# Designing eBooks to Facilitate Mathematical Dialogue during Shared Reading

**by**

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## Abstract

This research aimed to investigate the impact of variation in eBook design, specifically hotspots, on caregiver-preschooler dyads' communications about mathematics story content during shared reading. Two eBooks were designed and compared. Hotspots in the math eBook guided joint attention to mathematically-related activated features; hotspots in the emotion-action eBook guided joint attention to emotions and actions of the characters. The hotspots were matched in number and type across both eBooks. The narrative and illustrations remained consistent between the two eBooks. The dyads' interaction with different types of hotspots; and their use of spoken utterances and gestures were compared across the two conditions.

Thirty-two dyads participated in this study; 16 in each group. Findings showed that, in both groups, all caregivers and children used spoken utterances and gestures, albeit to different extent, to express the mathematics content in the narrative. However, spoken utterances and gestures that aligned with mathematics occurred more frequently among dyads in the math condition compared to the other condition. Further, caregivers in the math condition responded to hotspots by asking high-level cognitive questions, and both caregivers and children in this condition reacted mostly by repeating what was heard. In the emotion-action condition, dyads reacted emotively to the hotspots.

Findings also showed that dyads in the math condition – as opposed to their peers - tended to discuss the embedded mathematics activities. Thematic analysis was done to explore in more depth the interplay between the acting on the hotspot and the narrative concerning the communication about mathematics as the dyads discussed two activities embedded in the story. Three themes emerged regarding scaffolding of mathematical ideas, co-construction of ideas, as well as seeking self-discovery and agency of the child. Findings from the Caregiver Satisfaction Questionnaire showed differences across conditions in regards to the children's attention; and similarities in perceptions of the children's enjoyment and willingness to share eBooks in the future. Findings from this research raise implications for the future designs of eBooks; particularly regarding the content and placement of the hotspots.

**Keywords**: eBooks, Shared reading, Hotspots, Mathematics, Communication, Joint attention

*To my beloved*

*Ameer & Mohammad*

*This dissertation is wholeheartedly dedicated*

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~ The hardest arithmetic to master is that which enables us to count our blessings ~

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# Table of Contents

# List of Tables

## List of Figures

# Chapter 1.

# Introduction

## 1.1. Overview

Literary practices, including those that facilitate early mathematical understanding (Anderson, 1997, 1998), are best engaged within an intimate and nurturing setting such as the home (Bus, 2003). Shared reading activity between children and their caregivers/adults is one such method that children enjoy (Adams, 1990). The relationship between children and caregivers while sharing print books has been well-established; however, their relationship while sharing eBooks has not been identified in the same manner. There is reason enough to propose that eBooks prompt both children and their caregivers to act in manners that differ from print books (Oakley & Jay, 2008). The incorporation of multimedia design features - such as hotspots (clickable locations that activate animations and/or sounds), sound effects, background music, and animations - may play a role in how children and caregivers direct their attention and prompt communication. These features, however, can also distract and/or divert attention away from narrative themes.

Communication between the children and their caregivers is likely to impact the way they direct each other's attention, and yet a reversal effect could just as easily be possible. The multimedia features could potentially stifle dyadic communication, hampering a fruitful exchange of mathematical concepts.

To date, studies of shared reading practices have not explored the influence of varying multimedia features within eBooks on dyadic communication. This field of research deserves refining through additional, empirical studies, such as the current study. This study's primary aim is to examine the impact of variation in eBook design, specifically hotspots, on communication between children and their caregivers during shared reading of eBooks presenting mathematics-related content. The present research

explores whether the inclusion of hotspots focuses the dyad's attention to the mathematics-themed narrative, and in turn increases communication about mathematics. Various ways that children and caregivers attend to mathematics content and thinking while sharing the tailored eBook are also examined in the study.

One possible outcome is that the eBooks will facilitate shared attention due to an entertainment function which draws attention to central narrative aspects, enhancing the shared reading activity for both children and caregivers. Hotspots can focus visual attention to virtual objects and/or actions on screen (Moody, Justice & Cabell, 2010). Multimodal interactions may facilitate this process. For instance, when a child or caregiver activates a hotspot producing an audio of giggling, cheerfulness may be evoked. This combination may prompt more meaning construction.

Alternatively, hotspots may prompt joint attention but function solely to entertain children and, as a result, distract children from focusing on the story content or communicating about it with the adult who is reading to the child (Bus, de Jong & Verhallen, 2007). According to previous studies, this is more likely to happen when the eBook is highly dynamic or when the information activated by hotspots is underspecified or tangential to the storyline (Parish-Morris, Mahajan, Hirsh-Pased, Golinkoff & Collins, 2013). In light of controversial findings from the literature on effects of hotspots, it is important to explore variation in hotspot designs and their influence on caregiver-child joint-attention, communication, and meaning co-construction of the story content.

This chapter first outlines caregiver-child communicating in the literature on shared reading, viewing communication from the lens of social-cognitive perspectives. That is followed by research findings that highlight shared reading practices of stories with mathematics related content, an area of research that has gained little attention. The chapter then overviews research on shared eBook reading practices for young children. This includes discussing the design features that led to controversy in the literature and then, findings that guided the design of the eBooks used in this research.

