one for sharing interactions, the other for exchanging data. Custom serialization methods were employed to minimize the amount of data transmitted thus speeding up the delivery and reception of data.

The communication architecture to share and synchronize data and interface interactions is key to the success of Mobile Stories. Since the .NET Compact Framework does not support remoting (as does the full .NET Framework), custom serialization and exchange protocols were developed to transfer data over the two

communication portals. A general serialization and deserialization interface was implemented by all data and interface update objects. The communication mechanism utilized this interface to generically break down and create objects before and after going through the data connections. Because of the mobile nature of mobile devices, a mechanism to reconnect connections after a connection was lost was developed. Data locking was not implemented, although some interface configurations were locked in certain instances. For example a user could not enter a collaborative mode (e.g. content splitting or space sharing) if it would change their collaborator's page and that collaborator was editing part of a page.

The architecture supports different media elements; namely, audio, text, and images. It also has a flexible architecture that enables structured, semi-structured, and unstructured narrative activities by having more or less preloaded content.

3.4.4.2 User Interface

Mobile Stories 3.0 supports both content splitting and space sharing. In fact, Figure 1.2 and Figure 1.3 on page 10 are captures from Mobile Stories 3.1. It also supports switching between collaborative modes (see the top menu items in Figure 3.29). The three buttons across the top (going left to right) represent a synchronized data mode, content splitting, and space sharing. Currently the synchronized data mode is selected which is indicated by the square highlight around that button. The synchronized data mode is reminiscent of how Mobile Stories 1.0 worked where data is synchronized, but navigation (e.g. zooming in and out, or changing pages) is not.

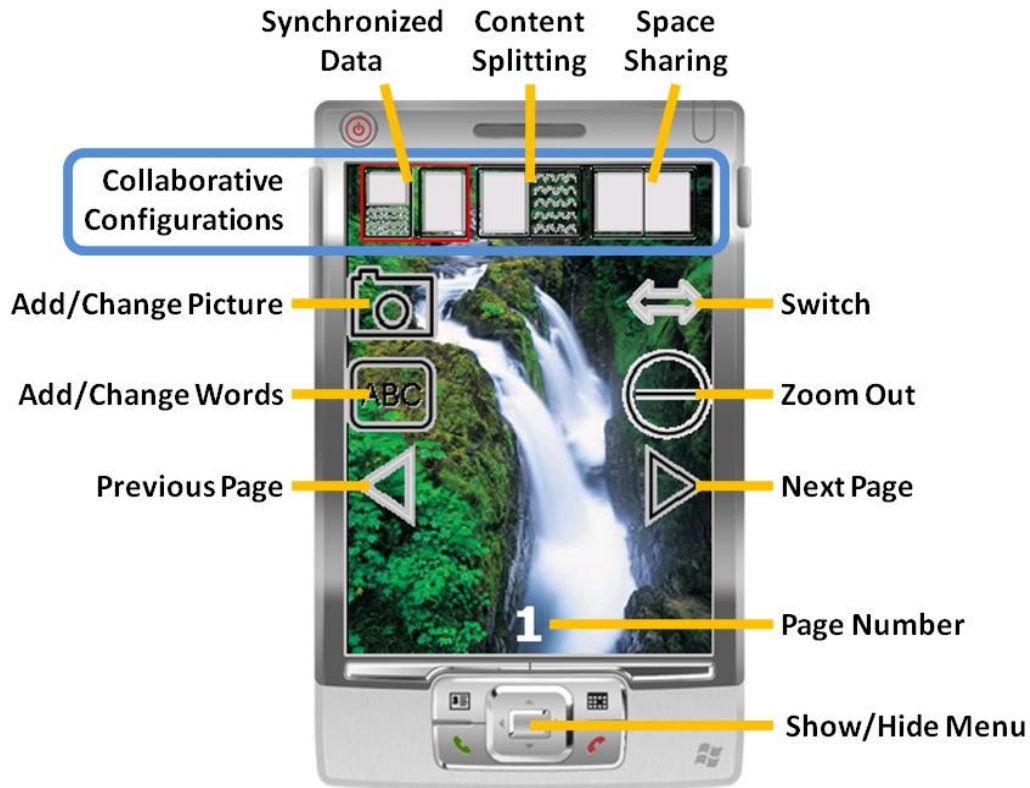


Figure 3.29 – Mobile Stories 3.1 page-level interface, showing the menu.

The remainder of the buttons shown in Figure 3.29 have the following functionality. The triangles at the bottom, are directional arrows which enable switching from page to page. The left arrow is disabled because it is on the first page, but the user can go to the right to the next page. On the left, the camera and “ABC” button enable the user to add or change the image or add or change the text on that page. Users can also just press a camera physical button to initiate taking a picture, or open the slide out keyboard to change the words. Figure 3.30 shows how the keyboard folds out and how the interface changes to accommodate editing text in a landscape layout. On the right of Figure 3.29, the double arrow button is a “switch” button which is context and mode dependent; when using the synchronized data collaborative mode it is disabled (as shown in Figure 3.29). While content splitting it

switches which phone has the words or the picture. While space sharing it changes which phone is on the left or right (if users are on opposite sides of each other). For example if the words were shared across both the devices (as in Figure 3.31 left) or the pages were out of order (as in Figure 3.31 right), the switch button would realign them so they would be as one would anticipate. The last button is the zoom out button. To zoom in, one would just touch the item they wanted to zoom in on. For example from the story view one could touch a page and the interface would zoom into that page. Touching the picture would further zoom into the picture, touching the words, would zoom into the words.



Figure 3.30 – Landscape layout while editing text: *left*, fold out keyboard; *right*, editing text when keyboard is extended.

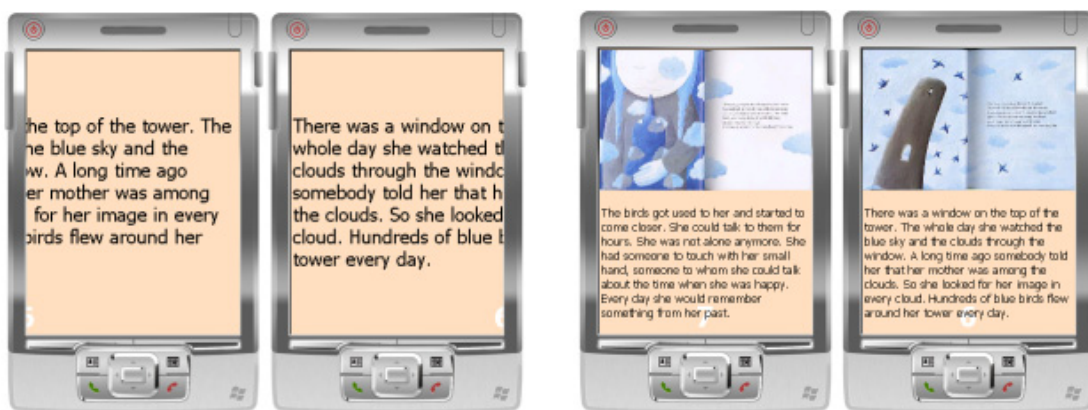


Figure 3.31 – Misaligned words (left) and pages (right; pages 7 then page 6) using space sharing.

Notice in Figure 3.29 how all menu items are translucent. This is a design idea that came from Kidsteam design sessions. It allows users to interact with the menu while still being able to see the context behind with minimal occlusion. The menu is shown or hidden by pressing the direction pad's (d-pad's) center button – or the enter button. This simple interaction was deemed easy to remember by the children and was included in Mobile Stories 3.0 and above.

Audio playback and recording was also supported in Mobile Stories 3.0 and above. For simplification purposes, it was not used in the collaborative story study (and thus is excluded in the menu description of Figure 3.29). Since it is an important aspect, recording is illustrated in Figure 3.32, and playback in Figure 3.33. When a page has no audio the icon displayed is that in Figure 3.32 left, when pressed a the stop button appears with a count-up timer showing how long the sound segment is. The maximum length of a sound segment is sixty seconds. For a page with a sound segment already on it, the displayed icon is that of Figure 3.33 left, which shows a speaker and the length of the audio segment. Once pressed the sound menu expands to show the stop and record buttons as well as a count-down timer for playback. Pressing the stop button stops the playback. Pressing the record button enters the recording mode discussed above and displayed in Figure 3.32. After five seconds the menu collapses to show just the stop button and the count-down timer. The user can also collapse the menu right away by pressing the playback icon again.

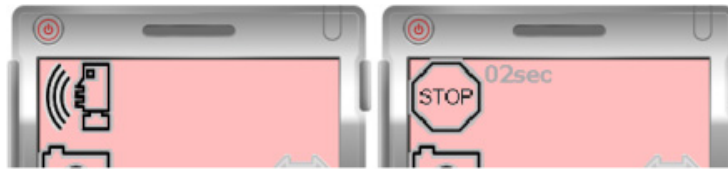


Figure 3.32 – Audio recording in Mobile Stories 3.0: *left*, record button, *right*, stop button (with a counter displaying the current length of the audio segment).



Figure 3.33 – Audio playback in Mobile Stories 3.0.

Some of the physical buttons of the device were utilized while all others were disabled. Since children could (and would) push all the buttons, this was necessary to ensure a more stable user experience. This was noted in earlier versions during Kidsteam sessions, when some would exit the application by accidentally and purposefully pushing different physical buttons. The physical buttons that were enabled were: the direction pad (d-pad) for navigating from page to page, the center button of the d-pad for hiding and showing the menu, and the camera button for taking pictures. Secret combinations of physical buttons were used for administrative purposes – no children discovered these combinations – and therefore were not impacted by them. Unfortunately the power button could not be disabled which caused problems with the TCP/IP communication. This was resolved by physically covering the power button. In the chapter that follows is a formal evaluation of Mobile Stories 3.1.

Chapter 4: Collaborative Story Study

This chapter describes a collaborative story study which was a formal evaluation of the concepts and prototypes discussed in the previous chapter. The study investigated mobile collaboration and the use of the collaborative modes while using Mobile Stories 3.1. Having had little success with AutoSwitch (see Table 3.1) in the formative study discussed in Section 3.4.3, the focus here was to compare content splitting and space sharing collocated collaborative configurations. The study had three phases which account for three collaborative story tasks: reading, creating, and sharing a story. The study was designed to further investigate the research questions: (1) how does the collaborative mobile technology Mobile Stories affect children's collaboration and mobility, and (2) what are the appropriate interfaces for collocated mobile collaboration for young children, and (3) when are these interfaces preferred and why.

Section 4.1 below addresses the study details and outlines the procedures followed. Section 4.2 presents the methods used in analyzing the data from the collaborative story study. The analysis is broken up into a presentation and discussion of the results on reading and sharing stories which is presented in Section 4.4, and creating a story in Section 4.5. An introduction to these two sections is given in Section 4.3.

4.1 Study Approach and Procedures

Pairs of children were asked to come in together to participate in this collaborative study. In total, twenty-six children ages 8 and 9 participated in the

study. There were eleven female and fifteen male participants. Age was not used as a unit of analysis but there twelve 8 year old children and fourteen 9 year old children. The children were recruited through local schools, and recruiting emails. None of the participants had previously seen or used Mobile Stories. Appendix A has a copy of the approved Institutional Review Board (IRB) parental permission form. Appendix B has copies of two flyers used to recruit participants. Throughout the analysis, individual participants will be referred to as P01-P26, and boy or girl.

Figure 4.1 shows a picture and overview of the child-friendly lab space where the study was conducted. (This same kid-friendly lab-space is where Kidsteam is conducted.) The green diamond in Figure 4.1 is the designated starting place for each of the phases of the study. All instruction was given at this point and children were invited to go wherever they pleased while reading, creating, or sharing the story. This large open space allowed the children to move about together or individually as well as to sit together or apart if they so chose.

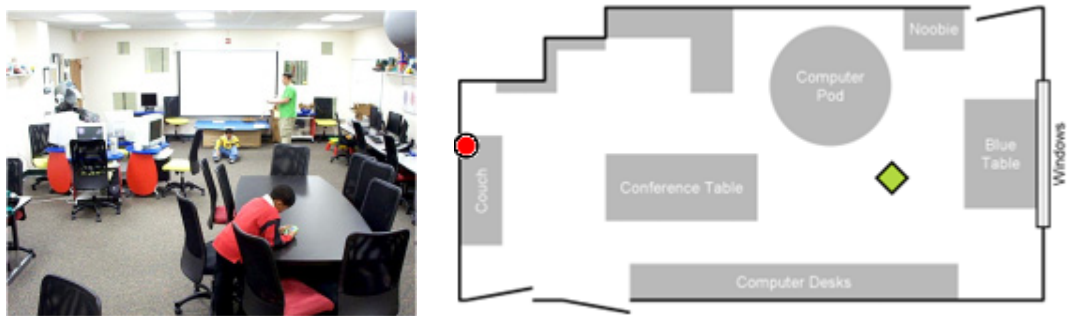


Figure 4.1 – Setting of collaborative story study: *left*, picture; *right*, schematic (red circle, overview camera position; green diamond, starting position for each stage of the study).

The three parts of the study were: reading a story using content splitting and space sharing, creating a story being able to choose one of the collocated collaboration configurations or to work alone, and to share that story with adult

facilitators using one of the two collaborative configurations. Table 4.1 shows the approximate timing for the collaborative story study, the highlighted items were timed. Only one of the groups opted to take a brief break in between the reading and creation portion of the study. Most studies took approximately an hour.

Table 4.1 – Outline of and approximate timetable for collaborative story study (shaded items were timed).

Activity	Timing* (minutes)
IRB Signing	4
Welcome and explanation	4
Configuration #1	
Demo	2
Read	4
Interview (Q1-5)	3
Configuration #2	
Demo	1
Read	4
Interview (Q6-10)	3
Summary Interview (Q11-22)	3
Break (optional)	10
Motivate story creation / demo	6
Story creation	
Reminder of other modes (5 min)	15
Reminder of other modes (10 min)	
Share story with adults	5
Final interview (Q23-47)	6
Total	70

Before starting, consent forms were signed by parents, children were introduced to the facilitators, and the children were given an overview of the study.

An overview was presented to participants in this way:

Today you will be using cell phones to read and create stories. This technology is new and you will be helping us figure out what works well and what doesn't work well with this technology. Your opinions are very important to us. There are some timed portions, with short

breaks in between. If you need a longer break, just ask. You may stop at any time.

For the reading portion, children were given an overview of the technology and shown how the collaborative configuration worked. After demonstrating the functionality of the technology, and answering any questions, the children were handed the devices and asked to read the story together for the next four minutes. After reading with a collaborative configuration the children were given a short interview consisting of five questions (Q1-5). The children were then given a demonstration of the next collaborative configuration, used it for four minutes, and then asked the same questions (Q6-10) about the second configuration. Then the children were asked questions that compared the two collaborative configurations while reading (Q11-22). This concluded the reading portion. The order of presentation of the collaborative configurations was alternated and participants were randomly assigned to different orders in order to minimize bias towards any one particular configuration due to order effects.

After completing the reading portion, the children were presented with information on how to create a story. They were shown how they could add or change the words and pictures on each page. Words could be changed using an on-screen or physical keyboard. The picture could be changed by taking another picture using the camera or choosing from one of the pictures the children had already taken. The children were also shown how they could change the collaborative configuration using the menu. The options available to the children were: synchronized data (navigation was not synchronized), content splitting, or space sharing. The children were given a specific theme and could add words or pictures to their story. The

children started with a blank, six-page story and were asked to use all of the pages. The children had fifteen minutes to work on their story. When the fifteen minutes expired, the children were asked to share their story with the two adult facilitators. The children were then each asked some questions about reading and sharing their story (Q23-47). This concluded the study. All children were given a Frisbee, a notebook, and verbal thanks for their participation. For more complete details of the procedures or instructions given to the children see Appendix C. For a list of all questions children were asked, see Table 4.2 or Appendix C.

There were always two facilitators to conduct the study. I was always one of the facilitators, and another lab member was the second facilitator. Each facilitator had a clipboard with the instructions, observation sheets, and blank question/answer sheets for the child they were observing. The same facilitator always gave the instructions for each part in the study. The second facilitator followed along with the instructions to ensure the instructions were all given and also operated the timer. All facilitators were trained in conducting the interviews so that each child could be interviewed individually. In all, there were five people who were trained as additional facilitators.

Before conducting the full, study a pilot study was performed to familiarize facilitators with the protocol, to test the protocol, and ensure the timing for each tasks was appropriately accounted for. The protocol was slightly adjusted, to minimize the amount of time it would take. Some questions were eliminated. Originally participants were going to do the reading task with the synchronized data configuration, this was eliminated due to time constraints and because the focus was

to investigate the difference between the collaborative configurations. Also, children noted that the devices were slippery, and Kidsteam suggested adding wrist-straps and sticky materials to make them easier to hold. These adjustments were made.

4.2 Data Collection and Analysis Methods

This section details the data collection and analysis methods including the video coding scheme. In short, the data collected were: video, field notes, interviews, mobile phone interaction logs, and the created collaborative stories. Video observations of the each phase of the study were codified using a scheme which is detailed in Section 4.2.2.2.1.

4.2.1 Data Collection

In order to provide thick description with cross-validation, various data collection methods were used in order to enable triangulation in the analysis [269]. The information artifacts include video, field notes, interviews and questionnaires, interaction logs from the mobile devices, and the collaborative narratives created by the children. These are individually addressed below.

Video: Each of the two facilitators was responsible for video recording one of the children participating in the study. There was also a single overhead camera that captured the overall activity in the room. (Figure 4.1 left indicates the location of the overhead camera.) The cameras were used to capture participant's activities throughout the study.

Field Notes: Written field notes were taken to capture children and adult participants' activity. Protocols were used for recording each participant's absolute location in the room as well as relative location to their collaborator/partner.

Interviews and Questionnaires: All participants were given oral interviews at the end of each section as described above (see Table 4.1). Questionnaires and interviews focused on various characteristics of collaborative systems. These were adopted from collaborative heuristic evaluation instruments [135, 223]. Data were collected on: usability and subjective interest of each collaborative configuration, awareness of their partner's activities, overall preferences, etc. A copy of all of the questions, as well as the observation sheets that were used can be found in Appendix C. Since questions are addressed directly in the analysis portion, an abbreviated list of questions is given here in Table 4.2.

**Table 4.2 – Collaborative story study interview questions
(*open-ended questions that were analyzed qualitatively).**

Q#	Post Reading Configurations #1 and #2
1 / 6	Circle the configuration used first. (Split / Share)
2 / 7*	How easy/hard was it to read the story? (1 Very Hard / 2 / 3/ 4 / 5 – Very easy) Why?
3 / 8*	How cool/lame was the way you read it? (1 Very lame / 2 / 3/ 4 / 5 – Very cool) Why?
4 / 9*	What was < insert name of partner > doing while you were working?
5 / 10	How often did you know what your partner was doing? (1 – Never / 2 / 3 / 4 / 5 – All the time)
Q#	Reading Comparison
11	Configuration order (number 1, 2): (Split-Share / Share-Split)
12*	Which would you choose to use now, the first way or the second? (Split / Share) Why?
13*	Which was easiest to read? (Split / Share)
14*	Which did you like the most? (Split / Share)
15*	When would you want to read with someone?
16*	When would you want to read with someone with the words and pictures split?

Q#	Reading Comparison
17*	When would you want to read with someone with the previous/next pages, or the picture or words shared across both phones?
18*	How would you prefer to read together with someone? (Split / Share) Why?
19*	What was the book about?
20	How much did you like the book? (1 – Not at all / 2 / 3 / 4 / 5 – Very much)
21*	Which would you prefer to read a story on: paper or a cell phone? (Paper / Cell phone)
22*	[If read out loud (Yes / No) Why?]

Q#	Post Story Creation and Sharing
23*	Which configuration did you use to share the story with (can be noted from observation)? (Synchronized Data / Split / Share) Why?
24*	Which was easiest to create with? (Synchronized Data / Split / Share) Why?
25*	Which was hardest to create with? (Synchronized Data / Split / Share) Why?
26*	When would you want to create a story with someone?
27*	How would you prefer to create a story with someone? (Synchronized Data / Split / Share) Why?
28*	How much did you like to work alone (use Synchronized Data)? (1 – Not at all / 2 / 3 / 4 / 5 – Very much) Why?
29*	How much did you like to (split content)? (1 – Not at all / 2 / 3 / 4 / 5 – Very much) Why?
30*	How much did you like to (share space)? (1 – Not at all / 2 / 3 / 4 / 5 – Very much) Why?
31	How well did you get along with your partner? (1 – Not at all / 2 / 3 / 4 / 5 – Very much)
32	How well do you know your partner? (1 – Not at all / 2 / 3 / 4 / 5 – Best friends)
33	How frequently do you use a computer? (Never / Once a month / Once a week / 2-3 times a week / Every day)
34	How old are you? (8 / 9)
35	Have you ever used a cell phone? (Yes / No)
36	How frequently do you use a cell phone? (Never / Once a month / Once a week / 2-3 times a week / Every day)
37	How much would you like to <u>read</u> stories <i>by yourself</i> on a cell phone? (1 – Not at all / 2 / 3 / 4 / 5 – Very much)
38	How frequently would you like to <u>read</u> stories <i>by yourself</i> on a cell phone? (Never / Once a month / Once a week / 2-3 times a week / Every day)
39	How would you like to <u>read</u> stories <i>with someone else</i> on a cell phone? (1 – Not at all / 2 / 3 / 4 / 5 – Very much)
40	How frequently would you like to <u>read</u> stories <i>with someone else</i> on a cell phone? (Never / Once a month / Once a week / 2-3 times a week / Every day)

Q#	Post Story Creation and Sharing
41	How much would you like to <u>make/create</u> stories <i>by yourself</i> on a cell phone? (1 – Not at all / 2 / 3 / 4 / 5 – Very much)
42	How frequently would you like to <u>make/create</u> stories <i>by yourself</i> on a cell phone? (Never / Once a month / Once a week / 2-3 times a week / Every day)
43	How much would you like to <u>make/create</u> stories <i>with someone else</i> on a cell phone? (1 – Not at all / 2 / 3 / 4 / 5 – Very much)
44	How frequently would you like to <u>make/create</u> stories <i>with someone else</i> on a cell phone? (Never / Once a month / Once a week / 2-3 times a week / Every day)
45	How well do you read? (1 – Not well at all / 2 / 3 / 4 / 5 – Very well)
46	How much do you like to read? (1 – Not at all / 2 / 3 / 4 / 5 – Very much)
47*	Which would you prefer to create a story on: paper or a cell phone? (Paper / Cell phone) Why?

Mobile Phone Interaction Logs: Mobile Stories is instrumented to capture the children’s interactions with the tools and with each other. This information is tracked through a client ID that can be related to the child using the device during the session. Information captured includes:

- When and how long each collaborative configuration was used
- When and how long each of the different zoom levels were used
- When and who made additions/changes while creating the story
- When and who changed pages

Collaborative Stories: The story artifacts created by the children were saved including individual contributions, the evolution of the story, and the final story outcome. Some of these stories can be found in Section 4.5.2.

4.2.2 Analysis Methods

A mixed methods approach was used to analyze the data [92, 280]. This included both quantitative and qualitative methods. These methods are discussed further in this section.

4.2.2.1 Quantitative

Statistical techniques were used to analyze the numerical data gathered from the interviews. Many questions required responses along a five-point scale. Paired-sample t-tests are well-suited for comparing two variables among multiple participants assuming the participants are selected randomly. The assignment of participants to condition order was random regardless of age or gender. Thus having met the parameters of the paired-sample t-tests, they were used to compare different variables among participants and groups. Also used were the two-sample t-test to compare samples among unpaired groupings, such as gender comparisons where the number of participants is unequal (11 females, 15 males). Pearson's correlations were used to identify relationships [84].

In reporting traditional statistics including paired-sample t-tests, two-sample t-tests and correlations, the following designations are used: three asterisks (***) were used for $p < 0.01$, two asterisks (**) for $p < 0.05$, and one asterisk (*) for $p < 0.10$. The respective language used to describe these designations are: there is a strong significant relationship, a significant relationship, and there is evidence of a significant relationship. These designations adhere to guidelines for significance for samples of this size [84, 169].

The analysis of the quantitative data is designed to identify patterns and associations between variables. It is not appropriate to make inferences to the population based on small-sample experimental data. As such, significance levels are reported as a measure of the strength of the association in the experimental setting and not to make inferences about a population.

4.2.2.1.1 Limitations

The strength of the statistical analysis is affected by the small sample size of 26. Because of the relatively small sample size a repeated measure, or within-subject, experimental design was used. While this sample size is large enough to perform basic statistical analyses, it is difficult to evaluate many interactions between variables. Some of the metrics were by pair and some by individual. For pair or group statistics, the sample is cut in half to a size of 13. Further splits by gender means there are 5 girl-girl dyads, 7 boy-boy dyads, and 1 girl-boy dyad.

It is important to be somewhat cautious in interpreting the results because the paired and two-sample t-tests require that one makes assumptions that are questionable in some cases. For example, the sample is small enough that one must assume that the variables are normally distributed in the population, and when that assumption is violated the test statistics may be slightly biased. Because the p-values are not used to make inferences about the population, these minor deviations would not substantially affect the interpretations below.

Also, it is important to note the experiences of the paired children were not statistically independent. A Pearson's product-moment correlation was computed to assess the relationship between the responses of the participants for the same question. For example, when each of the paired children were asked if content splitting was easy or hard, there was a correlation between the responses [$r = 0.34$, $n = 26$, $p = 0.10$]. For space sharing the correlation was stronger [$r = 0.77$, $n = 26$, $p < 0.01$]. This dependence is not surprising as the experience was collaborative and each participant's actions could change the interface or program state of their partner. This

correlation means that these collaborative interactions had an impact on both of the paired participants. Alternating the order of presentation of the configurations, the within-subject design, and the use of paired t-test statistics ameliorate the effects of this dependence.

4.2.2.2 Qualitative

Qualitative analysis was conducted to analyze participant's actions during the study as well as their responses to the interview questions. The three video streams (one for each child, and an overview camera) for the reading, creating, and sharing were manually synchronized and transcriptions including what was said and done were made by me. The video was coded using the scheme discussed below in Section 4.2.2.2.1. Interview responses were transcribed and analyzed using the coding methods described in Section 4.2.2.2.2.

4.2.2.2.1 Video Coding

A two-part coding scheme was devised to investigate mobility and collaboration while performing the various tasks. The scheme includes group and individual metrics which are discussed in the following subsections. The choice of codes was based on collaborative indicators as suggested in the Collaborative Usability Analysis (CUA) [135, 223]. CUA proposes the following low-level actions and interactions are important: communication, coordination, planning, monitoring, assistance, and protection. This framework echoes much of what is mentioned as important to observe in collaborative situations (see discussion above in Section 2.2). The codes discussed below reflect these categories of interest with some minor

changes to facilitate coding accuracy, and to tailor them to the specific tasks related to story reading, creation and sharing. Figure 4.2 summarizes the video coding scheme.

For the reading and sharing tasks (which were respectively 4 and 1½ minutes in duration), codes were used for analysis if they occurred or not within every five second interval. For the creation task (which was approximately 15 minutes), the coding was done on ten second units. Only proxemic distance and mobility were coded on the creation video. Since codes were evaluated over an interval of time, no codes were mutually exclusive as many codes could occur during that time period. The reliability of the coding scheme was established by having an external person analyze 15% of the reading data using the scheme outlined and defined below. Using this scheme, the coders had a 97.13% median value of agreement [M = 93.25%, SD = 7.46%] using an exact match interrater reliability metric (the strictest form of agreement). The minimum value was 77.55% on the variable Navigation Wars. Using a more flexible reliability metric of percent differential agreement of interval counts, this variable reached 90.82% agreement. This means that all variables used in this report have surpassed the minimum requirement of 70% agreement and are well within the acceptable range for interrater reliability [59, 92, 280].

1. **Joint codes** – for each group/pair
 - a. Proxemics – how far apart participants were from one another (see Table 2.1)
 - b. Navigation war – whether competitively navigating away from each others
 - c. Number of pages read together
 - d. Start time of reading

2. **Individual codes** – for each participant
 - a. Mobility
 - i. Moving – if participant was moving
 - ii. Location changes – how far from last location (> 3 feet, > 10 seconds)
 - iii. Poses – positioning of participant (e.g. leaned forward or back; relative position to partner: side-to-side, corner-to-corner, face-to-face)
 - b. Task
 - i. Distracted – if was distracted (e.g. looking around)
 - ii. Navigating – if was navigating (e.g. changing the page)
 - iii. Reading – if was reading (e.g. looking at the picture or words on his/her or partner’s device)
 - c. Communication and awareness
 - i. Reading out loud – if was reading out loud
 - ii. Story navigation – if discussed navigating (e.g. changing page)
 - iii. Physical location – if discussed going somewhere (e.g. “let’s sit here”)
 - iv. Planning – if discussed plans (e.g. for reading “let’s go to the 1st page”)
 - v. Assistance – if asked for or gave assistance (e.g. “how do I ___?”)
 - vi. Frustration – if exhibited frustration (e.g. “[Johnny], stop that!”)
 - vii. Glance – if glanced or looked at other device or person

Figure 4.2 – Summary of video coding scheme: joint and individual codes.

4.2.2.2.1.1 Individual Codes

Mobility: There were three different subcategories within this code, which differentiate whether or not the individual moved, changed location, or changed their current pose. The *moving* code is a simple Boolean value. For *location changes*, an indication was made if they reached a new resting spot, and how far the individual’s resting spot was from his/her previous location. A resting time of at least 10 seconds and a movement of greater than 3 feet were required to qualify as a location change. *Poses* had a looser specification, but included categories such as: side-to-side, corner-to-corner, and face-to-face (see Figure 4.3, top). While these illustrated examples are

joint, relative positions, when the children were apart, their individual poses were also noted such as hunched over or laid back (see Figure 4.3, bottom). Under this category, raters also indicated whether the children were standing or sitting.



Figure 4.3 – Pose examples: *top left*, side-by-side, *top middle*, corner-to-corner, *top right*, face-to-face, *bottom left*, hunched over; *bottom right*, laid back.

Task: There were three different subcategories for this code. *Distracted* was noted when the child was looking around the room, or if they were fidgeting with the device or some other item – seemingly off-task. *Navigating* noted if the individual was navigating using the interface. Navigation included changing pages, zooming in/out, or using the switch button. *Reading* indicated whether or not the individual was reading from a device. Reading included looking at the words or the pictures on either device (that held by the individual or partner).

Communication and Awareness: Communication and awareness are strong indicators of collaboration [54, 89]. Within the category of communication and awareness several items were coded for, including: reading out loud, story navigation

(e.g. “go to the first page”), physical location (e.g. “let’s sit on the couch”), planning (e.g. “you do the first, third, and fifth page and I’ll do the second, fourth, and sixth), assistance, frustration or confusion, and whether or not they looked at the other device (the held by his/her partner). *Reading out loud* greatly enhances awareness and affords a high level of consequential communication – meaning coordination and collaboration without directly discussing it. *Story navigation* is a direct discussion of coordination and collaboration. *Physical location* indicates when a new location or physical configuration is discussed (e.g. “should we read from across the room”). *Planning* is more generic in that it is communication regarding accomplishing the task (e.g. for reading: “let’s go to the first page”). For reading tasks this is often synonymous with the story navigation task, but for the creation task it indicates discussions about story content. *Assistance* defined as asking for help indicates requesting (e.g. “How do I ___?”) or rendering (e.g. “The ‘L’ is on the left-hand side [of the keyboard]”) verbal assistance. *Frustration or confusion* which is defined as a verbal or non-verbal exclamation (e.g. “[Johnny] stop doing that”, “Ughh” combined with hitting one’s leg) can be an indication that the collaboration is not fluid, or that the technology is not adequate. *Glancing or looking at the other* device or person indicates awareness and collaboration.

4.2.2.2.1.2 Joint Codes

There also were analyses involving group dynamics, namely how close the two participants were to one another, and the second is whether or not they were engaging in what is called a navigation war.

Proxemics: Proxemics defines measurable distances between people as they interact [136]. This is used as a measure to see how different collaborative configurations fare in different proxemic categories. It was also used as a measure to compare gender differences. The proxemic categories are intimate, personal, social and public with close and far phases [136]. Distances for each category and phase were already outlined and can be found in Table 2.1 on page 46; the labels (1-8) are used to represent each proxemic distance within the graphs.

Navigation War: A navigation war occurred when participants engaged in conflict or were frustrated by the . They are characterized by a participant navigating to a different page while the other participant is trying to navigate elsewhere. In other words it was competitive navigation, oftentimes accompanied by frustration by one or both of the participants.

For the reading task, additional overall codes included: when the group started reading, and approximately how many pages were read. This was used as a comparison to qualitatively see how readily participants were able to start the collaborative reading task, as well as to estimate performance on the open-ended task.

4.2.2.2.2 Interview Coding

The asterisked interview questions listed in Table 4.2 were coded using the methods and scheme discussed in this section. Many of the qualitative interview questions were open-ended follow up questions probing why a child chose the rating they did or why s/he acted a certain way. Others suggested the child's collaborative awareness. Several other questions asked about when, or in which scenarios, participants might use Mobile Stories and/or each collaborative configuration.

The coding scheme was developed by using the following process. First, I transcribed all interview responses. I then reviewed the transcriptions multiple times [49, 57]. Through this process themes emerged from the data and the codes were refined for each question [59, 103, 248]; some general themes stretched beyond each question. Individual themes per question were devised by me. Another researcher confirmed that all themes were present in the coding scheme on a question by question basis using all of the participant's responses for each question. Occasionally codes were split to provide better clarity for the analysis. In these cases both researchers recoded the questions using the new code. Both researchers independently coded individual participant responses as to the presence or not of each code category. Using this duplicate coding for the entire data set, researchers reached 94.33% agreement using an exact match if present interrater reliability metric. The question-by-question codes were clustered to consolidate overlapping codes. There were several similar themes to those that were used in the video coding scheme, namely the broad themes of: proximity, task, mobility, and collaboration. An overview of the interview coding scheme is shown in Figure 4.4. The qualitative analysis of the interviews was used to triangulate, support, and explain some of the observed actions and trends from the video observations.

For some questions, such as the "when would you" questions (Q15-17, Q26) and the paper / cell phone preference questions (Q21, Q47), lists of reasons and scenarios were created and clustered. Some participants responses were omitted because they had no comment, an "I don't know", or an off topic/nonsensical remark. These categories were included in the coding scheme. In all cases if there are

opposing views expressed by respondents, an effort was made to express those alternate perspectives.

- 1. General codes**
 - a. Emphatic – responses that included strong words like always, never, every; or follow-up why responses that explained why a participant gave a 1 or 5 rating
 - b. Mentoring – if response eluded to a mentoring relationship either the participant mentoring someone else, or someone mentoring the participant; wanted to share
 - c. Novelty – indicates when response eludes to a preference because it is new, cool, modern, technology, etc.
 - d. Nonsense – response does not make sense or is off topic (e.g. I like tornadoes, biting your nails is disgusting); No response and I don't know
 - e. Looked like a book
 - f. Digital benefits – anything that alluded to a benefit of being digital
- 2. Proximity (+/-)** – if related to relative distance from each other
 - a. Close (+/-) – if designated it was better, worse, or feasible to be close
 - b. Far (+/-) – if designated it was better, worse, or feasible to be far
- 3. Mobility (+/-)** – if related to in/ability to move in positive or negative way
 - a. Portability/in situ – have wherever and whenever you wanted
 - b. Multiple books – ability to carry multiple books
 - c. Location – if referred to a location (e.g. home, school, doctor's office)
- 4. Task**
 - a. On-task behavior – mentioned on-task behavior (e.g. reading, looking at pictures)
 - b. Off task – if talking about any of these types of behavior
 - i. Navigation war – (e.g. my partner was just changing pages)
 - c. Ease/difficulty
 - i. Size of words (+/-) – (e.g. the words are bigger / too small)
 - ii. Challenging – thought it was challenging, or required collaboration
 - iii. Confused/lost – (e.g. it was more confusing, you would get lost, don't know which side is which [share space specific])
- 5. Communication and awareness**
 - a. Awareness (+/-) – was aware or not what partner was doing
 - b. Coordination (+/-) – whether hard or easy to coordinate
 - i. Reading out loud – why they read out loud
 - ii. Being connected (+/-) – how they liked or dislike being connected
 - iii. Navigation (+/-) – easy or hard to navigate the interface/book; also related to task (e.g. how they coordinated changing pages)
 - iv. Planning – if discussed plans (e.g. *for reading*: let's go to the 1st page)
 - c. Look at other device (+/-) – whether liked or did not looking at other device
- 6. Collaborative mode specific**
 - a. Split content (+/-) – positive/negative comments about split content configuration
 - i. Has pictures or words (+/-) – liked or not that had one or the other
 - ii. Switching (+/-) – liked or not that could switch
 - iii. Look at both (+/-) – have to look at both devices
 - b. Share space (+/-) – positive/negative comments about share space configuration
 - i. Has pictures and words – liked or not that had both
 - ii. Looked like book – mentioned two-page spread looked like a book
- 7. Time – a time specification was made (e.g. when bored, on weekends)**

Figure 4.4 – Summary of interview coding scheme.

4.2.2.2.3 Limitations

The qualitative analysis is limited in that it was not possible to follow-up with participants after the coding analysis. The video and interview coding schemes were established and validated via interrater reliability by reaching an interrater reliability of 85% or better on each of the codes that were used. The coding of the video is also supported by interview responses.

4.3 Introduction to Analysis, Results and Discussion

The remainder of this chapter discusses the analysis and results of the study using the methods described above in Section 4.2. Section 4.4 addresses the research questions pertaining to the collocated collaborative modes by presenting and discussing findings from the reading and sharing phases of the study. Section 4.5 addresses mobile collaboration by presenting and discussing findings from the story creation phase of the study. The reason for this division is that the formative findings of Section 3.4.3, that suggested the collaborative modes were primarily used for sharing were corroborated in this study as only a few children used or attempted to use the collaborative configurations while they were creating their joint stories. Due to this division, these sections also directly correlate to the research questions. Section 4.4 addresses the second two which deal with the appropriateness of the collocated collaborative interfaces; and, Section 4.5, the first which discusses how mobile collaboration affects mobility and collaboration.

4.4 Collocated Collaborative Reading & Sharing

This section addresses the overall preferences as determined by interview data and chosen or exhibited behaviors during the study tasks of reading and sharing. It discusses why those choices may have been made using mixed-methods data from video and interview coding. It then concludes by discussing both configurations and when each may or may not be appropriate as designated by participant responses.

4.4.1 Content Splitting Preferred Overall

Overall the data reveals a preference for the split content configuration. The numerical data from the interviews as well as a behavioral choice when sharing their created stories showed this preference. This is also noted despite both being thought of as being “cool” on Q3/8 where median values for each question were a 5.

For the direct comparison question, “which would you choose to use now”, sixteen of twenty-six preferred the content splitting configuration. A Pearson’s product-moment correlation was computed between the most recently used configuration (Q6, the second one used), and the configuration they reported to be the participant’s preference (Q12). There was a positive correlation between these two variables [$r = 0.41, n = 26, p < 0.04$]. This correlation signifies there was a recency effect. In other words when choosing which configuration was preferred most, more often than not, the children chose the most recent configuration as their preferred configuration.

Another way the children showed the split content configuration was preferred was when the children were asked to share the story they created with the facilitators. Ten of the thirteen groups decided to share their story using the content splitting

configuration. A Pearson's product-moment correlation was computed to assess the relationship this choice (Q23) and their stated preference at the end of using both configuration to read (Q12). The time between stating their overall preference and sharing the story they created was no less than twenty minutes. The results identified a possible correlation [$r = 0.32, n = 26, p < 0.12$]. Although the previous decision may have had an effect, the time on different tasks between the stating their reading preference and sharing their stories, not only was a natural progression, but a conscious effort to assuage effects between the two. The acted out behavior of the majority choosing to use content splitting to share is a strong indicator of overall preference.

With these overall indications, the following subsections discuss other relative advantages content splitting had over space sharing as exhibited in the collaborative story study while reading and sharing the story. These areas are ease of reading/using, task completion, and collaboration.

4.4.1.1 Easier to Read/Use

A paired-samples t-test was conducted to compare how each participant rated the different configurations on the question, "how easy/hard was it to read the story that way" (Q2/7). There is evidence of a significant difference in the scores for the split content [$M = 3.62, SD = 1.20$] and share space [$M = 2.88, SD = 1.37$] conditions [$t(25) = 1.97, p < 0.06$] (see Figure 4.5). Figure 4.6 presents the sum of each of the ratings for both content splitting and space sharing. The trend lines illustrate how the preference for content splitting is more uniformly positive.

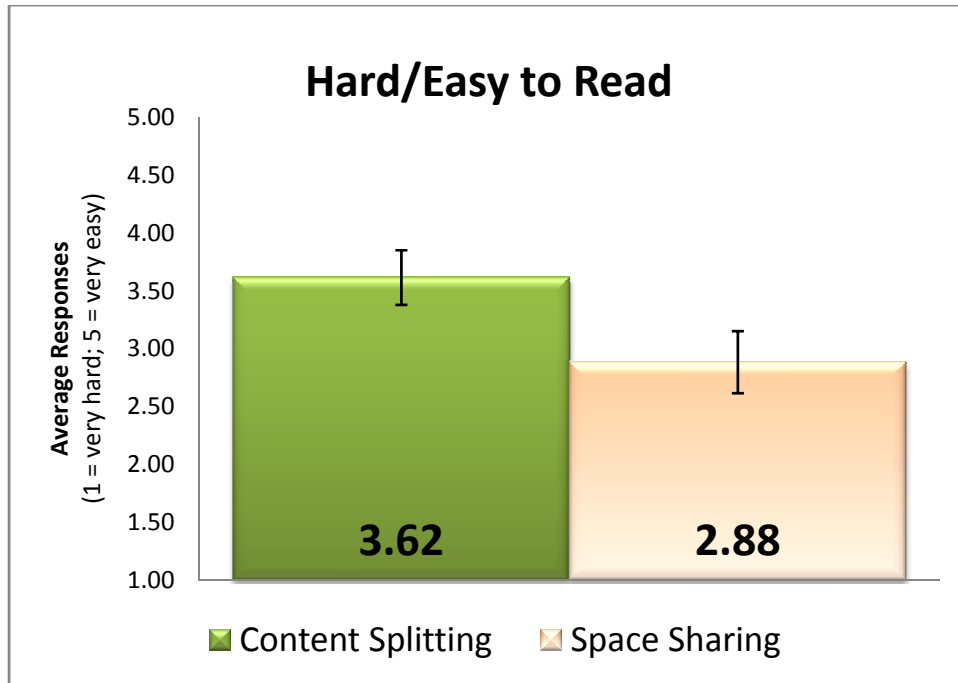


Figure 4.5 – Average participant responses to “How hard/easy was it to read the story?” for content splitting and space sharing (1 = very hard, 5 = very easy).

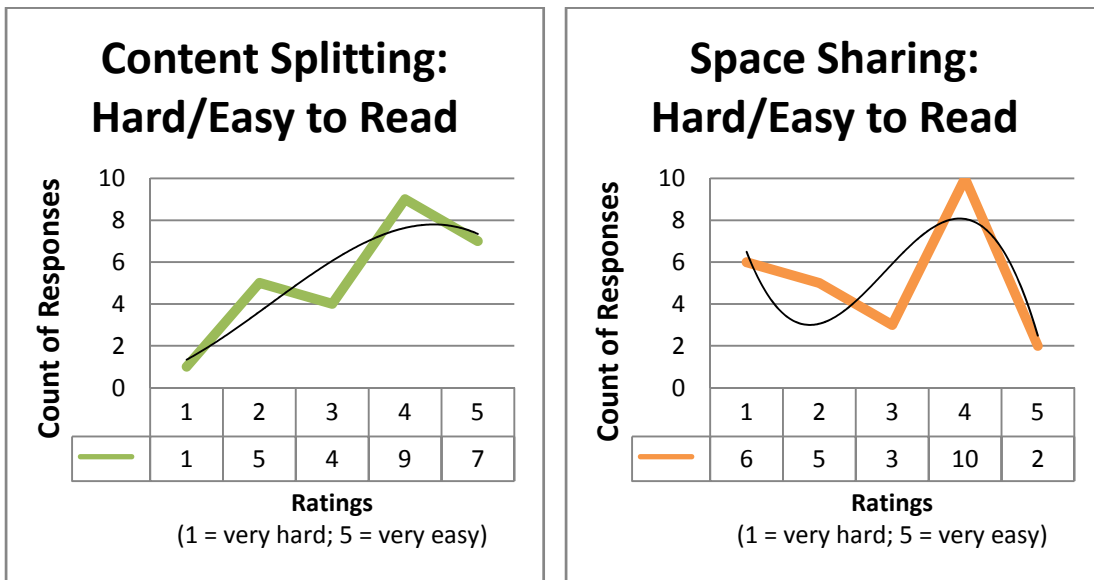


Figure 4.6 – Details of participant responses to “How hard/easy was it to read the story?” (see Figure 4.5); *left*, content splitting; *right*, space sharing. Despite both having a high number of 4 ratings, and the same number of 2 ratings, content splitting overall has higher ratings (and fewer low ratings).

Figure 4.7 illustrates how male participants (boys) were more emphatic about their preference for content splitting. Figure 4.7 also shows how overall, female

responses were more positive in general than their male counterparts. Consider these two quotes from male participants when asked: “Which would you choose to use now?” (Bold words were emphasized by the participants).

Definitely split because it works a **lot** better, you basically have a full book, bigger pictures, bigger words, you aren’t missing read the book, you can read the full book and it doesn’t waste time because one person’s looking at the pictures while the other person is working at reading the words. (Q12: P23)

Split because it was a **lot** easier, you knew what you’re partner was doing, and you don’t have to read very close. (Q14: P12)

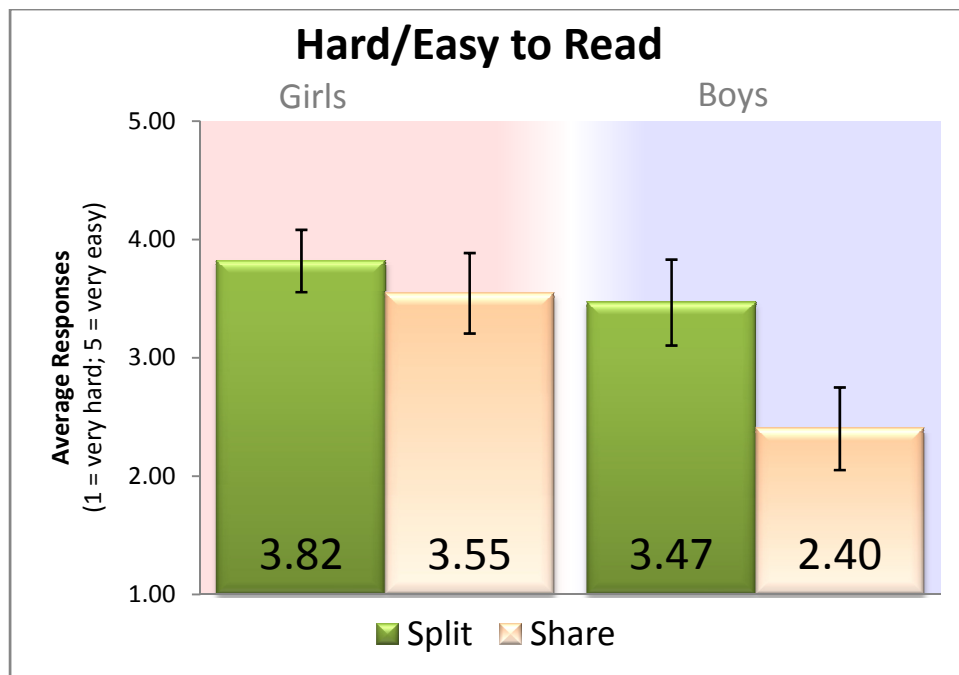


Figure 4.7 – Gender differences in readability using content splitting or space sharing: larger difference between configurations for boys than for girls; boys gave slightly lower ratings.

For Q2/7, only one participant rated split content as very hard, while six rated the share space configuration as very hard. There were emphatic responses to the open-ended questions as to why the participants rated space configuration so low. Several – most of which were boys – said they would never use this configuration,

(Q17: P01B, P04G, P06B, P10B, P12B, P23B). From these participants, some responses as to when they would use space sharing were:

Pretty much, almost never, because it was just so complicated. (Q17: P06)

Not really, I mean I could do it when we were right next to [the other person] and we're talking and waiting for everybody, but you don't get enough screen space to really do it. ... I wouldn't really want to do it, it just doesn't seem like a good way to read ... I mean the only time I would want to, is if there was **not** another person to do the network connection with, [and] ... if I were reading by myself. (Q17: P23B)

Probably ... only if we had to. If it was for leisure I wouldn't choose it because it was not easy. (Q17: P04)

These emphatic responses echoed the overall preference of children of which configuration was easy or hard. More examples of comparative responses in favor of the split content configuration are:

Split, because [sharing] was more confusing. (Q18: P09)

Split, because I'd actually be able to read. (Q18: P26)

Split, because then you don't mess each other up. (Q18: P06)

Split, because again it is a lot easier ... because in general you don't have to keep looking over, and you can switch [picture and words]. With the second one it's a lot more complicated (Q18: P12)

Despite the previously mentioned order effect, those who used the split first still rated the split configuration higher than the readability of the space sharing configuration (see Figure 4.8). The order effect emphasizes the difference between the two when the content splitting configuration is used second.

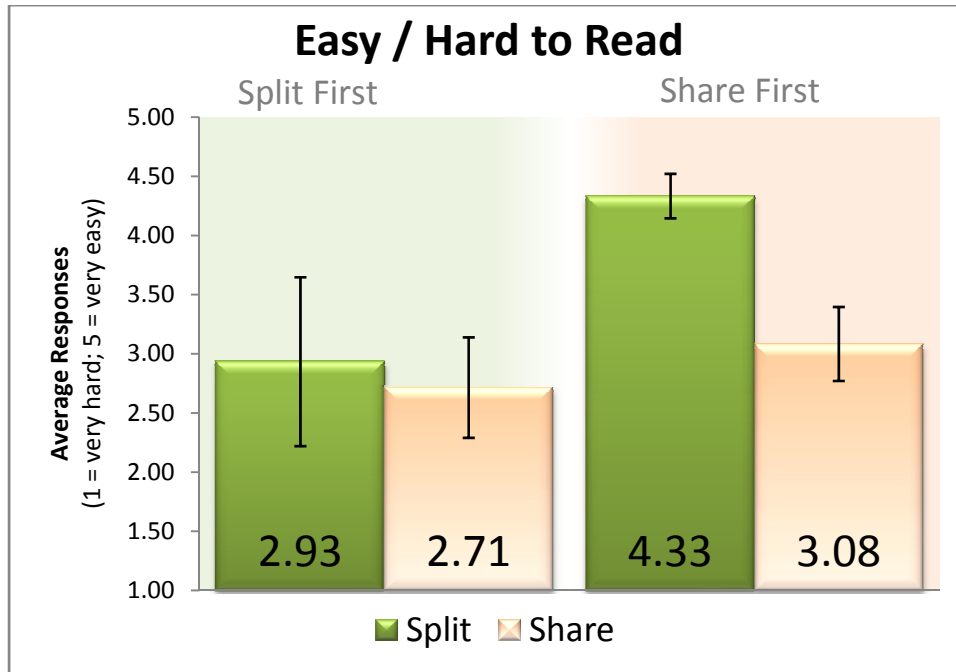


Figure 4.8 – Readability order effect: participants liked content splitting even more if they used the space sharing configuration first.

In direct comparison (Q13), fifteen of twenty-six said that content splitting was easier to read. The reasons given for this choice were the ease in coordinating navigation, the increased awareness (which is discussed further in collaboration, see Section 4.4.1.3.1), because the words were bigger than the previous/next page spread that continued to be used most in the shared configuration (see Section 3.4.3.2.2), and because of the ability to readily switch words and pictures between the phones.

4.4.1.2 Task Completion

For the reading task children were asked to read the story together using the mobile devices. While logs were kept of all of the participant’s interactions, there was a challenge in being able to capture an accurate measure of reading. The principal items of interest were: when the children started reading, and how many pages the children read. While start time appears to be simple, the item of interest is

when they started “reading” (i.e. digesting story content) not when they started the reading task (i.e. the four minute timed reading task). Despite the training and experience the children had before starting the task, the children still did not start the task immediately. Often they would play or experiment with the interface, before they started the task or reading the book together. Using this metric there was an overall difference between the two configurations. The overall averages were approximately 50 seconds for content splitting and 1½ minutes for space sharing. A paired-sample t-test was conducted to compare the reading start times for the different configuration. There is evidence of a significant difference between the split content [$M = 50.00$, $SD = 36.69$] and share space [$M = 87.69$, $SD = 39.40$] configurations [$t(12) = -1.94$, $p < 0.07$].

For pages read, a simple quantification that could have been used would be to use the number of pages dwelt on for a certain number of seconds using log data. This measure however, would not account for the variability in reading speeds, nor would it be accurate because of the collaborative nature of the interactions. Because of these reasons, a more subjective method was used by the coders, where the coders estimated the number of pages read from the video (while also having access to the data logs). The resulting numbers were not exact matches by both raters, but the comparison between the configurations (i.e. group g read more pages using configuration x than configuration y) was consistent. Using this comparative metric, ten of the thirteen groups read more pages using content splitting. Using the average of the coders indicated number of pages read, a paired-sample t-test was conducted comparing the number of pages read using each configuration. There is evidence of a

significant difference between the split content [$M = 5.77, SD = 2.92$] and share space [$M = 3.96, SD = 2.17$] configurations [$t(12) = 1.83, p < 0.10$]. This means that children read more pages using the split content than when using the share space configuration.

P23, a nine-year old boy had this to say about content splitting:

[It was] a little cool, it was efficient the way it was done. You just got more out of it. One person could look at the picture while the other read, and then switch. So it really didn't take more time and then it wasn't like switching the pages. ... It didn't take more time. It wasn't like I was *trying* to read – I could really understand the story. With [space sharing] I actually couldn't read the story at all. I just read a few words out of the text and I sort of made up a story on that one that wasn't at all like this one where I could actually read it. (Q3/8)

[Split content] worked better, it's a lot more efficient, you can really see and read the book. With [space sharing] you can't really read the book. (Q14)

4.4.1.3 Collaboration

In order to investigate the collaborative differences between content splitting and space sharing the different areas of comparison were: awareness, communication, frustration, and navigation wars (as defined above in Section 4.2.2.2.1), and proxemic distances and poses. Each of these is discussed below.

4.4.1.3.1 Awareness

Awareness is a key aspect of collaboration. Q5/10 asked how often the child knew what their partner was doing. A paired-sample t-test was conducted on responses to this question for the split content and share space configurations. There was a significant difference in the scores for the split content [$M = 3.92, SD = 0.84$] and share space [$M = 3.31, SD = 1.26$] configurations [$t(25) = 2.26, p < 0.04$]. In

other words, participants were significantly more aware of their partner's actions while using the split content configuration. A Pearson product-moment correlation was conducted on Q5/10 between paired participants. For this question there was a strong correlation between partnered participants for both the split content [$r = 0.55$, $N = 13$, $p < 0.01$] and share space [$r = 0.49$, $N = 13$, $p = 0.01$] configurations. In other words, there was a mutual understanding of how aware each paired participant was of one another using both of the configurations.

This increased awareness could be due to several factors. Using the split content configuration, on average, participants looked at his/her partner's device approximately 30% of the time, as opposed to space sharing where they only looked 18% of the time. A paired-sample t-test was conducted to compare the amount of intervals participants looked at his/her partner's device for each of the configurations. There was evidence of a significant difference between the amount for the split content [$M = 14.83$, $SD = 13.96$] and share space [$M = 8.77$, $SD = 9.09$] configurations [$t(25) = 1.83$, $p < 0.08$]. Another fact is that the children were always sharing the exact same view (story or the same page), just with either the words or the pictures being displayed. P01 stated this fact simply. When asked which was easier and why he stated: "Split because both [children] were on the same page, so it was easier to tell when you were done" (Q13). This sentiment as to why split content was easier was echoed by other participants (Q13: P04, P24).

4.4.1.3.2 Explicit Communication, Frustration, and Navigation Wars

Overall, there was slightly more task-oriented communication (e.g. planning, coordination) that took place in the split content configuration. On average there

were 7.11 intervals that contained explicit task-related communication versus 6.05 for sharing space. The average number of time intervals is 50 (12, 5-second time intervals per minute, for approximately 4 minutes). This difference was not statistically significant across all participants; however, there were differences in the kinds of other communications that occurred such as frustration.

There was a difference between the two configurations in frustration and navigation wars. A paired-sample t-test was conducted to compare the amount of frustration experienced while using each of the configurations. There was a significant difference in the amount of frustration experienced in the split content [$M = 2.12$, $SD = 2.74$] and share space [$M = 4.31$, $SD = 5.17$] configurations [$t(25) = -3.15$, $p < 0.01$]. This means there was more frustration when using the space sharing configuration than when using the content splitting configuration. Using a paired-sample t-test, the amount of navigation wars by configuration was compared. There is evidence of a significant difference between content splitting [$M = 6.89$, $SD = 7.23$] and space sharing [$M = 13.52$, $SD = 12.68$] when it comes to navigation wars [$t(12) = 1.77$, $p = 0.10$]. Qualitatively, when asked what the partner child was doing, while using the split content configuration, participants stated mostly on-task behaviors, with only three discussing some minor navigation difficulties. On the other hand, when using the space sharing configuration, ten of twenty six mentioned their efforts were thwarted by their partner navigating away from where they wanted or needed to be within the story to complete the reading task.

4.4.1.4 Proxemics, Pose, and Mobility

On average participants were closer together when using the split content [$M = 3.39$] configuration than when using the space sharing configuration [$M = 4.42$]. A paired-sample t-test was conducted to compare the average proxemic distances for each of the configurations. The difference was not significant between the split content [$M = 3.39$, $SD = 2.17$] and share space [$M = 4.42$, $SD = 2.68$] configurations [$t(12) = -1.38$, $p = 0.19$]. While this difference was not statistically significant, analyzing the data further revealed some interesting trends. Figure 4.9 shows the distribution of proxemic distances by configuration. The graph illustrates how when using the split content configuration, children were closer together. Figure 4.10 and Figure 4.11 illustrate one explanation for this difference is that boy's proxemic distances dramatically differed while using each of the configurations. None of the boys were intimately close to each other (< 6 inches) while using the share space configuration; but when using the split content configuration, boys were intimately close approximately thirty percent of the time. A paired-sample t-test was conducted to compare the boys' proxemic distances for each of the configurations. There is evidence to suggest a significant difference between the split content [$M = 5.18$, $SD = 2.60$] and share space [$M = 3.32$, $SD = 2.37$] configurations [$t(6) = 1.85$, $p = 0.11$]. Also, while not significant, the overall average proxemic distances for girls and boys, was 3.59 and 4.25 respectively. This means that, on average, girls were closer to each other than boys while reading.

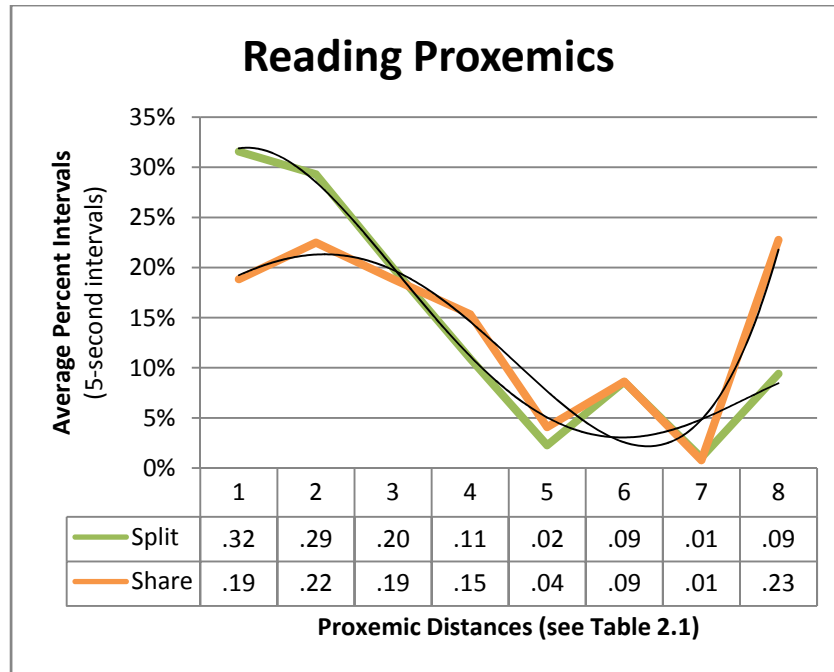


Figure 4.9 – Average reading proxemics for the split content and share space configurations. (1-8 are four categories with each two phases, see Table 2.1)

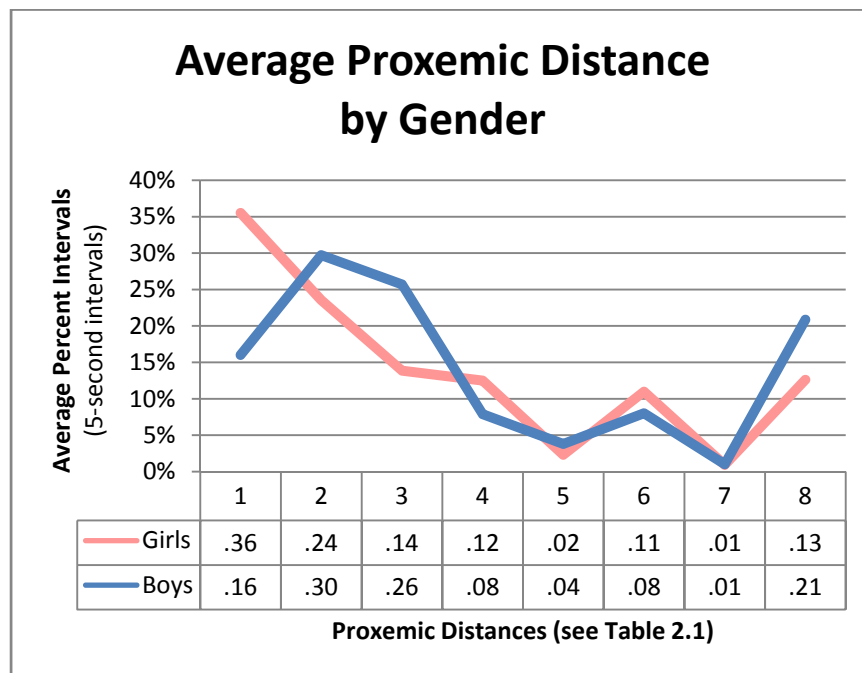


Figure 4.10 – Average proxemic distance by gender while reading.

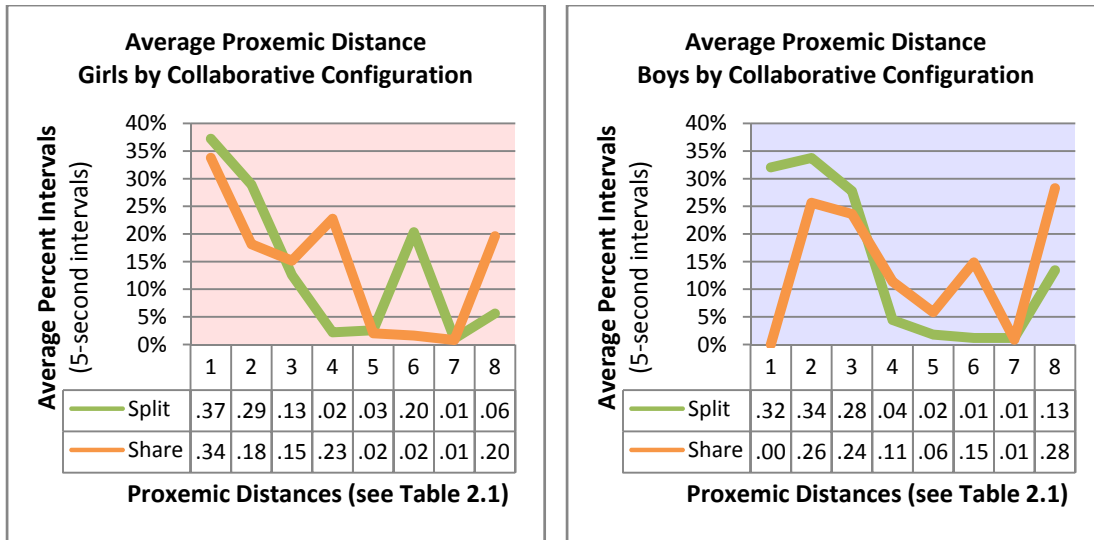


Figure 4.11 – Average proxemic distances by collaborative configuration for girls (left) and boys (right) while reading.

There was another significant correlation between the number of pages read and proximity. A Pearson’s product-moment correlation was computed to assess the relationship between the number of pages read per group and their average proxemic distance. The results identified a significant correlation [$r = -0.45, n = 26, p < 0.03$]. This means that participants who were closer to one another read more pages.

Recall from Section 4.4.1.2 that there is also a significant difference between the configurations for pages read. In order to exclude any bias gender may introduce, and to identify which variable – average proxemic distance or configuration – had the greatest effect on pages read, an ordinary least squares (OLS) linear regression was used to control for the effects of gender on proxemic distance and configuration and the number of pages read. The model uses three independent variables – gender, configuration, and average proxemic distance – and pages read as the dependent variable. In this model, the effect of average proxemic distance is large (-0.41) and significant ($p = 0.06$); the effect of configuration is also large (1.66) and significant

($p < 0.10$). Since the magnitude of the standardized coefficients for average proxemic distance (-0.37) is slightly larger than that of configuration (0.32), average proxemic distance is the more significant factor in predicting the number of pages read. This means that average proxemic distance has more of an effect on pages read than does the configuration that is used.

There were no distinguishable advantages or large differences in pose by collaborative configuration. In general, participants sat approximately 85% of the total time, and were standing for the remainder of the time. Most pairs sat the full time (10 of 13). The exceptions were: G05, where P09 sat the whole time, while P10 stood; G09 where both participants stood most of the time; and, G13 where both participants stood and sat with each other, sitting ~60% of the time. One overall slight difference in pose was that approximately 9% of the time children using split content sat on the floor, while 20% did using share space. This is due to the fact that girls never sat on the floor while using split content. There is no apparent advantage to this difference.

In looking at gender differences among the poses, one difference surfaced. Recall the relative positions of side-by-side, corner-to-corner, and face-to-face that were mentioned above in Section 4.2.2.2.1 and illustrated in Figure 4.3. When participants were close enough to orient themselves to these positions (which occurred approximately 77% of the time), girls were oriented side-by-side approximately 83% of the time versus boys who were oriented this way only 64% of the time. For the remaining 37% of the time boys were evenly split between the corner-to-corner and face-to-face poses. For the girls, they were corner-to-corner

12% of the time, and face-to-face 5% of the time. Even though boys were side-by-side more often than not, this adds to the overall difference between the proximity of boys and girls while collaborating as even when the boys were close they preferred a corner-to-corner or face-to-face configuration which is not as intimate as a side-by-side orientation.

There were no distinguishable differences in mobility by collaborative configuration. On average, participants only moved during approximately 7% of the time intervals (on average 3.56 of the ~50 time intervals). They generally went to one location and remained there for the duration of the reading task, although there were exceptions to this rule. The few exceptions only changed locations a maximum of three times.

4.4.1.5 Summary

A summary of all the comparisons is presented in Table 4.3. As noted, the units of measure for each are different. For more detailed description refer to the corresponding sections above. What the table presents is that in the study performed described and analyzed herein, there were numerous cases, where there is a preference or benefit to using the content splitting configuration. Some of the comparisons are ratios, and cannot be compared statistically. For those that are not ratios, if they are significant the appropriate confidence level (α) is indicated.

Table 4.3 – Comparison summary of content splitting and space sharing.
 (* $p < 0.10$; ** $p < 0.05$; †ratio)

Category	Content Splitting	Space Sharing	Unit
Overview			
Overall preference [†]	16	10	Count (Participant)
Used to share story [†]	20	6	Count (Participant)
Easier to ...			
Read*	3.62	2.88	Rating (1-5)
Use [†]	15	11	Count (Participant)
Task completion			
Start reading time*	50	87	Seconds
Read more pages [†] /*	10 / 5.77	3 / 3.96	Count (Group)
Collaboration			
Awareness**/*	3.92 / 30%	3.31 / 18%	Rating (1-5) / % Time
Communication	7.11	6.05	Count (Intervals)
Frustration*	2.30	4.09	Count (Intervals)
Navigation wars*	6.92	13.07	Count (Intervals)
Reading proxemics	3.39	4.42	Closeness (1-8)
Mobility	3.85	3.27	Count (Intervals)

4.4.2 Relative Advantages and Disadvantages of Each Configuration

Despite the benefits in favor of content splitting discussed above in Section 4.4.1, participants and researchers noted advantages and disadvantages of using content splitting and space sharing (Q1-10). This section discusses those pros and cons individually and concludes with another direct comparison using data and quotes from the reading comparison questions (Q12-14). Corresponding participant comments have been clustered and grouped using the interview coding scheme described in Section 4.2.2.2.2.

4.4.2.1 Split Content

As for some of the cons of splitting content, several participants noted splitting content was hard because you had to look at both devices (Q2/7: P08, P19, P20, P25). Another issue was that it was more difficult if they were not close to each other. Once they were closer to one another they could hear one another better and it was easier (Q2/7: P05, P17). Two people mentioned difficulties navigating (Q2/7: P12, P21) when asked about why split was difficult, but this number of people was minimal compared to the number who reported difficulties in space sharing (Q2/7: P01, P02, P04, P07, P09, P12, P16, P18, P21, P26). One person said it was hard to navigate because they were connected (Q2/7: P21). Also, it was observed that navigation wars were often started by the person who had the pictures (G03, G05, G06). It appeared to the observers that the children who were done, or became bored with the current picture, would change the page before their partner finished reading the words on that page.

Despite being a frequently reported challenge that both that participants needed to look at both phones, one participant stated an alternate positive view which was echoed by other participants as well (P22):

[Reading with content splitting was] easy because if you held the phones next to each other, you could glance at the picture, then read the whole thing together. And then glance at the picture again and then turn the page. ... [In this way] it would be perfect, and you wouldn't get in the way of your partner. (Q2/7: P06)

Another participant noted the virtues of reading using content splitting:

[Reading with content splitting was] very easy because it's a small screen but we each got to see a different part of it so it made it bigger. But then we were both connected – because with the network connection when one person [went from] one page to the next it moved it so the other person didn't have to do a thing. (Q2/7: P23)

It was also noted that switching was not only cool, but important to be able to work with a partner (Q3/8: P16, P19, P21, P23). P21 stated: “it was just like, really cool how they worked together and if one had the pictures and one had the words, so if you put it together you could see both.”

4.4.2.2 Share Space

The space sharing configuration overall was preferred less, but that does not mean it was without appreciation from users. Foremost was that both the picture and words can be seen on one device (Q2/7: P17, P21, P25; Q17: P24; Q18: P17, P21, P22, P24). As found previously (see Section 3.4.3.2.2), participants most frequently used the two-page spread view while reading (except for Groups 06 and 08), so they could still see both the words and the pictures.

Despite this advantage other disadvantages were mentioned such as difficulties when zoomed in to just the words (which were spread across both phones) and navigating. When words were shared across both the phones, it was mentioned that “if you don’t have them close, or right up against each other you don’t know the words” (Q2/7; P11). This group overcame this difficulty by the participant who struggled asking for help and the other participant helping him understand what the word should be.

Several participants mentioned getting lost or confused (Q2/7: P01, P02, P04, P07, P09, P12, P16, P18, P21, P26) while using the share space configuration. It was also noted that it was “hard to figure out which one is on which side” (Q2/7: P02), as well as when to coordinate turning pages (Q2/7: P01). Three people had no idea what their partner was doing while they were collaboratively reading using the share space

configuration (Q4/9: P05, P06, P07). When asked what their partner was doing, ten of the twenty-six participants said their partners would navigate away from what they wanted to see (i.e. navigation wars); compared to split this is significantly different where only three mentioned it. This is highly due to a real and or perceived difficulty in coordinating navigation using the space sharing modality.

Despite general navigation difficulties while space sharing, Group 10, found coordination easy. P19 said it was: “very easy because you could just read it and then the other person reads the next page, and then you flip it and then the other person reads the next page, so all you have to do is flip the page” (Q2/7); his partner, P20, concurred saying: “I liked how we each got to share and we both had to do our own part reading out loud” (Q3/8). P11 stated that space sharing was “very easy ... because they were together and it looked like a book with a crease down the middle and it was kind of neat.” Another participant liked the difficulty because it was more challenging. “[Space sharing] was pretty cool because it’s more of a challenge ... [content splitting] was easy but it was still cool” (Q3/8; P24). And P18 mentioned “... it was a different way than just reading a book you had to really cooperate with the person you were with, you really had to do it [together] (motions back and forth)” (Q3/8).

4.4.2.3 Comparison

From the interview data, it appears as though the number one concern for the reading task is coordinating page changes. Nine participants said this was easier in the split content configuration than in the share space configuration (Q2/7: P04, P07, P09, P10, P19, P22; Q13: 01, P24; Q14: P12, P24). “Split content ... was easier

because ... we'd know when we were done" (Q13; P24). "[Split content is easier] because you're both on same page, so it's easier to tell when you were done" (Q13, P01). "Split content ... was a lot easier [because] you knew what your partner was doing and you [didn't] have to read very close [to one another]" (Q14; P12). "Split content [was easier] because we'd always be on the exact same page" (Q14, P24). On the negative side, fifteen reported getting confused/lost or having navigation difficulties while using the share space configuration; eight mentioned some of these problems in the content split configuration.

Switching was noted to be important to support particularly for the split content configuration (Q3/8: P11, P16, P19, P21, P23). Two reported difficulty coordinating this with their partner (Q3/8: P11, P19). P21 stated of the switching configuration:

[Split] ... wouldn't really be as cool if you couldn't change it to [be] different, if you had to stay at the same thing. But I like that you could change it [switch words and pictures] when you're finished. It wouldn't be as cool if you could only stay with the words and they could only stay with the pictures. (Q14: P21)

Of those who preferred the share space configuration, two noted that switching made the split content configuration more difficult (Q18: P17, P21). For the shared configuration switching was not used, apparently the children did not grasp the concept of switching sides as they did switching pictures and words. While using the space sharing configuration there were several instances where the children just physically swapped places instead of using the "switch" button to change sides. P02 was the only person who mentioned it was "hard to figure out which one [was] on which side" (Q2/7).

Split content was appreciated for its efficiency. Consider the following two

quotes:

Split, well the first way [share] was hard even though you had both [the pictures and the words]; the second one was a little easier because, since because, um ... since she was looking at the pictures and I was reading, she had enough time to look at the pictures while I was reading the [words] (Q12: P21)

Definitely split, because it works a lot better, you basically have a full book, bigger pictures, bigger words, you aren't missing read the book, you can read the full book and it doesn't waste time because one person's looking at the pictures while the other person is working at reading the words (Q12: P23)

The relative advantages and disadvantages as derived from the themes described above of each are compiled in Table 4.4.

Table 4.4 – Advantages and disadvantages of the split content and share space collaborative configurations.

	Split Content	Share Space
Advantages	“Simpler”/easier (to coordinate, navigate)	See the pictures and words
	Bigger words (than just previous/next on sharing)	Bigger words (if zoomed into words)
	Not across two phones, need only focus on one phone (for words or picture)	You can just read without having to look over partner’s shoulder
	Fewer navigation problems	Like a book (with a crease down the middle)
	Could switch between pictures and words	If read out loud every other page, it’s easier
Disadvantages	Had to look at both devices	More difficult to navigate, confusing, got lost
	Had to be close to your partner; which conflicted with others who said you did not need to be as close	Words smaller (in previous/next page view; which was the view most frequently used)
		Hard to know which should be on which side

4.4.3 When to Read Using Mobile Devices for Each Configuration

Given that each configuration has its relative advantages, the question is left as to when each configuration should be used. The following are suggestions from

participants (Q2/7, Q16-18) about when they would choose to use each of the two configurations, followed by a summary in Section 4.4.3.3.

4.4.3.1 Split Content

For splitting content participants noted it would be best in situations where one would prefer to see either the pictures or words. This was mentioned as a simple preference (Q16: P21, P22, P24) as well specifically in mentoring situations such as reading with younger children (Q16: P13, P16). Some representative quotes are:

If someone really liked the pictures and they just loved looking at details, and someone liked to read a lot. (Q16: P22)

... like my little sister she's four. She doesn't know how to read. She can get the picture one so it's easier for her. (Q16: P16)

Other comments related to proximity of pairs – working close together (Q16: P17, P20) and far apart but where both can hear (Q16: P18). P20 said he would use content splitting “when you had both of the phones together and both the people were there ... [when] both the phones were in the same place at the same time.” P18 explained that the role assignment provided by content splitting allowed for some flexibility in distance as long as you could hear one another. He said:

If you are a decent distance away, where you can still hear each other, but you can't see each other. ... Because if you're reading it you get a lot more out of it and you can picture it, but when you're looking at the picture it can be easier to imagine it and what you are doing (Q16: P18)

Another comment pertained to heterogeneous device pairing. P19 stated, when asked when he might use content splitting:

When there's like a big screen so that, like, you can see what the other person is doing or reading. [If I had a bigger screen and smaller screen], I'd put the words on the bigger screen and the picture on the smaller screen. (Q16: P19)

This suggests that in such cases where one device was larger than the other, that the words should be on the larger screen and the picture on the smaller screen. Space sharing could have several pitfalls in this situation. By using the splitting content concept, users can choose which part of the content or interface they want on which device, thus enabling a larger range of flexibility.

4.4.3.2 Share Space

Sharing the space was deemed best for when both wanted to see the text and pictures on one device at the same time (Q2/7: P17, P21, P25; Q17: P24). It was also mentioned as possibly suitable for when reading “with someone who reads just as well as me [or an individual], or better” (Q17: P13).

Proximity too was mentioned as an important situation when to use this configuration. You should use it “when you’re close together, because there’s not really any way you can do it when you’re far apart” (Q17: P17). Being able to hear or speak to one another was also identified as a prerequisite [“when we could both be able to speak to each other” (Q17: P20)].

4.4.3.3 Summary

Table 4.5 summarizes the situations or scenarios when each collaborative configuration might be used.

Table 4.5 – When to use each collaborative configuration.

Split Content	Share Space
When someone prefers pictures or words	When want to see both the picture and words at the same time
When reading with someone younger, smaller	When reading with someone who reads as well as you or better
When close together	When close together, because you can't really do it when you're far apart
When separated but can still hear each other	When able to speak to one another
When using heterogeneous devices (e.g. devices of different sizes)	

One final suggestion of when to use each configuration was offered by a nine year-old girl. In response to “how would you prefer to read together with someone”, she said:

I think it depends on my audience. Like, if my audience was my little brother than I'd want to read [splitting content], but if it was [my friend] then I'd want it to be [sharing the space]. (Q18: P13)

4.5 Mobile Collaboration While Creating a Story

The formative findings of Section 3.4.3, that suggested the collaborative modes were primarily used for sharing were confirmed in this study. In fact, only two groups used either of the collocated collaborative configurations while creating their story. Both of those groups were groups of girls who used content splitting: one only for a short period of time (~30 seconds, G11), and the other, for the full duration of the story creation task (~15 minutes, G07). Of the other groups seven of them explicitly decided via verbal discussion to use the synchronized data mode where they could work independently without navigation being synchronized, but still work on the same story (G01, G03, G08, G09, G11, G12, G13). The other groups made no audible or explicit decision but used the synchronized data mode for the full time.

One group (G10) noted they considered trying out the space sharing configuration, but ended up not doing so.

In the interview questions, eighteen of the twenty-six participants stated that the synchronized data mode was the easiest way to create a collaborative story (Q24). (The others were equally split between the genders and the two other configurations with two undecided.) It seems the reasons for that preference was that the children could work on different parts of the story at the same time (Q24: P01, P22, P23, 24) and that it was the least confusing (Q24: P18). Another reason was because participants noted they could elaborate easily this way. Consider the following quotes:

[Synchronized data] because then you just work together and then you ... so it's like you do one thing, you give it to your partner and your partner builds off of that to match it. (Q24: P06)

[Synchronized Data] because if [P12] took a picture, I could write the words for it, and if I took a picture [P12] could write words for it. (Q24: P11)

I think it worked better when we were working alone, because we were sort of working together. I was working mostly on the words, and he was working mostly on the pictures. So we could have done it that way [splitting content], but I just think that it was probably easier to do it that way because we could add things [independently]. (Q24: P23)

In all, after having used all of the collaborative configurations (synchronized data, content split, and space sharing), synchronized data [$M = 3.85$, $SD = 1.26$] was indicated as the overall preferred method, followed by content splitting [$M = 2.65$, $SD = 1.29$] and space sharing [$M = 2.54$, $SD = 1.45$] (Q28-30; see Figure 4.12). Pair-wise comparisons using paired-sample t-tests were conducted for each of the three questions. There was a strong significant difference between the synchronized data

and split content [$t(25) = 3.01, p < 0.01$], and synchronized data and share space [$t(25) = 2.98, p < 0.01$] configurations. This means that overall there was a strong preference for the synchronized data configuration while creating a story.

Despite this preference, children collaborated in ways that correlated to those of the collocated collaboration configurations of content splitting and space sharing. For example, children would divide roles into photographer and writer, and occasionally switch, which would have formally been available via the content splitting collaborative mode. Children would also coordinate working on one page and the other on the next which could have been accommodated by the space sharing configuration. Children spontaneously entered into these collaborative modes through verbal coordination, yet did not use the structured collocated collaborative modes that were provided in the interface. The automatic data synchronization made the entering of these roles seem seamless.

Gender preferences are shown in Figure 4.13. Pair-wise comparisons using paired-sample t-tests with each gender and two-sample t-tests across the genders were conducted for each of the three questions for boys and girls. The boys liked synchronized data [$M = 4.07, SD = 1.03$] most [split: $t(14) = 4.74, p < 0.001$; share: $t(14) = 2.75, p < 0.02$], and split content [$M = 2.13, SD = 1.13$] and share space [$M = 2.40, SD = 1.72$] were indistinguishable. In reference to split content, girls [$M = 3.36, SD = 1.21$] liked it more than boys [$t(24) = 2.67, p < 0.02$].

In comparing the two collaborative configurations, content splitting had many observed and stated advantages over space sharing. First, content splitting was the only collocated collaborative configuration used while creating a story. Second,

space sharing was identified by seventeen of the twenty-six as the configuration that would be the hardest to use while creating a story.

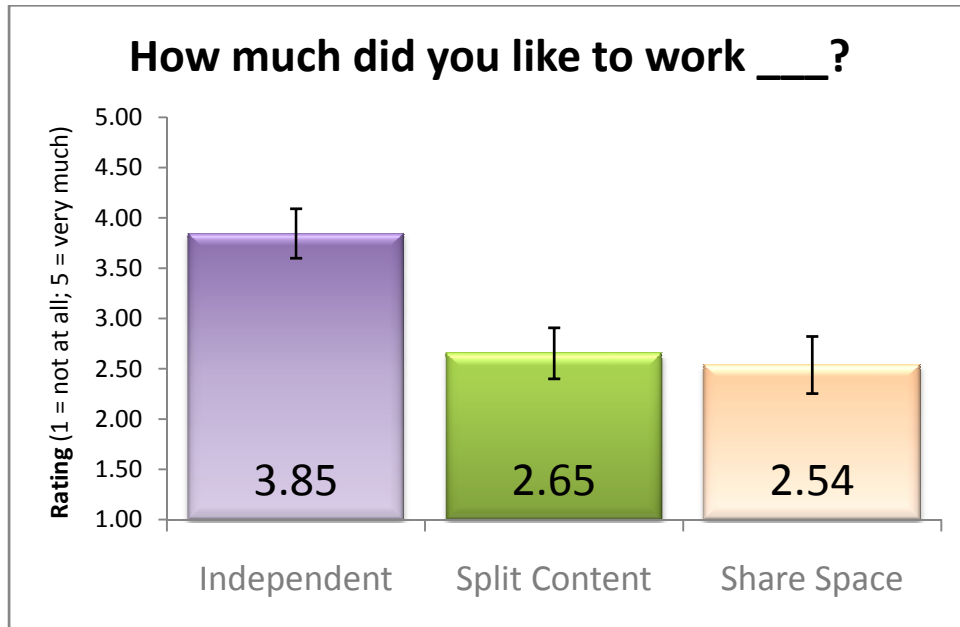


Figure 4.12 – Average of how much participants liked using each of the collaborative configurations (Q28-30; 1 = not at all, 5 = very much) after creating their stories.

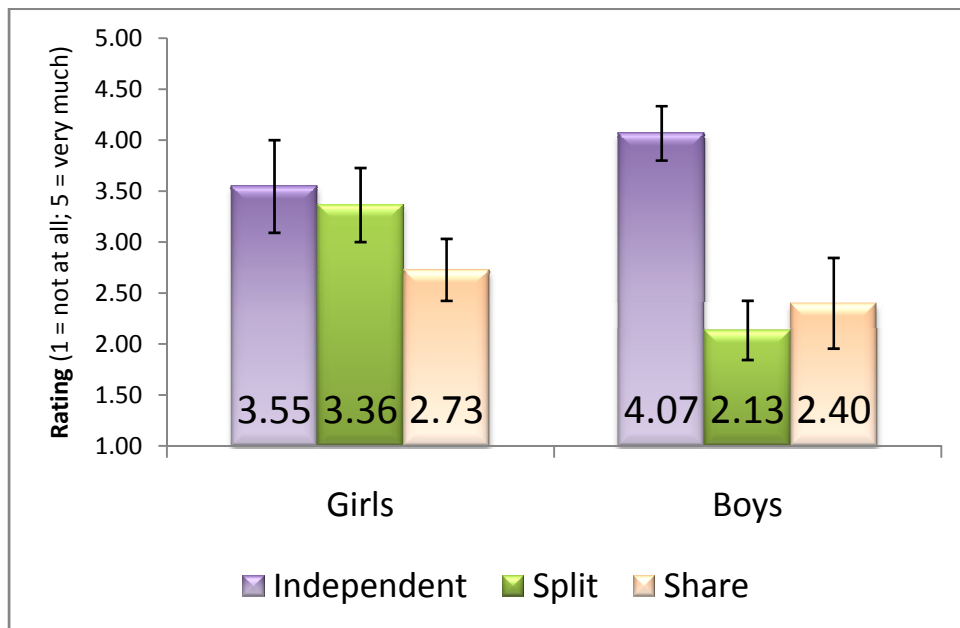


Figure 4.13 – Average of how much participants liked using each of the collaborative configurations (Q28-30; 1 = not at all, 5 = very much) by gender after creating their stories.

4.5.1 Proxemics and Mobility

Overall, participants moved around more frequently while creating the story as compared to when they were reading the story. To examine this, a paired-sample t-test was conducted using the video coding for mobility for reading and creation. Values were normalized as the length of times for the tasks were different (a total of 8 minutes for reading tasks, and 15 minutes for the creation task). There was a strong significant difference in mobility or movement between the reading [$M = 0.0688$, $SD = 0.0393$] and creation [$M = 0.2922$, $SD = 0.1969$] tasks [$t(23) = -5.80$, $p < 0.00001$].

In the reading portion proxemics distances differed between the genders (Section 4.4.1.4). There was also a difference in the creation task; Figure 4.14 shows the average proxemic distances by gender. Using a weighted average of each group's proxemic distance, a two-sample t-test was conducted to compare proxemic distances by gender. There was a strong significant difference between girl [$M = 3.75$, $SD = 1.50$] and boy [$M = 7.31$, $SD = 1.67$] groups [$t(9) = 3.73$, $p < 0.01$]. This means that, on average, girls were significantly closer than boys while creating their stories.

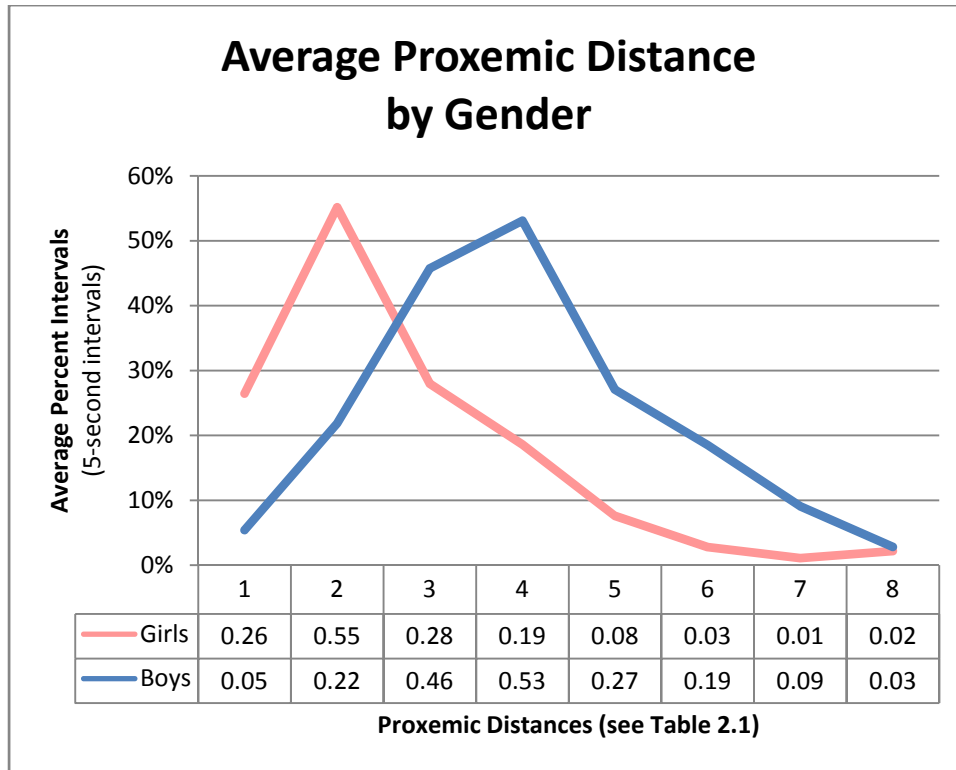


Figure 4.14 – Average proxemic distance by gender while creating a story.

While both boys and girls did move around in the study space, boys moved significantly more than girls. A two-sample t-test was conducted to compare the average movement between boy and girl participants. There was a strong significant difference in the mobility of girl [$M = 13.66$, $SD = 8.18$] and boy [$M = 38.13$, $SD = 17.13$] participants [$t(16) = 4.38$, $p < 0.001$]. This means that girls moved during 13.76 of the ~90 10-second time intervals (~15%), while boys moved during ~38.4 of the intervals (~42%). Figure 4.15 illustrates the average proxemic distances over time (during each coded 10 second interval), and graphically shows the interplay between proximity and mobility as well as the differences between girls and boys.

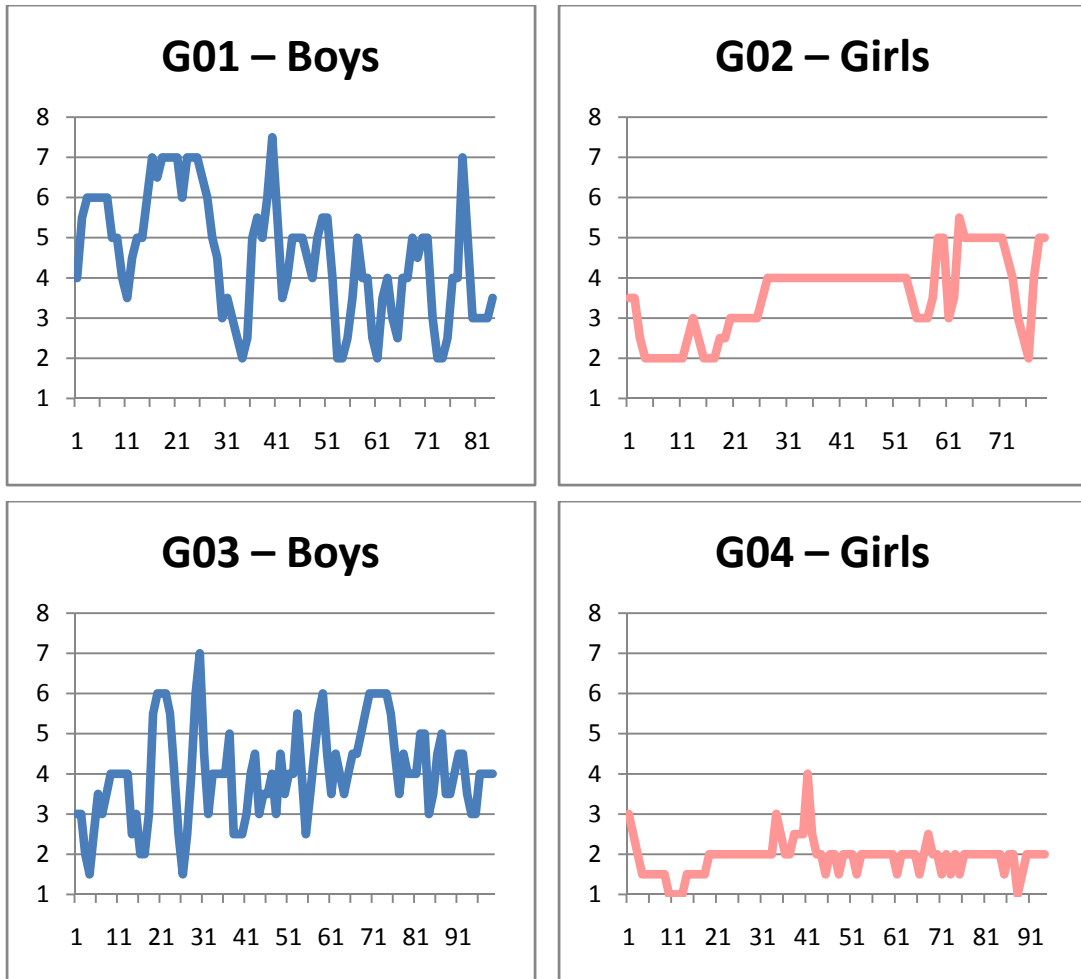


Figure 4.15 – Representative gender differences in average proxemic distances (vertical axes, see Table 2.1) over time (horizontal axes, 10-second intervals) while creating a story: *left*, boy groups; *right*, girl groups.

Girls tended to come closer together in one place for longer periods of time. The relative closeness and immobility exhibited by the girls is one explanation as to why the girls used a collocated configuration (content splitting) while creating a story and the boys did not. The results from the reading task illustrate how those who were closer had an easier time collaborating with one another. The relative distances between partners and the overall mobility while creating the story differed from those that occurred while reading. Being mobile and not as close are some reasons as to why the collocated collaborative modes may not have been used.

A crude measure of task completion for the creation task is how many pages were created. A Pearson product-moment correlation was conducted on the number of pages created and the average proxemic distance of each pair. There was a strong, significant correlation between these two variables [$r = 0.82$, $N = 11$, $p < 0.01$]. This means that for the creation task, pairs who were on average further from each other, created more pages. Recall how this is the opposite correlation found for the reading task where pairs who were closer were able to read more pages (Section 4.4.1.2). This difference provides another possible reason as to why the collocated collaborative configurations were rarely used during the creation task. The one group that used the split content configuration while creating their story had an average proxemic distance of 1.59 or within the intimate proxemic distance category, and they only edited one page in the fifteen minute period allotted for story creation.

There was also a relationship between number of pages created and mobility. A Pearson product-moment correlation was conducted on the number of pages created and the average mobility of each pair. There was a strong, significant correlation between pages created and average mobility [$r = 0.66$, $N = 11$, $p < 0.03$]. This could be due to a relationship between mobility and proxemic distance. There was such a strong relationship. A Pearson product-moment correlation was conducted on the average mobility and proxemic distances of each group. The result revealed a significant correlation between mobility and proxemic distance [$r = 0.90$, $N = 11$, $p < 0.001$].

In order to exclude any bias gender may introduce, and to identify which variable – average proxemic distance or mobility – had the greatest effect on pages

read, an ordinary least squares (OLS) linear regression was used to control for the effects of gender on proxemic distance and configuration and the number of pages read. The model uses three independent variables – gender, configuration, and average proxemic distance – and pages read as the dependent variable. In this model, the effect of average proxemic distance is large (0.86) and significant ($p = 0.04$); the effect of mobility is not significant ($p \approx 0.36$). This means that average proxemic distance is a better predictor of how many pages will be created. This finding is similar to that of the reading task where average proxemic distance was an indicator of greater task completion (pages read).

4.5.2 Collaborative Stories

The task given to the paired children was to create a collaborative story. Table 4.6 shows an overview of the changes made by each of the participants, on each page, for each media type (words and pictures). This table illustrates how some groups elected to strictly divide the task into the roles of pictures and words (G03, G04, G07), while others used a looser role division by media type (G01). Some groups divided the task by page, so one participant would have primary responsibility for a certain page or pages (G06, G10, G13).

Table 4.6 – Changes made to words and pictures by each participant. A is the odd numbered participant in the group (e.g. P07 in Group 04); B, the even (e.g. P08 in Group 04).

	Gender	Media	Page 1	Page 2	Page 3	Page 4	Page 5	Page 6
Group 01	MM	Words		A		A		A
		Pictures	A		BBA		B	
Group 02	FF	Words	BB			A		
		Pictures	B		B	B		

	Gender	Media	Page 1	Page 2	Page 3	Page 4	Page 5	Page 6
Group 03	MM	Words	AAA				A	
		Pictures	B	B	BB		BB	
Group 04	FF	Words	A	A				
		Pictures	B					
Group 05	MM	Words	AB	AB	ABBBAB	BAB	B	ABB
		Pictures	BA	B	B	B	A	B
Group 06	FM	Words	AB	A	BBB	ABA	A	
		Pictures	A	A	BB	B	B	
Group 07	FF	Words	B					
		Pictures	A					
Group 08	MM	Words	A	BB		BA		A
		Pictures	A		BA	A		
Group 09	FF	Words	ABBB	A	BA	B	A	
		Pictures			A	B		
Group 10	MM	Words	B	A	B	A		
		Pictures	A					
Group 11	FF	Words	B	ABA	AA		BBA	
		Pictures	A			B		
Group 12	MM	Words	BB	A	AA			
		Pictures	B	B	ABA			
Group 13	MM	Words	A	BBBB	AAAA			B
		Pictures	A	B	A	B		

While several groups demonstrated collaboration, a few individual cases are presented in the following subsections. The cases show: the use of content splitting, creating a story serially by first doing the pictures and then the words, and lastly an exemplary collaborative experience. The second case also illustrates a highly competitive group – where conflicts (malicious overwriting) arose during story creation.

4.5.2.1 Case #1 – Content Splitting (Group 07)

Group 07 (G07) used content splitting the whole time they were creating a story. They were very close to one another for a little more than twelve of the fifteen minutes, or ~81% of the time. Throughout the duration of the task P14 had the words and P15 had the pictures. P13 mostly sat talking about the story and helping P13 type by showing and telling her where the different buttons were on the keyboard. P14 painstakingly added different ideas, changed her mind, and then re-added words to the page. She also tried to be meticulous with spelling, punctuation, and capitalization, which greatly slowed her typing. With these contributing factors, even though in their discussions they planned an intricate and elaborate story, during the full fifteen minutes, they were only able to work on and almost complete one of the pages (see Figure 4.16).

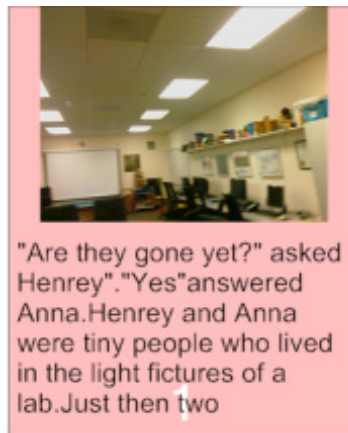


Figure 4.16 – Group 07’s collaborative story.

4.5.2.2 Case #2 – Pictures Then Words; Competitive Captions (Group 05)

Group 05 (G05) was highly engaged throughout the fifteen minutes, but their interactions can probably best be described as competitive. During the first five minutes P09 and P10 each added pictures to the story – P09 adding five, and P10

4.5.2.3 Case #3 – Collaborative (Group 10)

The collaboration between the partners in this group was characterized by lots of verbal communication with one another. First, the two participants had a discussion about what they wanted to do with their story before they even started. Some examples of their communication once they started are: “I’m going to take a picture” (P19), “I’m going to add words to this first page” (P20), “I’ll add words to the second page” (P19), “OK, now I’m going to start the second page” (P19). Also, even though they coordinated and were working in parallel, they would read their page out loud to the other after they had completed their page. In the allotted time, the group completed a title page and three pages. The final story is displayed in Figure 4.18.

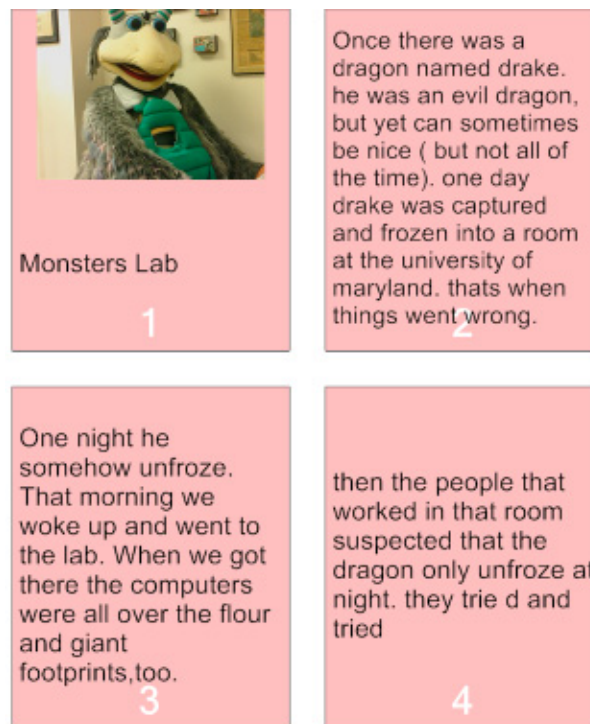


Figure 4.18 – Group 10’s collaborative story.

4.5.3 Overall Observations

Creating the story was the most energizing and collaborative portion. There was a notable excitement during and after the fifteen minute period of creating a story. In fact, all of the groups wished they had more time to add more to their stories. A few of the participants were very excited about the ability to read and create stories and expressed how they really wanted to keep the devices (P8, P9, P10, P15, P16, P22). Two of the children offered to trade their Nintendo DSs for the mobile phones (P15, P16).

Even though sharing was discussed mostly in Section 4.4, it is important to mention here a brief note about the sharing – as similar excitement was expressed about sharing their stories. For the most part the children were very excited about sharing their stories; the only reason children were not excited seemed to be because they had not finished as much of their story as they had liked. For some, sharing stories included sound effects, and dramatic readings and actions. Children also were excited to share their stories with others, asking if they could take their stories home to show their parents.

4.6 Reading and Creating Stories on Mobile Devices

After using the technology, there were several general remarks made about reading and creating collaborative stories. There was universal approval of how cool the technology was. Several participants recognized that one of the advantages of digital books is that they are portable and mobile. They liked the idea of having multiple books available on devices. For example, two participants stated:

... It's a good portable way to have a book, because you can store lots of books on phones and you could have a huge pile of books and store it on a phone that wouldn't be heavy to carry like on a vacation, but then you could just read it. (Q3/8: P23)

It was fun. It's a lot easier than reading a book, because in the book it's probably a lot more pages, but on that they turn it into one little page, and in a book you'd ... it's probably a lot heavier and you'd have to lug it around. But with that [Mobile Stories on mobile phones] you can just stick it in your pocket. (Q3/8: P12)

Several participants commented on the navigation. P14 stated it succinctly: "I liked the way I could move around the pages" (Q3/8). This was in reference to the finger swiping motions for previous and next pages, and zooming in and out. Participants used all of the different ways of navigating: the finger swiping motions, the physical buttons, and the virtual buttons in the menu. One interesting point made by another participant was "it's easier because you don't have to turn the pages, you don't get paper cuts, and you don't skip pages" (Q3/8: P04).

The remainder of this section address the different times, locations and circumstances that participants reported they would use Mobile Stories to collaboratively read (Q15) or create stories (Q26). The final subsection (Section 4.6.3) discusses the projected frequency of use that participants reported during their individual interviews.

4.6.1 When to Read a Story Together

Participants noted they would read a story with someone at different locations such as school (Q15: P02, P03, P07, P10, P12, P15, P20, P22), or in a car or bus (Q15: P16, P20). Four said they would read collaboratively if and when they were bored (Q15: P06, P17, P18, P22). One child expressed that he would do it: "almost any time. If it was on regular phones I would probably do it a lot. And, depending on

what stories there were I'd do it by myself" (Q15: P05). This response implies he might be more interested in reading more books with a collaborator than individually.

Four participants identified specific collaborative advantages to reading with others (Q15: P04, P18, P19, P23). One child recognized the power collaborative reading could have in mentoring situations. He said he would want to collaboratively read:

When there's a book to read together, a book to share, a book to talk about, you know. ... Like some books that really can be taught, actually like books that really have sentences and stuff. Only if you have a system like this, where you have pages on either side and you have to have cell phones to read them, this is a good system. ... But when you just get a book out of the library – even a book like this – you just sort of want to read it on your own. It's not really a share book. ... But I think this way is really a good way to do it though. If you have to read a book on a small device this is the best way to do it. It worked with pictures on one, and words on the other [splitting content]. (Q15: P23)

Another child identified that reading together could help her overcome any challenges she may run into while reading.

When I was reading something that is challenging for me and I might need help on the book and understanding what I am reading. I might just want to read with someone if I am reading for entertainment and I am a little bored. (Q15: P18)

Another identified with this collaborative work response from a slightly different perspective by saying he would collaboratively read "so that you can ... um, like, not do all of like the work. You have another person to, like, help you." (Q15: P19) One participant identified the primary reason the collocated collaborative reading modes were developed when he said he would collaborative read with someone "if there was something that [he] wanted to show to someone" (Q15: P24).

4.6.2 When to Create a Story Together

Eleven participants indicated they would collaboratively create a story: a lot, whenever they had time, whenever they were bored, or in their free time (Q26: P01, P02, P05, P06, P07, P15, P19, P22, P23, P24, P26). Two quotes from this group emphasize the importance of supporting mobile collaboration as the children express they want to create the stories they make *in situ*.

At a time I was bored and didn't know what to do, or something. It's also useful whenever you're waiting for something, because then you can do, like a story, and you can take a picture and you can make a story really easy and you can have a story *with that setting at the place you're at*. (Q26: P05, emphasis added)

[I'd create a story] when I'm bored; when I want something fun to do. But it's fun to create them, you know, on a phone because then you don't have to write it down or draw the pictures. You can just take them and *build the story right there*. (Q26: P23, emphasis added)

Others mentioned they would create stories on the weekends (Q26: P07, P11, P12). Various locations were mentioned such as school (Q26: P03, P10, P12, P13, P20, P21, P25), home (Q26: P07, P13, P17), and the library (Q26: P15). A couple mentioned it would be nice to felicitously use it when you were bored and had to wait for something, like when you were at the doctor's office (Q26: P05, P22). Others still noted how it would be nice to use spontaneously when you and/or your friend had a great idea (Q26: P16, P18, P24).

Only a few mentioned expressed negative feelings about creating a story with someone (Q26: P08, P09, P12). P08 stated "it's easier for me to work on it by myself so I get in my own ideas." One was not sure when he would use it, another said he would never do it. For the most part, however, there was broad enthusiasm about

creating stories together on a cell fun. P12 enthusiastically stated: “Any day; that was fun! ... Really [I’d do it] pretty much any time”.

4.6.3 Frequency of Use

During the interview, children were asked how much they would like to read or create stories alone or with someone else. Responses were on a five-point scale where one meant not at all, and five meant very much. The median response for all of the four combinations (read alone, read with someone, create alone, create with someone) was a four, which meant they would like to do each of those activities. Children were also asked at what frequency they thought they would do each of these tasks. The median response for reading alone was 2-3 times a week, and for the rest it was once a week.

4.7 Paper versus Digital

The relative collaborative advantages of paper versus digital systems have been addressed in other studies that have shown that awareness is increased, as well as elaboration [81]. The collaborative story study design does not address this question. However, participants were asked what their preference would be and why between using paper or mobile phones while reading (Q21) and creating stories (Q47). The overall preferences for reading was 7:1:16 (paper:same:cell), while for creating it was 5:19 (paper:cell). This section summarizes the answers given by the participants.

4.7.1 Reading a Story Together

The primary reasons for preferring paper were issues of control, ease in reading, and physical affordance. Of twenty-four, seven preferred paper all of which stated it was easier to read that way (Q21). Some specified this was because the words were bigger or the pictures clearer on paper (P13, P21, P23), or that the phones size was smaller than that of paper (P23, P24). Two reported that paper was easier to control (P08, P18). P18 stated her preference to be paper “because on a cell phone if you accidentally press a button you pressed the button and you made a mistake. On paper there aren’t any buttons to get confused about.” P08 stated she thought paper was easier to control, because:

It feels easier, because I’m controlling it. I’m not exactly controlling a cell phone. I’m controlling how fast I read. [F: What makes you feel like you’re not controlling a cell phone?] Because I’m turning the pages with paper and I’m not really turning pages with a cell phone. You’re not feeling the book.

This notion of physical and sensorial affordances was also expressed by P13 who stated:

I like feeling the paper. And sometimes, um, like new books really smell good. They smell like new pencils which I really like.

The majority stated they would prefer to read a book using a cell phone (17 of 24). Most of the responses stated the reason being it is fun, new, interesting, cool, different, and/or modern to read a book on a cell phone. One stated the ability to read it easier because the cell phone has “good handwriting” [clearly typed letters] (P20). Some made statements that contrast the physical affordance comments made by those who preferred paper. One stated they like a cell phone because they could “hold it up close with one hand”, whereas they could not do that with paper (P14). A few noted

how physical and digital affordance made control (navigating through the book) easier on the cell phone. For example, using a cell phone you can turn the page with one hand (P07, P09); and in a paper book the pages stick up and you have to hold them down (P05). A cell phone is easier to find than a piece of paper (P24), and it is mobile (P05). With a cell phone, “you can just stuff it in your pocket” (P10) – something you could not do with a paper book.

4.7.2 Creating a Story Together

For creating a story (Q47) the preference was more heavily weighted towards the cell phones than for reading (19:5). All of those who preferred paper mentioned that being able to print or write was the primary reason for this choice, because typing takes a long time (P08, P13, P14, P18, P24).

Most of those who preferred cell phones mentioned some notion of coolness, or how it was fun, interesting, or new. Other reasons related to typing, taking pictures, or that it was digital, easier to be creative, or increased mobility (P12).

Ten mentioned typing as being somehow better than writing on paper (P03, P05, P06, P10, P11, P15, P16, P20, P21, P22). Six stated this was because they just preferred typing (P03, P05, P06, P10, P16, P21). Comments also indicated typing was better because participants had messy handwriting or a cell phone had good handwriting (P06, P11, P15, P20, P22). Two stated that typing was faster or easier (P10, P15), or there was less strain when typing than writing on paper (P21). P18 expressed that because she could type, she was more mobile as “you don’t have to like write it on like a desk because if you do that [walked around creating a story] it would just go through the paper, and that won’t happen on a cell phone”. One

participant expressed how, even though he does not think he types well, he enjoyed creating the story using the keyboard:

[Creating words in the story is] a lot like typing, but I seem to do better at it than typing, because it's smaller, but it's like a keyboard. I'm not good at typing, but this I actually like doing and I would do almost the exact same thing I did there on typing. I wouldn't like go to like home position or something. I would just put my fingers down and go wherever I would need to go.

Eight participants liked that they could create or take their own pictures (P05, P09, P11, P12, P17, P20, P21, P23). One mentioned this was because he felt he did not draw well (P20).

Four noted advantages of the stories being digital instead of made on paper (P04, P05, P17, P23). P05 expressed that he liked how, because it was digital, he thought he could easily share it, and even download to your computer and print it out.

He said:

It's different and it's more fun because you can put in photographs without having to go get a separate camera and having to put it on the computer and then paste it. And then on the cell phone you could probably send it to other cell phones and you could even probably download it to your computer and print it out if you wanted. (P05)

One environmentally friendly participant mentioned how if it were not digital “you're cutting down trees ... [and] if everyone did it [used cell phones] than you probably wouldn't be cutting down many trees.” (P17). Correspondingly, another participant mentioned her preference was because “you wouldn't really run out of space” (P04).

In closing, P23 expressed how he felt the digital collaborative story-making was effective and helped his thoughts flow.

Cell phone because you can do pictures well; you can really work well and create a story. And then it seems like easier to work on a cell

phone because you can really erase and it's not like the hassle of paper where you ... it's just paper seems harder than a cell phone. It seems like you have more ideas when using a cell phone – your thoughts can flow. (P23)

4.8 Limitations

The limitations of the study are discussed in this section. The limitations include the participant population, interface design, tasks, environment, data collection, quantitative analysis, qualitative analysis, and data coding. The last three were previously discussed in sections 4.2.2.1.1 and 4.2.2.2.3. These limitations also suggest future areas of research that could address some of these concerns.

4.8.1 Participant Population

Participants were recruited from the area using email list-servs, word-of-mouth, and several hundred flyers distributed to neighborhood schools. As participation was voluntary this was a convenience sample of who could come and participate in the study. All participants were siblings or friends. There was an attempt to make the gender distribution somewhat equal with relative success (11 girls, 15 boys). While the sampling was somewhat random, the sample does not necessarily represent a complete random sample of children in the United States. In order to more specifically define the scope of this study, children ages 8 and 9 participated thus eliminating age as a factor of analysis. As such the results may be less relevant to children of other ages.

4.8.2 Interface Design

Cooperative Inquiry was used to develop the interface of Mobile Stories and the collaborative configurations. While Cooperative Inquiry, is an effective design

method it is not considered to be a replicable process. Despite this being a non-replicable process, it is regarded as an effective means of design as it follows user and participatory design principles to give children a voice in the design process [107, 108]. This being said, there was only one interface used for this study of Mobile Stories and one implementation of split content and space sharing. The arrangement and understandability of the menus and icons were not the focus of the study, but could have had an impact on the results of these studies. As both had the same look and feel, it is mostly assumed that participants would be able to only distinguish them via their collaborative interactions, which was the focus of the study.

Also, Mobile Stories 3.0 and above used an off-the-shelf device, the HTC TyTNII. This device had some inherently bad physical attributes. One being that the device needed to be rotated different directions for the keyboard and camera. This meant that children had to flip the phone 180° when switching between the two. While this could be advantageous the children found this difficult to do, especially with the wrist-band that was attached as safety precaution.

4.8.3 Context, Tasks & Environment

The collaborative configurations were investigated using the context of reading and creating stories in mobile settings. While this context has previously been justified, and it is appropriate for children, further work needs to be done in other contexts to corroborate and establish the overall preference for the split content and the scenarios when the different collaborative configurations may be appropriate. As for the tasks of reading, creating, and sharing a story, these are obvious tasks in within this context. Because the study could not be much longer than an hour, the

children only had a limited amount of time to work on each task. Being able to observe over a more extended period of time in a longitudinal study would be advantageous in establishing the trends. Additionally, the study was performed in a lab setting. While the room selected was large to enable children mobility, it lacked the real-world context of larger-scaled mobility.

4.8.4 Data Collection (Different Interviewers)

Due to scheduling logistics, different facilitators conducted different study sessions. As the primary facilitator, I was there throughout, and gave all of the instructions. For most of the time, one person acted as the secondary facilitator. In cases where this could not occur due to scheduling conflicts, the primary facilitator went through all instructions and questions with the replacement facilitator. Despite the training, there could be some variation due to facilitation differences; however, since the study was a within-subject design, it should have had less of an effect.

Video data was collected using several video cameras. While three cameras were used, it was impossible to always see what the child was doing on the screen and get a representative view of their interaction in the environment and/or the other child. There were also lapses in the camera – or times when one or two cameras were not functioning properly. Although increasing the coding complexity as each video stream needed to be manually synchronized with the others, having alternative views helped overcome issues of not being able to see different aspects of the interaction as well as any camera failures.

Chapter 5: Contributions, Future Research and Conclusion

This concluding chapter addresses the contributions, implications, future research, and conclusions.

5.1 Contributions

One of the major contributions of this research is the design and development of Mobile Stories which is a system that supports mobile collaboration for young children within the context of reading, creating, and sharing stories. Corresponding to this are investigations of the viability of mobile collaboration and a discussion of the types of collaborative experiences it supports. Another main contribution is the presentation and investigation of the collocated mobile collaboration configurations: content splitting and space sharing. This dissertation includes an investigation into when and where these configurations are more appropriate and what impacts they have on mobility and collaboration for children who are reading, creating, and sharing stories.

5.1.1 Addressing the Research Questions

The above contributions are in response to the stated research questions, and are discussed below in regard to each of those questions.

5.1.1.1 How does the collaborative mobile technology Mobile Stories affect children's collaboration and mobility?

In terms of collaboration, there were many insights. The Fort McHenry experience was informative in how mobile collaboration supported a collaborative

and elaborative experience (Section 3.4.1.2). The comparison between digital and paper revealed some differences, primary of which was that in the digital stories, children used more space and more media types per page (Section 3.4.3). Participant responses also revealed insight into why children may prefer digital over paper stories, and vice-versa both for reading and creating stories (Section 4.7).

Data and observations from the final three-part study also contributed interesting trends in mobility, proxemics, and collaboration. Answers to this question are presented and discussed in Chapter 3 and 4.

5.1.1.1.1 Collaboration

The collocated collaborative configurations were designed to overcome an observed technological disconnect when children came together to share something while they were creating a shared story. In some of my initial design sessions and in the collaborative story study I required children to use certain collaborative modes. This was done only for comparative purposes. From the design sessions (including the first week of the 2008 Summer Kidsteam as discussed in Section 3.4.3) I found that it was not beneficial to require children to use collocated collaborative modes for a long period of time. While there are times to be “connected”, it is not appropriate to always be connected. There needs to be time where children can work separately or independently even though their data was synchronized. This was how Mobile Stories 1.0 worked as well as the synchronized data collaborative mode of Mobile Stories 3.1. While this is not a new finding it is important to clearly state that encouraging instead of enforcing is the key to productive collaboration.

In the design sessions for Mobile Stories 1.0-3.0, as well as the collaborative story study (Section 4.4.2.3; G09, G11, G12), children occasionally swapped their devices. It happened only occasionally during the collaborative story study, and more frequently in the previous design sessions. This was somewhat surprising as mobile devices are generally a personal device. While this may likely be due to the fact that the devices did not actually belong to the children, it may be of interest to keep this in mind while designing content or applications for children.

5.1.1.1.1.1 Proxemics for Children Are Different Than for Adults

The study of proxemics suggests certain social norms that correspond to the different proxemic categories (see Table 2.1). As such, some who have designed devices intended for adults have implied anything within the intimate proxemic distance can only be intended for a single-user [142]. This apparently does not hold for 8-9 year-old children as they worked very closely principally while reading and sharing their stories with one another (Section 4.4.1.4). So, while the proxemic distances are a helpful guide as to how close people are to each other when they interact, it does not have all of the connotations that each proxemic category would have for adult social interactions.

5.1.1.1.1.2 Collaborative Reading and Sharing

Collaboration and sharing are simple things that children do frequently. Children like to share their own creations with friends and family. In the collaborative story study, the children were quite excited to share their stories with the facilitators, and asked if they could take their stories home to share them with

their families (Section 4.5.3). In designing for mobile devices, this should be kept in mind. Features that allow seamless sharing with others are important.

5.1.1.1.3 Collaborative Creation

Creating is fun! Anecdotally, the part of the session which most engaged and enthused the children was the time they were working together to create a story. In the collaborative story study, there was not a single session (Chapter 4) where the children finished the fifteen minutes of creation time and did not say something to the effect of “aw, we didn’t finish”, or “can we come back and do this again”, or “can we finish this later”. Creating stories is a social and motivating activity.

5.1.1.1.2 Mobility

In terms of mobility, when reading using the collocated collaborative configurations, participants moved very little and there was no distinguishable difference between in participant mobility between the two configurations (Section 4.4.1.4). There was a difference, however, when it came to creating stories (Section 4.5.1). First, children moved significantly more while creating stories than while reading stories. Second, boys moved significantly more than girls. There was also a link between mobility and number of pages created. In general children who moved around more added more pages to their story, although average proxemic distance between participants was a greater predictor of number of pages created than was mobility.

5.1.1.2 What are some of the appropriate interfaces for collocated mobile collaboration with children?

The two collocated collaborative configurations I designed, developed, and evaluated were: split content and share space. These concepts were presented in Section 3.1. A discussion of their design and development iterations follows in Section 3.4.

5.1.1.3 When are these interfaces preferred and why?

Also included is a discussion of each configurations relative advantages (Section 4.4.2), and when participants stated they would use each of them for reading (Section 4.6). In the collaborative story study, there were many indications pointing to advantages of the split content configuration over the share space configuration (Section 4.4.1). These indicators included: reading more pages (4.4.1.2), increased awareness (Section 4.4.1.3.1), fewer coordination and navigation problems (Sections 4.4.1.3.2 and 4.4.2.1), and participants used the split content configuration more frequently to share stories (Section 4.4.1). While the collocated collaborative interfaces were rarely used while creating a story – indicating they may best be suited for reading and sharing tasks, it was the only collocated collaborative interface used while creating a story (Section 4.5). Participants also rated the split content configuration easier to use when reading (Section 4.4.1.1), and preferred it overall after having used both configurations (Section 4.4.1).

Other contributions include the following lessons learned and implications for mobile designers and developers.

5.1.2 Additional Lessons Learned

Many lessons were learned from both the formative studies discussed throughout Chapter 3 as well as the formal collaborative story study which is discussed in Chapter 4. This section is meant to discuss some of the “smaller” findings that may have repercussions for those intending to include collaboration in their mobile applications and systems.

5.1.2.1 Gender Differences

Girls and boys are different – even when it comes to mobile collaboration. Girls worked closer than the boys and worked side-by-side more frequently than boys (Section 4.4.1.4). Boys were also much more emphatic in their preference for content splitting as well as their dislike for space sharing (Section 4.4.1.1). While girls overall preference tended towards favoring splitting content, they were less emphatic and more favorable of space sharing than their male counterparts.

5.1.2.2 Multimedia Narratives

When creating digital stories, there was great interest in supporting multiple types of media (Section 3.4.3) including: audio, words, and pictures.

5.1.2.2.1 Audio Recording/Playback

Also, while supporting creation, we found it was important to support recording and playback of audio (Section 3.4.1.2). This feature was supported in all of the versions of Mobile Stories. It was not used in the collaborative story study for reasons of simplicity, as the children already had to “learn” several new things in order to create their stories. Audio capture encouraged some to read, narrate, add

sound effects, and the addition of the media enriched not only the product, but the apparent fun children had while creating their stories.

5.1.2.2.2 Taking Pictures

Participants visibly enjoyed taking pictures (Section 4.7.2). At times, when a picture needed to be taken children would rush to take the best picture, other times children would assign the role of photographer to one of the children on the team. Some stated they liked taking pictures because they did not feel they drew well. G05 took all their pictures at the beginning of the creation session, and then added some captions for the remainder of the time.

5.1.2.2.3 Text and Typing

Despite being difficult or time-consuming, from the early design sessions (Section 3.4.1.1), children showed great interest and care in typing. This was observed also in the collaborative story study (Section 4.7.2). Children took great care to make sure they capitalized appropriate words and use the correct punctuation. They found it slow and painstaking even with the pull-out keyboard, and requested help to be able to add the necessary punctuation. While not all children spelled all of the words correctly, this engagement the high level of engagement and interest was of note.

Informally children suggested better labeling of buttons or even alternate configurations. The TyTN II, which was used in all but the initial design sessions (e.g. used in Mobile Stories 2.0+), allows the typing punctuation by using a special function key which is labeled in a subdued color and then typing the corresponding

keyboard button which is labeled in the same subdued color. Children found it very difficult to see the subdued color, and suggested a brighter color or special punctuation buttons.

5.1.2.3 Current Hardware Not Designed for Children

Many current mobile devices are not designed for use by children. The physical buttons on the devices used in this study were difficult for the children to use, necessitating the addition of other ways of interacting. For this reason gesture recognition was added as well as maintaining on-screen navigation controls (Section 3.4.3). Because of the awkwardness of the physical buttons, all but those that were used needed to be disabled, as children accidentally (and sometimes purposefully) would exit the application and lose their place (Section 3.4.4.2).

While not specific to children, and it may be due to other hardware factors, children mentioned and facilitators noted the awkwardness of the transition between taking pictures and using the physical keyboard. This transition required rotating the device 180° to use the keyboard and camera, which was made even more difficult when the wrist-strap was used as the tether was at the bottom by the directional pad. Because of this awkward transition, the wrist-strap was not used by the children, even though it had been requested by earlier children (Section 4.1). It is understood because of the compactness of mobile phones there are various hardware constraints that must be addressed, while some of these issues may be impacted by these constraints, some of these lessons could readily be applied to improve the usability for children and improve the ease of use of the device for novice, first-time, or less technologically-tolerant user groups.

5.1.2.4 Impact of Novelty

In the formative study comparing paper and digital Mobile Stories implementations, participants reported a preference for using cell phones (see Section 3.4.3.2.3). Also, despite the overall preference expressed for the content splitting configuration, both configurations were reported to be just as “cool” (see Section 4.4.1). This could partially be explained by a novelty factor, where children view something positively just because it is new or different. With the current widespread usage of technology and the anticipated continued proliferation of technology – specifically mobile phones – any concerns of a novelty effect will likely disappear within the next decade.

5.1.2.5 Scope and Applicability to Other Contexts (Generalizability)

Limitations of different aspects of this work have been discussed previously in this dissertation (see sections 4.2.2.1.1, 4.2.2.2.3, and 4.8). The specific scope of this research pertains to children as they read and create stories. The collaborative interactions supported by Mobile Stories include collocated and distributed, and synchronous and asynchronous interactions, with a focus on synchronous collocated interactions. The results could have been affected by numerous variables including variability between children, and the contexts of each formative study and the formal study. An effort was made to reduce confounding variables as much as possible.

One question left is: how do the results of this research impact other application areas. The collaborative creative applications of email, instant messaging, and voice communication are the primary uses of mobile phones. The focus of these applications is to support distributed collaboration, whereas the focus of this research

is to primarily support collocated collaboration. This research therefore has less an impact on those applications than on other applications that are well suited for collocated interactions such as shared web browsing, collaborative viewing, reading and sharing, and semi-structured artifact creation (e.g. pages in a story).

5.1.3 Implications

There are several implications, including those already outlined in the lessons learned. First and foremost are the implications for collocated mobile collaboration. Additional implications are to mobile designer and developers, as well as those creating software development kits for mobile devices.

5.1.3.1 Collocated Collaboration

In developing the collocated collaborative configurations of split content and space share, no theories were explicitly developed for which would be best suited for which situation, nor that either would categorically be better than the other. While there are many indications of relative advantages for the split content configuration, the share space configuration cannot be disregarded. Previously, I have discussed how these both of these configurations can accommodate different layouts of books (see Section 3.1). When it comes to heterogeneous devices, however, I believe split content has the advantage because the content can fill the space of its respective device, whereas sharing the space may be less appealing because of the resulting odd shaped viewable and interactive space.

Both configurations could be used for other content domains. For example a calendar, pictures, or documents could be shared (spread) across two phones,

enabling a larger view of each of these interfaces. Where one media is involved (e.g. text, pictures, video), space sharing would likely be most appealing as it would maximize the view of the single item. The split content configuration is flexible to include not only story content, but can include controls and interactive spaces. Another application of this concept could be to split the direct manipulation space (e.g. document viewer) from the indirect controls (e.g. menu[s]). For interfaces with more media, or even more controls, the split content configuration could have an advantage. In all, I believe the split content configuration has a lot of functional flexibility; but even as the participants in the collaborative story study mentioned sharing space was cool (Section 4.4.1), sharing space has a visual affect that is enticing and “cool”. While, I think split content may still have many advantages even for adults, I think adults may find it simpler to use the share space configuration than the children did and therefore find more uses for it.

Bringing multiple devices together expands the interactive space, so for example one could single-touchscreens being combined to enable multi-touch, or if each has a physical keyboard, one being used for letters, one for punctuation and numbers. The possibilities are numerous, but what would easily make sense to users may be less expansive.

5.1.3.2 Mobile Designers & Developers

There are implications for both hardware and software designers and developers. The hardware issues have previously been discussed, but in summary, children’s input could improve the overall design of the devices enabling a simpler, sleeker interaction. As far as software goes, it is claimed herein that mobile

collaboration is instrumental in overcoming perceived weaknesses of mobile devices and also to encourage and support collaboration – something which only continues to grow in desktop platforms as well as in the mobile platforms.

5.1.3.3 Interactive Development Environments (IDEs) & Software Development Kits (SDKs)

While recent mobile software development kits (SDKs) for the iPhone and Android have application programming interface (API) support for peer-to-peer (P2P) communication, there is still room for improvement as far as development tools for creating collaborative applications for mobile devices. Current interactive development environments (IDEs) do not easily support emulating multiple device connections, making debugging and robust development more difficult. Because of this, developers need to invest more resources (e.g. time and money) to develop for mobile platforms. They need to have numerous expensive devices in order to robustly develop peer-to-peer applications. Also, despite the current strength of the iPhone, the mobile market is much more diverse than platforms for desktop computers. In contrast to mobile developers, desktop developers who want to work across multiple platforms, generally need only support the predominant platforms of Windows and Linux (UNIX, Mac). Having better support for multiple emulators that can communicate with one another would be a big step towards overcoming these development and proliferation barriers.

In terms of collocated collaborative configurations, SDKs and IDEs could integrate these into their platform. Developers could mark a viewing space as sharable (share space), and/or could specify groupings of content that could be split

(split content). If desired, a more flexible architecture could be employed where users could specify how widgets were distributed using the split content of share space configurations. This would work most readily for something like the iPhone SDK, because it would avoid the challenge space sharing experiences when collaborating devices have heterogeneous displays.

5.2 Future Research

There are many avenues for future research, some of which are discussed below. In general, the following items fall within the larger scope of more accurately describing the use space of mobile collaboration as well as extensions to the work conducted within the purview of this dissertation.

5.2.1 Other Collocated Collaborative Interactions

Only two collocated collaborative configurations were created and investigated in conjunction with this research; other configurations are possible. One such configuration is where devices are synchronized to the same view. This was not examined as others have developed desktop or screen sharing applications that have been used for technical support services as well as remote desktop collaboration [29, 56]. While this was not examined it and other possible collaborative configurations would be interesting to investigate. Also, while the split content configuration was investigated, another possible way to split would be to put content on one device and interactive menus and/or overviews on another device.

5.2.2 Longitudinal Study & Sense of Ownership

It would be beneficial to get mobile devices into the hands of children, so they could “own” the device and observe how the collaborative story software is used in everyday life. How frequently would they use it in actuality and would the way they chose to use it differ from that which was observed in the collaborative story study.

Another interesting item that was observed throughout various sessions was that children occasionally swapped mobile devices with one another. This only happened in the collaborative story study a few times, for very short amounts of time, but in our earlier design sessions we noticed it more frequently. The reason for swapping seemed to be a functional one in that one, the other, or both children wanted to see what was on the other device even though they had the same data and could connect with one another. It has been reported that adult users view their mobile phones as a very personal item – mostly because of the amount of personalization and personal information that they have on them. Children tend to use current mobile devices for entertainment purposes, and do not necessarily have the same amount or kind of personal information on their phones or devices. It would be interesting to investigate further the ownership of the device if its intended purpose is collaborative construction.

5.2.3 Semi-automatic Collaborative Mode Switching

In order to change collaborative configuration modes (synchronized data, split content, share space) as well as to switch relative positions (left or right) and roles (picture and words), children needed to access the menu. By changing the hardware, proximity sensors could be used to infer relative positioning and the software could

automatically configure to the relative positions or prompt connecting to nearby collaborators. Such hardware configurations were not the focus of this research and by implementing this one could investigate the relative costs and benefits of having such automatic or semi-automatic mode switching. As has previously been reported, any automatic changes to the state would need to offer informative, clear feedback to the user [259].

Automatic or semi-automatic collaborative mode switching could also have an effect on the original assumption made that the collaborative space would be completely public. Based on tilt and proximity from the partner, the interface could implement some locking mechanism to disconnect and enter a private space. The split content concept already supports limited private spaces, depending on the mechanism used for role assignment. If users can take a role, they could infringe on the privacy of another, but if it was a request or offering protocol, then privacy could be maintained. For the share space configuration it could be more difficult as the interface is shared across both phones. Investigating the use of automatic switches could enable both private and public shared space.

5.2.4 Other Uses, Users and Contexts

This research focused on young children collaboratively creating stories in mobile contexts. There are several other collaborative tasks that occur in adult situations ranging from calendaring to viewing and modifying a documents of various sizes. Further investigation into the applicability of the results of using mobile collaboration including the collocated configurations in these “adult” domains could

reveal even more generalizable trends or better demarcate the distinct differences between these user populations.

5.2.5 Time Spent Collaborating

How much time does the task need to take for it to be worth “connecting” collaboratively? Would people prefer to use one device for short amount of times? How long or difficult must a task be to wait to not use a mobile device even if connected collaboratively? These unanswered questions require future research.

5.2.6 Heterogeneous Devices

While devices have flooded the earth, there is also a large diversity of the types of mobile devices that are used. With this disparity the concept of space sharing could become a complex tiling problem and therefore infeasible. Within the collaborative story study, one child suggested that splitting content would have advantages in this realm, and that, within the story context the larger device should have the words while the smaller device has the picture. While the initial stages of development were on various types of mobile devices, most were homogeneous in their display sizes. The collaborative story study was conducted solely with one type of device. As such, further research needs to be conducted to assess the viability and feasibility of the collocated collaborative concepts.

5.2.7 Collaborative Scaling

Mobile Stories 1.0 allowed for any number of devices to connect to each other via a server. Mobile Stories 2.0 and above were developed for peer-to-peer collaboration – specifically for pairs of collaborators. Section 3.4.2 addressed some

of the possible relative orientations of these two devices. While two collaborators may be the most frequent occurring scenario, in thinking about scale questions such as: could more be tiled together (such as in Siftables [195]), how many devices are still usable, how do you address heterogeneity, when are any collaborative benefits outweighed by the disadvantages.

5.2.8 Mentored Usage (Peer, Intergenerational)

Some of the participants in the collaborative story study suggested they would prefer to use content splitting with younger siblings, and space sharing with others who read just as well as they do or better. Investigating this in practice could be revealing and have implications for other mentoring opportunities between friends, schoolmates, and family relationships such as parent-child and grandparent-child mentoring possibilities.

5.3 Theory Revisited

This work relates to several collaborative and learning theories. This section revisits those theories and relates the findings to the collaborative characteristics of communication, roles, and proxemics.

One of the primary motivations for this work was to facilitate collaboration to impact learning. Two of the initially cited learning theories were constructionism [215] and activity theory [179]. The Fort McHenry experience showed how Mobile Stories implemented the tenets of these theories by supporting construction of a shared artifact which led to collaborative elaboration and reprocessing, as well as the ability to move around and share in context (see Section 3.4.1).

Mobile Stories further had implications for mentoring learning experiences. For the reading task in the collaborative story study, child participants mentioned how the two collaborative configurations of content splitting and space sharing could be used in mentoring situations (see Section 4.6.1). Participants stated that content splitting would be good to use when reading with younger children who do not yet know how to read. In this case, the younger child could primarily look at the pictures and look over at the words when they wanted to. Space sharing could be used in situations where children read as well as one another or in situations where both read well, but one read better than the other. These mentoring interactions are reminiscent of Vygotsky's developmental learning theories [287].

In general, it was noted that Mobile Stories supported different kinds of collaboration (see Section 2.2) including distributed and collocated collaboration, as well as synchronous and asynchronous interactions. Within the collaborative story study, collaborative differences were noted between the reading/sharing and creating tasks. These differences specifically relate to communication, the roles assumed by the children, and proxemics.

In terms of communication, explicit verbal communication was used in the creation tasks to coordinate, cooperate, and collaborate. This differed from the reading task, where children could get by using non-verbal cues or with having one of the pair orchestrating the navigation and completion of the task. In the creation tasks both children took more of an active role where each assumed different leadership roles – thus attaining a more collaborative interaction [293].

In terms of roles and communication, the automatic data synchronization seemed to facilitate spontaneous cooperation, coordination, and collaboration during the creation task. With synchronized data and unsynchronized navigation, children seemed to naturally coordinate different ways of working with one another by dividing their individual roles by media (photographer and writer) or assigning pages to work on (such as working on the previous or next pages or odd or even pages). This natural ability to coordinate was used instead of the structured synchronous, collocated interfaces of content splitting and space sharing. For example, some children divided the roles of photographer and writer similar to what is supported by content splitting, and others assigned previous and next pages which could have formally been done with the space sharing configuration. But only one of the thirteen groups used these formal, structured collaborative interfaces while creating a story. This also leads to a hypothesis that perhaps the automatic data synchronization provides the minimal support needed to facilitate a user negotiated means of collaboration when creating. The collocated collaborative interfaces were however successful while performing the structured activities of reading and sharing. While there is value in synchronous collaboration including collocated face-to-face interactions, a measure of independence is necessary.

In terms of proxemics, children created more pages when they moved around more and were, on average, further apart. Children read more when closer together while using the collocated configurations. While children performing the story creation task children created more pages when they were on average further from one another, it does not necessarily mean that complete independence is the answer as

the children would still come close to one another, establishing a pattern of coming together to coordinate, share, and re-establish mutual awareness of each other's activities, then separating to accomplish a task to be incorporated into the shared story (see Section 4.5 and Figure 4.15). This pattern reveals how it is necessary to support different levels or kinds of collaboration including coordination and cooperation that are both collocated and distributed in order to be effective.

In summary, the collocated collaborative interfaces for content splitting and space sharing formalized somewhat the way children could collaborate. It was observed that these structured synchronous, collocated interfaces worked for the structured activities of reading and sharing, but less so for the unstructured and free-form activity of creation (see Section 4.5). The collaborative story study suggested that the collocated configurations were more appropriate for reading and sharing rather than for creation. While performing a collaborative creative task such as creating a story, a synchronized data approach is effective as it enables the flexibility for users to coordinate, cooperate, and collaborate.

5.4 Conclusion

Mobile devices have permeated the daily life of billions, and promise to become the predominant computing platform of the 21st century. Social computing and collaborative environments are beginning to blossom. This work merges these two important areas of research and addresses the particular mobile, social, collaborative, and generative learning needs of young children. This research has illustrated how this merger can support different types of collaboration and has specifically investigated how different concepts and interfaces can support collocated

mobile collaboration within the context of reading and creating stories. The collaborative configuration concept of splitting content shows distinct promise, while space sharing has some relative benefits as well. This research has focused on, not just virtually connecting people, but physically bringing them together to expand, not only the interface, but also the way people – specifically children – collaborate.

Appendices

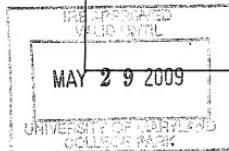
Appendix A: Institutional Review Board (IRB) Approved Parental Permission Form

A.1 *Original*

Consent Form Project Title: Mobile Collaboration for Young Children	Page 1 of 3 Initials _____ Date _____
<p><u>CONSENT FORM</u></p> <p>Please initial each page to indicate consent.</p>	
Project Title	Mobile Collaboration for Young Children
Why is this research being done?	This is a research project being conducted by Dr. Allison Druin of the Human Computer Interaction Lab at the University of Maryland, College Park. We are inviting your child to participate in this research project because he or she is of the target age range, 6-10 years old. The purpose of this research project is to explore and evaluate different collaborative interactive styles using mobile devices and desktop computers. Using the information collected in the study, we will be able to make recommendations and guidelines for creating collaborative mobile device experiences for young children.
What will my child be asked to do?	Children will create a collaborative story with a partner using either a desktop computer or a mobile device. Children will use different of collaborative configurations while reading and adding to a story. Your child will also participate in interviews designed to evaluate and compare the different configurations. Oral interviews will be conducted one-on-one with a researcher from the University of Maryland. Depending on the group he or she is assigned to, your child will use either a desktop computer or a mobile device. The maximum amount of time this will involve will be one, one hour session. All research activities will take place in the HCIL Kidsteam lab (Hornbake 2105). We also anticipate giving each participant a small gift of their choosing. Parental consent will be required to approve the gift the child chooses.
What are the risks of this research?	The only anticipated risk to subjects is if they become bored or frustrated with the tasks. However, past research with similar materials has found quite the opposite, so we expect the experience to be engaging for the children. Nevertheless, if any child grows overly bored or frustrated with the activities, he or she will be allowed to rest or stop his or her participation. Children will be using mobile devices during the study. While there is controversy over the safety of mobile devices (e.g. cell phones) by young children, this is not a risk as the phone capabilities of the mobile devices will be deactivated throughout the studies.
What are the benefits of this research?	Collaboration is an important aspect of child development and learning. We expect this to be a fun and beneficial experience for the children, including activities that will explore collaborative story-making.

Project Title	Mobile Collaboration for Young Children
What about confidentiality?	<p>We will do our best to keep your child's personal information confidential. To help protect your child's confidentiality, we will keep all data gathered in this study, including consent forms, assent forms, video and notes, in a locked room at the Human Computer Interaction Lab at the University of Maryland. We will not identify any child by name in reports or publications; children will only be identified through common demographic data such as gender, age, and ethnicity.</p> <p>Your information may be shared with representatives of the University of Maryland, College Park or governmental authorities if your child or someone else is in danger or if we are required to do so by law. Per law, consent forms are kept for three (3) years after the study.</p> <p>In accordance with legal requirements and/or professional standards, we will disclose to the appropriate individuals and/or authorities information that comes to our attention concerning child abuse or neglect or potential harm to you or others.</p> <p>To help us keep track of children's interactions with each other and the technology as well as their interview responses, <u>we will need to videotape and/or audiotape the study.</u> Please note that the purpose of these tapes is only to ensure that all interactions with the technology and collaborative partner as well as all interview responses are captured and noted correctly. Video and audio tapes will be stored in a locked room at the University of Maryland, and only researchers working on this project will have access to them. Because video collection will help us analyze the data we need, <u>those who do not accept videotaping will be unable to participate.</u></p> <p>Please <u>check one</u> of the below:</p> <p><input type="checkbox"/> I <u>agree</u> for my child to be <u>videotaped</u> and/or <u>audio-taped</u> during participation in this study</p> <p><input type="checkbox"/> I do <u>not agree</u> for my child to be <u>videotaped</u> and/or <u>audio-taped</u> and therefore <u>will not be able to participate</u> in this study</p> <p>If we write a report or article about this research project, <u>your child's identity will be protected to the maximum extent possible.</u></p> <p>Please <u>check one</u> of the below:</p> <p><input type="checkbox"/> I <u>agree</u> to allow pictures or video of my child to be used in research venues (to illustrate technology usage)</p> <p><input type="checkbox"/> I do <u>not agree</u> to allow pictures or video of my child to be used in research venues (to illustrate technology usage)</p>

Project Title	Mobile Collaboration for Young Children	
Does my child have to be in this research? Can my child stop participating at any time?	Your child's participation in this research is completely voluntary. You may choose for him or her not to take part at all. If you decide for your child to participate in this research, he or she may stop participating at any time. If you decide for your child not to participate in this study or if your child stops participating at any time, your child will not be penalized or lose any benefits to which you otherwise qualify	
What if I have questions?	<p>This research is being conducted by Dr. Allison Druin in the Human Computer Interaction at the University of Maryland, College Park. If you have any questions about the research study itself, please contact Dr. Druin at: Hornbake Building, College of Information Studies, Human-Computer Interaction Lab, Classroom wing, 2117H, University of Maryland, College Park, MD 20742; allisond@umiacs.umd.edu; (301) 405-7406.</p> <p>If you have questions about your child's rights as a research participant or wish to report a research-related injury, please contact: Institutional Review Board Office, University of Maryland, College Park, Maryland, 20742; irb@deans.umd.edu; 301-405-0678.</p> <p>This research has been reviewed according to the University of Maryland, College Park IRB procedures for research involving human subjects.</p>	
Statement of Age of Subject and Consent	<p>Your signature indicates that:</p> <ul style="list-style-type: none"> • You are at least 18 years of age and are the parent or legal guardian of the child listed below; • The research has been explained to you; • Your questions have been fully answered; and • You freely and voluntarily choose for your child to participate in this research project. 	
Signature and Date	PARTICIPANT INFO	Name: _____
		Gender: <input type="checkbox"/> Female <input type="checkbox"/> Male
		Birthday (mm/dd/yyyy) ____ / ____ / ____
		Telephone Number: ____ - ____ - ____
		PARENT OR LEGAL GUARDIAN OF PARTICIPANT (Print Name) _____
		SIGNATURE OF PARTICIPANT'S PARENT OR LEGAL GUARDIAN _____
		DATE (mm/dd/yyyy) ____ / ____ / ____



A.2 Renewal

Consent Form
Project Title: Mobile Collaboration for Young Children

Page 1 of 3
Initials _____ Date _____

CONSENT FORM

Please initial each page to indicate consent.

Project Title	Mobile Collaboration for Young Children
Why is this research being done?	This is a research project being conducted by Dr. Allison Druin of the Human Computer Interaction Lab at the University of Maryland, College Park. We are inviting your child to participate in this research project because he or she is of the target age range, 6-10 years old. The purpose of this research project is to explore and evaluate different collaborative interactive styles using mobile devices and desktop computers. Using the information collected in the study, we will be able to make recommendations and guidelines for creating collaborative mobile device experiences for young children.
What will my child be asked to do?	Children will create a collaborative story with a partner using either a desktop computer or a mobile device. Children will use different of collaborative configurations while reading and adding to a story. Your child will also participate in interviews designed to evaluate and compare the different configurations. Oral interviews will be conducted one-on-one with a researcher from the University of Maryland. Depending on the group he or she is assigned to, your child will use either a desktop computer or a mobile device. The maximum amount of time this will involve will be one, one hour session. All research activities will take place in the HCIL Kidsteam lab (Hornbake 2105). We also anticipate giving each participant a small gift of their choosing. Parental consent will be required to approve the gift the child chooses.
What are the risks of this research?	The only anticipated risk to subjects is if they become bored or frustrated with the tasks. However, past research with similar materials has found quite the opposite, so we expect the experience to be engaging for the children. Nevertheless, if any child grows overly bored or frustrated with the activities, he or she will be allowed to rest or stop his or her participation. Children will be using mobile devices during the study. While there is controversy over the safety of mobile devices (e.g. cell phones) by young children, this is not a risk as the phone capabilities of the mobile devices will be deactivated throughout the studies.
What are the benefits of this research?	Collaboration is an important aspect of child development and learning. We expect this to be a fun and beneficial experience for the children, including activities that will explore collaborative story-making.

Project Title	Mobile Collaboration for Young Children
What about confidentiality?	<p>We will do our best to keep your child's personal information confidential. To help protect your child's confidentiality, we will keep all data gathered in this study, including consent forms, assent forms, video and notes, in a locked room at the Human Computer Interaction Lab at the University of Maryland. We will not identify any child by name in reports or publications; children will only be identified through common demographic data such as gender, age, and ethnicity.</p> <p>Your information may be shared with representatives of the University of Maryland, College Park or governmental authorities if your child or someone else is in danger or if we are required to do so by law. Per law, consent forms are kept for three (3) years after the study.</p> <p>In accordance with legal requirements and/or professional standards, we will disclose to the appropriate individuals and/or authorities information that comes to our attention concerning child abuse or neglect or potential harm to you or others.</p> <p>To help us keep track of children's interactions with each other and the technology as well as their interview responses, <u>we will need to videotape and/or audiotape the study.</u> Please note that the purpose of these tapes is only to ensure that all interactions with the technology and collaborative partner as well as all interview responses are captured and noted correctly. Video and audio tapes will be stored in a locked room at the University of Maryland, and only researchers working on this project will have access to them. Because video collection will help us analyze the data we need, <u>those who do not accept videotaping will be unable to participate.</u></p> <p>Please <u>check one</u> of the below:</p> <p><input type="checkbox"/> I <u>agree</u> for my child to be <u>videotaped</u> and/or <u>audio-taped</u> during participation in this study</p> <p><input type="checkbox"/> I do <u>not agree</u> for my child to be <u>videotaped</u> and/or <u>audio-taped</u> and therefore <u>will not be able to participate</u> in this study</p> <p>If we write a report or article about this research project, <u>your child's identity will be protected to the maximum extent possible.</u></p> <p>Please <u>check one</u> of the below:</p> <p><input type="checkbox"/> I <u>agree</u> to allow pictures or video of my child to be used in research venues (to illustrate technology usage)</p> <p><input type="checkbox"/> I do <u>not agree</u> to allow pictures or video of my child to be used in research venues (to illustrate technology usage)</p>

Project Title	Mobile Collaboration for Young Children
Does my child have to be in this research? Can my child stop participating at any time?	Your child's participation in this research is completely voluntary. You may choose for him or her not to take part at all. If you decide for your child to participate in this research, he or she may stop participating at any time. If you decide for your child not to participate in this study or if your child stops participating at any time, your child will not be penalized or lose any benefits to which you otherwise qualify
What if I have questions?	This research is being conducted by Dr. Allison Druin in the Human Computer Interaction at the University of Maryland, College Park. If you have any questions about the research study itself, please contact Dr. Druin at: Hornbake Building, College of Information Studies, Human-Computer Interaction Lab, Classroom wing, 2117H, University of Maryland, College Park, MD 20742; allisond@umiacs.umd.edu ; (301) 405-7406. If you have questions about your child's rights as a research participant or wish to report a research-related injury, please contact: Institutional Review Board Office, University of Maryland, College Park, Maryland, 20742; irb@deans.umd.edu ; 301-405-0678. This research has been reviewed according to the University of Maryland, College Park IRB procedures for research involving human subjects.
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Signature and Date	PARTICIPANT INFO Name: _____
	Gender: <input type="checkbox"/> Female <input type="checkbox"/> Male
	Birthday (mm/dd/yyyy) _____ / _____ / _____
	Telephone Number: _____ - _____ - _____
	PARENT OR LEGAL GUARDIAN OF PARTICIPANT (Print Name) _____
	SIGNATURE OF PARTICIPANT'S PARENT OR LEGAL GUARDIAN _____
DATE (mm/dd/yyyy) _____ / _____ / _____	



Appendix B: Collaborative Story Study Invitation

Collaborative Story Study Using Mobile Phones

WHO: Children Ages 8-9

Children will be **paired** with another child

Friends are invited to participate together in the study

WHEN: After school or Saturdays in **February**

One-time visit; study takes approximately 1 hour

To schedule: <http://tinyurl.com/4kkpsu>, fails@cs.umd.edu, or 301-887-1332

WHERE: The University of Maryland's
Human-Computer Interaction Lab (HCIL)

For map: <http://tinyurl.com/4jp88v>

WHY: Did you ever wonder what good could come of a child having a cell phone or a PDA? Can mobile devices be educational? How can mobile devices support face-to-face interactions and collaboration? Please help us explore answers to these questions.

Upon completing the study, participants will receive a small gift.

If you have any questions, contact Jerry Fails:

<http://tinyurl.com/4kkpsu>, fails@cs.umd.edu, or 301-887-1332.

Thanks in advance for your participation.



Collaborative Story Study Using Mobile Phones

WHO: Children Ages 8-9

Children will be **paired** with another child
Friends are invited to participate together in the study

WHEN: After school or Saturdays in **March**

One-time visit; study takes approximately 1 hour
To schedule: <http://tinyurl.com/4kkpsu>, fails@cs.umd.edu, 301-887-1332

WHERE: The University of Maryland's
Human-Computer Interaction Lab (HCIL)

For map: <http://tinyurl.com/4jp88v>

WHY: Did you ever wonder what good could come of a child having a cell phone or a PDA? Can mobile devices be educational? How can mobile devices support face-to-face interactions and collaboration? Please help us explore answers to these questions.

Upon completing the study, participants will receive a small gift.

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Thanks in advance for your participation.

Collaborative Story Study Contact Jerry: 301-887-1332 or fails@cs.umd.edu or: http://tinyurl.com/4kkpsu	Collaborative Story Study Contact Jerry: 301-887-1332 or fails@cs.umd.edu or: http://tinyurl.com/4kkpsu	Collaborative Story Study Contact Jerry: 301-887-1332 or fails@cs.umd.edu or: http://tinyurl.com/4kkpsu	Collaborative Story Study Contact Jerry: 301-887-1332 or fails@cs.umd.edu or: http://tinyurl.com/4kkpsu	Collaborative Story Study Contact Jerry: 301-887-1332 or fails@cs.umd.edu or: http://tinyurl.com/4kkpsu	Collaborative Story Study Contact Jerry: 301-887-1332 or fails@cs.umd.edu or: http://tinyurl.com/4kkpsu	Collaborative Story Study Contact Jerry: 301-887-1332 or fails@cs.umd.edu or: http://tinyurl.com/4kkpsu	Collaborative Story Study Contact Jerry: 301-887-1332 or fails@cs.umd.edu or: http://tinyurl.com/4kkpsu	Collaborative Story Study Contact Jerry: 301-887-1332 or fails@cs.umd.edu or: http://tinyurl.com/4kkpsu
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Appendix C: Collaborative Story Study Protocol/Questions

The synchronized data collaborative mode is referred to as independent in the protocol, as the navigation is independent from that of a child's partner. The change from "independent" to "synchronized data" was made to clarify that while navigation was not synchronized in this mode – and therefore independent – the application still had synchronized data and was in a collaborative, shared mode and not completely independent.

Timing

Activity	Timing* (minutes)
IRB Signing	4
Welcome and explanation	4
Configuration #1	
Demo	2
Read	4
Interview	3
Configuration #2	
Demo	1
Read	4
Interview	3
Summary Interview	3
Break	10
Motivate story creation / demo	6
Story creation	
Reminder of other modes (5 min)	15
Reminder of other modes (10 min)	
Share story with adults	5
Final interview	6
Total	70

* Highlighted times will be timed with a timer

Setup

1. Camera and batteries charged and ready
2. Video of each child (two adults to video-tape; and interview children separately)
3. Reception area for parents to wait (treats)
4. Clipboards with timers on them
5. Cover power button
6. Encourage to only use finger (not stylus)

Things to Note While Observing

1. Where do the children read? (on a table, standing up, on the floor) – use the map provided on the observation sheet to indicate this information
2. How do they orient themselves relative to one another (side-by-side, face-to-face, distance)
3. Use the time on the camera/video segment when indicating a time to correlate with a note

Secret Program Button Combinations

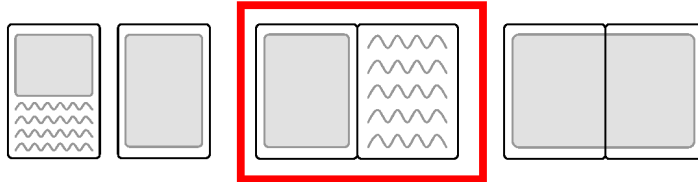
1. Voice Button (on the side), OK (on the side) – writes a begin/end marker in the log; this should be done at the beginning and end of each reading configuration, as well as at the beginning and end of the creation segment
2. Windows, OK (on the side) – will immediately exit the program

Welcome / Introduction

1. "Today you will be using cell phones to read and create stories. This technology is new and you will be helping us figure out what works well and what doesn't work well with this technology. Your opinions are very important to us. There are some timed portions, with short breaks in between. If you need a longer break, just ask. You may stop at any time."
2. "We will start by reading a book a couple different ways. Afterwards, I will ask you what you thought the book was about and what you thought of reading the book each of the different ways."

Introduction for Content Split

1. Switch mode to *Content Split*



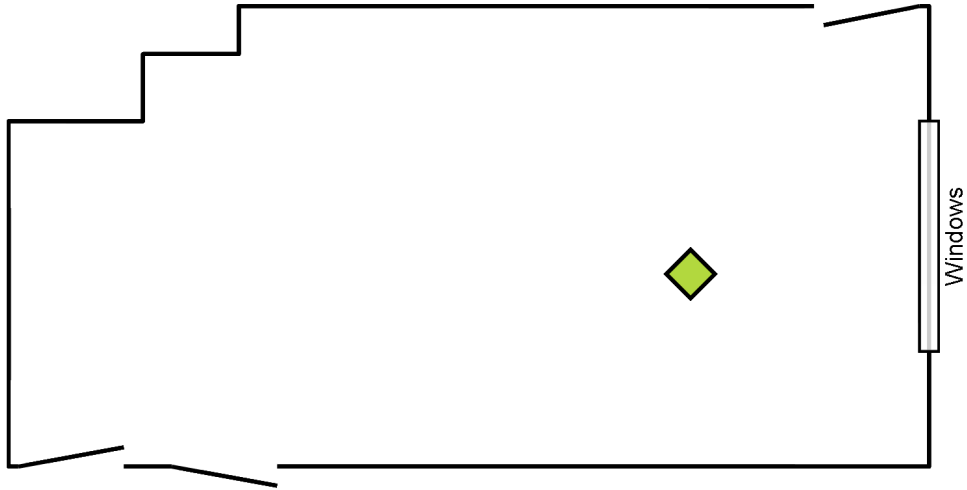
2. Demo – always do demo and start reading on the diamond on the map
 - a. You see the whole story at first; one phone has the words, one has the pictures
 - b. You can switch which phone has the pictures or words by pressing the switch button
 - c. You can touch a page to zoom in to it
 - d. To zoom out you can use the zoom out button or drag your finger up
 - e. To change page you can use a button on the phone or the screen, or drag the page left or right
 - f. To open the menu press the center button, to close it you push the button again
3. You can read anywhere in this room
4. Put a story marker in the log file [by pressing the Voice button (on the side), followed by the OK button (on the side)]
5. Hand the device to the child
6. Start the timer

Log Start Time:

Reading Collaborative Configuration #1 Observation Sheet

Circle Configuration:

Indicate where the children walk: Always start at the diamond
L (for lying on the floor), **F** (for sitting on the floor), **C** (for using a chair) and **S** (for standing)
each time they stop for more than ~10 seconds
Circle primary location of reading – note their orientation (face-to-face, side-by-side, distant)



Interesting Observations (and their times)

Participant ID _____

Device ID _____

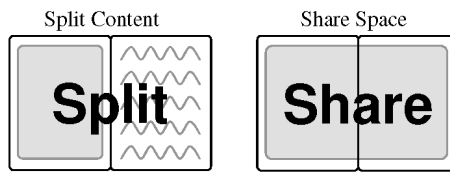
Camera ID _____

Page 1 of 10

**Reading
Collaborative Configuration #1
Oral Interview**

Take the device from the child

1. Circle the configuration:



2. How easy/hard was it to read the story?

Very hard 1	Hard 2	Neither easy nor hard 3	Easy 4	Very easy 5
----------------	-----------	-------------------------------	-----------	----------------

Why?

3. How cool/lame was the way you read it?

Very lame 1	A little lame 2	Neither lame nor cool 3	A little cool 4	Very cool 5
----------------	--------------------	-------------------------------	--------------------	----------------

Why?

4. What was <insert name of partner> doing while you were working?

5. How often did you know what your partner was doing?

Never 1	Occasionally 2	Sometimes 3	A lot / most 4	All the time 5
------------	-------------------	----------------	-------------------	-------------------

Participant ID _____

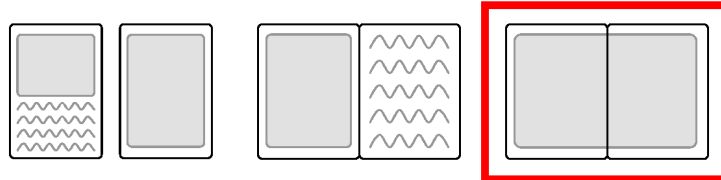
Device ID _____

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Introduction for Space Share

1. Switch mode to *Space Share*



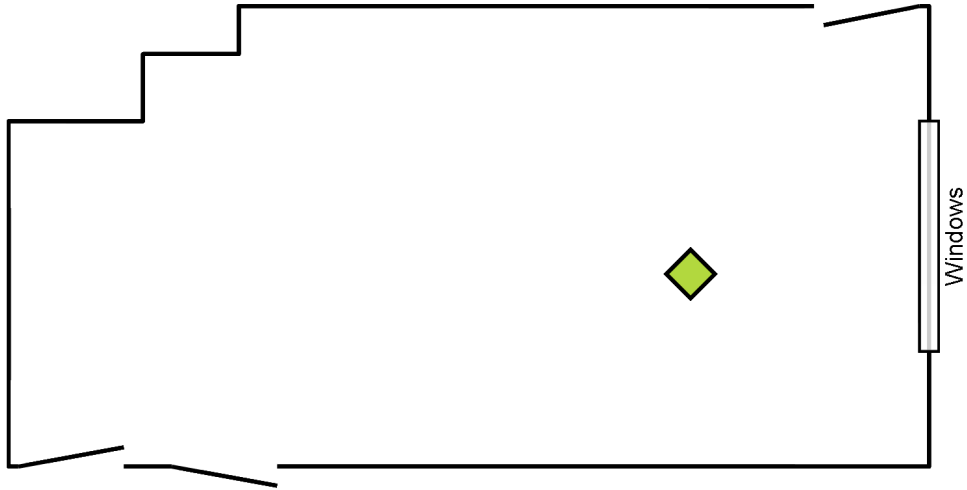
2. Demo
 - a. You see the whole story at first
 - b. You can touch a page to zoom in to it
 - c. You can touch the picture or the words to zoom in on them
 - d. To zoom out you can use the zoom out button or drag your finger up
 - e. To change page you can use a button on the phone or the screen, or drag the page left or right
 - f. To open the menu press the center button, to close it you push the button again
3. You can read anywhere in this room
4. Put a story marker in the log file [by pressing the Voice button (on the side), followed by the OK button (on the side)]
5. Hand the device to the child
6. Start the timer

Log Start Time:

Reading Collaborative Configuration #2 Observation Sheet

Circle Configuration:

Indicate where the children walk: Always start at the diamond
L (for lying on the floor), **F** (for sitting on the floor), **C** (for using a chair) and **S** (for standing)
each time they stop for more than ~10 seconds
Circle primary location of reading – note their orientation (face-to-face, side-by-side, distant)



Interesting Observations (and their times)

Participant ID _____

Device ID _____

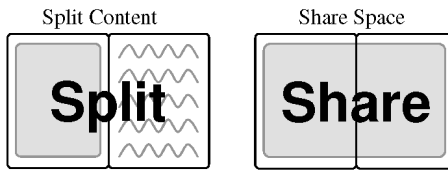
Camera ID _____

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**Reading
Collaborative Configuration #2
Oral Interview**

Take the device from the child

6. Circle the configuration:



7. How easy/hard was it to read the story?

Very hard 1	Hard 2	Neither easy nor hard 3	Easy 4	Very easy 5
----------------	-----------	-------------------------------	-----------	----------------

Why?

8. How cool/lame was the way you read it?

Very lame 1	A little lame 2	Neither lame nor cool 3	A little cool 4	Very cool 5
----------------	--------------------	-------------------------------	--------------------	----------------

Why?

9. What was <insert name of partner> doing while you were working?

10. How often did you know what your partner was doing?

Never 1	Occasionally 2	Sometimes 3	A lot / most 4	All the time 5
------------	-------------------	----------------	-------------------	-------------------

Participant ID _____

Device ID _____

Camera ID _____

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End of Reading Section Comparative Oral Interview

11. Configuration order (number 1, 2):

Split Content _____ Space Share _____

12. Which would you choose to use now, the first way or the second?

Split Content _____ Share Space _____

Why?

13. Which was easiest to read?

Split Content _____ Share Space _____

Why?

14. Which did you like the most?

Split Content _____ Share Space _____

Why?

15. When would you want to read with someone?

16. When would you want to read with someone with the words and pictures split?

Participant ID _____

Device ID _____

Camera ID _____

Page 5 of 10

17. When would you want to read with someone with the previous/next pages, or the picture or words shared across both phones?

18. How would you prefer to read together with someone?

Split Content

Share Space

Why?

19. What was the book about?

20. How much did you like the book?

Not at all
1

A little
2

Some
3

A lot
4

Very much
5

21. Which would you prefer to read a story on: paper or a cell phone?

Paper

Cell phone

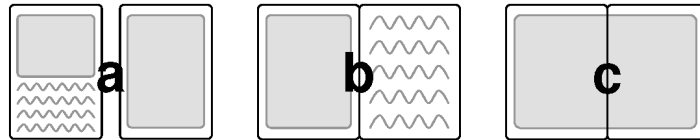
Why?

22. IF READ OUT LOUD

I noticed sometimes you read out loud, why did you read out loud?

Introduction for Story Creation

1. Now you will be able to create your own story
 - a. You will create a shared story, meaning when one person makes a change the other person's story is changed too. This means you will have to work together to create the story.
 - b. You will have 15 minutes to write a story about what happens when everyone leaves the lab. Just so you know, when everyone leaves this room, the toys and the computers come alive (kind of like in Toy Story), so write a story about what happens when everyone leaves.
2. The different ways you read the story can also be used to create a story. So you can:
 - a. Work alone
 - b. Split the words and the pictures, or
 - c. Share the space on both phones

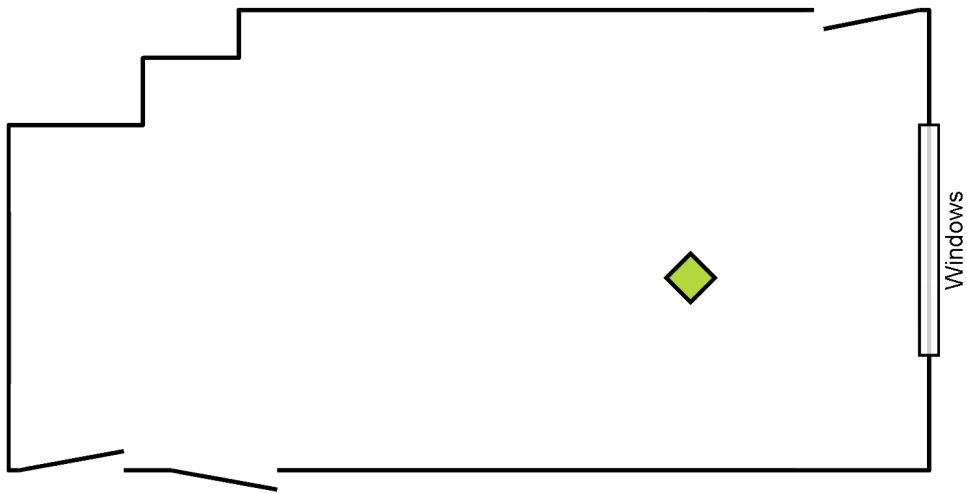


3. You can change the words or the pictures
 - a. To change the words you can push the ABC (words) button or open the keyboard and start typing; press save when you're ready to save what you've written
 - b. To change the picture you can push the camera (picture) button or push the camera button on the side of the phone; hold down the button to take a picture; press the return arrow button when you're done taking a picture
4. Use all six of the pages provided, adding pictures and words
5. You can go anywhere in this room to create the story
6. Put a story marker in the log file [by pressing the Voice button (on the side), followed by the OK button (on the side)]
7. Hand the device to the child
8. Start the timer
9. Every five minutes: "Just as a reminder, you can work together, split the words and the pictures (content) or share space while you are creating your story; and you can go anywhere in the room."

Log Start Time:

Collaborative Creation Observation Sheet

Indicate where the children walk: Always start at the diamond
L (for lying on the floor), **F** (for sitting on the floor), **C** (for using a chair) and **S** (for standing)
each time they stop for more than ~10 seconds
Circle primary location of reading – note their orientation (face-to-face, side-by-side, distant)



Interesting Observations (and their times)

[Empty rectangular box for recording observations]

Participant ID _____

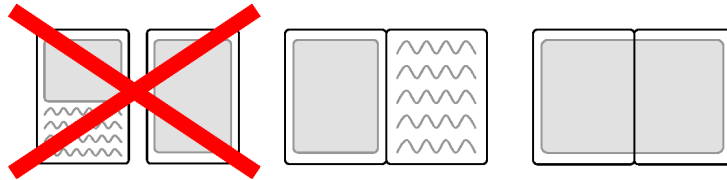
Device ID _____

Camera ID _____

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Introduction for Story Sharing

1. Now, please share your story with the adults
2. You may either of the two ways to read together that you would like:
 - a. Split the words and the pictures, or
 - b. Share the space on both phones



3. You can go anywhere in this room to share the story
4. Put a story marker in the log file [by pressing the Voice button (on the side), followed by the OK button (on the side)]
5. Hand the device to the child
6. Start the timer

End of Creation Section Comparative Oral Interview

Take the device from the child

23. Which configuration did you use to share the story with (can be noted from observation)?

Independent Split Content Share Space

Why did you use that one?

24. Which was easiest to create with?

Independent Split Content Share Space

Why?

25. Which was hardest to create with?

Independent Split Content Share Space

Why?

26. When would you want to create a story with someone?

27. How would you prefer to create a story with someone?

Independent Split Content Share Space

Why?

28. How much did you like to work alone (use independent)?

Not at all 1	A little 2	Some 3	A lot 4	Very much 5
-----------------	---------------	-----------	------------	----------------

29. How much did you like to split the words and the pictures (use content splitting)?

Not at all 1	A little 2	Some 3	A lot 4	Very much 5
-----------------	---------------	-----------	------------	----------------

30. How much did you like to spread the previous/next pages or the picture or words shared across both phones (use screen sharing)?

Not at all 1	A little 2	Some 3	A lot 4	Very much 5
-----------------	---------------	-----------	------------	----------------

31. How well did you get along with your partner?

Not at all 1	A little 2	Some 3	A lot 4	Very much 5
-----------------	---------------	-----------	------------	----------------

32. How well do you know your partner?

Not at all 1	A little 2	Some 3	Pretty well 4	Best friends 5
-----------------	---------------	-----------	------------------	-------------------

33. How frequently do you use a computer?

Never	Once a Month	Once a Week	2-3 times a Week	Every day
-------	--------------	-------------	------------------	-----------

34. How old are you? 8 9

35. Have you ever used a cell phone? Yes No

36. How frequently do you use a cell phone?

Never	Once a Month	Once a Week	2-3 times a Week	Every day
-------	--------------	-------------	------------------	-----------

37. How much would you like to read stories *by yourself* on a cell phone?

Not at all 1	A little 2	Some 3	A lot 4	Very much 5
-----------------	---------------	-----------	------------	----------------

38. How frequently would you like to read stories *by yourself* on a cell phone?

Never	Once a Month	Once a Week	2-3 times a Week	Every day
-------	--------------	-------------	------------------	-----------

39. How would you like to read stories *with someone else* on a cell phone?

Not at all 1	A little 2	Some 3	A lot 4	Very much 5
-----------------	---------------	-----------	------------	----------------

40. How frequently would you like to read stories *with someone else* on a cell phone?

Never	Once a Month	Once a Week	2-3 times a Week	Every day
-------	--------------	-------------	------------------	-----------

41. How much would you like to make/create stories *by yourself* on a cell phone?

Not at all 1	A little 2	Some 3	A lot 4	Very much 5
-----------------	---------------	-----------	------------	----------------

42. How frequently would you like to make/create stories *by yourself* on a cell phone?

Never	Once a Month	Once a Week	2-3 times a Week	Every day
-------	--------------	-------------	------------------	-----------

43. How much would you like to make/create stories *with someone else* on a cell phone?

Not at all 1	A little 2	Some 3	A lot 4	Very much 5
-----------------	---------------	-----------	------------	----------------

44. How frequently would you like to make/create stories *with someone else* on a cell phone?

Never	Once a Month	Once a Week	2-3 times a Week	Every day
-------	--------------	-------------	------------------	-----------

45. How well do you read?

Not well at all 1	Not very well 2	OK 3	Pretty well 4	Very well 5
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46. How much do you like to read?

Not at all 1	A little 2	Some 3	A lot 4	Very much 5
-----------------	---------------	-----------	------------	----------------

47. Which would you prefer to create a story on: paper or a cell phone?

Paper	Cell phone
-------	------------

Why?

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