## 1.2. Shared Reading Practices

Shared reading practices are essential in shaping children's early literacy experiences and development (Bus, 2003). Shared reading practices have long-term benefits for social development and cognitive-linguistic benefits of young children (Bus, Van Ijzendoorn & Pellegrini, 1995). They are also substantially different from other social settings that can foster the child's meaning construction (Panofsky, 1994) as the caregiver models a unique use of language compared to other shared activities such as free-play or typical parental interaction (Girolametto, Weitzman, & Greenberg, 2003; Lonigan & Whitehurst, 1998).

Cultural differences lead to different ways of scaffolding children (Anderson, Anderson & Shapiro, 2004). Caregivers in middle class homes tend to read a story by the caregiver in a supportive and guided manner (Courtade, Lingo, Karp & Whitney, 2013). The child and the caregiver attend to the spoken narrative in combination with the printed text and illustrations. The caregiver scaffolds the child's meaning-making about the story by pointing to images, asking prompting questions, and discussing the meaning of words unfamiliar to the child.

During shared readings, the child is often exposed to advanced or unusual vocabulary (Senechal, Thomas, & Monker, 1995). This prompts the child's participation through open-ended questions (Whitehurst et al., 1988), expanding and recasting the child's speech (Whitehurst et al. 1988). Relating illustration to text also contributes to meaning-making (Bus et al. 2007), as do praise and feedback (Whitehurst et al. 1988). As children continue to engage with caregivers, they become more facile with complexity in discourse and subsequently expand their own vocabulary and language use (e.g., Girolametto et al. 2003).

In experimental studies, training programs for caregivers facilitated their techniques when reading to children. This has been referred to as dialogical reading (e.g., Valdez-Menchace & Whitehurst, 1992). In that study, caregivers of preschool-aged children were taught how to draw their children's attention to the narrative by asking practical and open-ended questions. Caregivers were also instructed to elaborate

thoroughly on the content and to be attentive to their child's reactions. Those in the control group were instructed to read as they normally would, without the influence of the training programs. Scores on expressive language of the children in the experimental group were higher.

In examining the feasibility of trained dialogical readings programs (meta-analyses of intervention studies), Mol, Bus and De Jong (2008) found that shared reading training programs have a moderate impact on the children's expressive vocabulary.

Literacy development and emotional awareness benefit directly from shared reading activities. Emotionally, repeated interactions between the child and the caregiver help the child form mental models of responses and expectations. This sort of communication is fundamental in constructing a relationship of trust between the caregiver and the child, which is a cornerstone principle of the Attachment Theory (Ainsworth & Bell, 1970; Egeland & Erickson, 1999). Repeated shared readings are considered effective for building strong, emotional ties between the caregiver and the child (Sameroff & Fiese, 2000).

The caregiver and the child can elicit various verbal cues from the print and illustrations. The subjective impression and multiple meanings available from the print and the images can stimulate oral language the caregiver and the child generate about the story (Golden & Gerber, 1990). Variability in the interaction can be attributed to several factors: the different interpretation of the content of the print and illustrations, previous knowledge, and the way the content is interpreted within a specific social or cultural context (Golden & Gerber, 1990).

### 1.2.1. Socio-cognitive perspectives on shared reading practices.

Shared reading practices emphasize the mediating role of the caregiver in the child's meaning-making but, in turn, the child's active role is less understood. Socio-cognitive views (i.e., Mead, 1934; Tomasello, 2003; Carpendale & Lewis, 2004; Brinck, 2008; Carpendale, Atwood & Kettner, 2014) describe dyadic communication as a recursive process in which the child and the caregiver jointly contribute to meaning

construction. The child becomes an active learner and self-constructor of culture literacy routines – e.g., pointing or turning the page - spontaneously as participating in a shared reading activity. Expressing emotions, making queries, or explaining perspectives are all facilitated through cultural tools in both the child and the caregiver (Halliday & Hasan, 1976).

The child becomes adaptive to the shared reading setting when there are mutual gains that result from interactions with the caregiver and an interactive eBook (Lerner & Schmid, 2014). On one hand, the child becomes more familiar with and anticipates repeated dynamic features, and also with concepts within the story as the caregiver repeatedly mentions them through explanations or questions. On the other hand, the caregiver may adjust the level of communication complexity according to the child's level of development, interest, and engagement in the activity.

Carpendale and his colleagues (2014) emphasized the importance of caregivers' attention to their children's state of knowledge when trying to share perspectives with them. Caregivers can mediate by asking clarification questions, regulating their perspectives in relation to the child's opinions, and providing frequent feedback. This implies that the child's actions influence and are influenced by those of the caregiver (Lerner, Lerner, De Stefanis & Apfel, 2001). Based on this, the child and the caregiver are expected to jointly adjust features such as reading pace or the use of the touchscreen hotspots, to enhance shared understandings.

Socio-cognitive perspectives suggest that design features within eBooks can function effectively in child-caregiver communication and, in turn, increase joint social attention (e.g. Tomasello, 2003). Caregiver-child interactions with interactive features like hotspots or animations create an essential, intersubjective space in which communication patterns emerge (Carpendale & Lewis, 2004; Brinck, 2008) expressed through language, symbolic expression, or display of thoughts or emotions (Gee, 1996).

Hotspots and animated features can draw caregivers' and children's visual attention to the screen, but that alone is not sufficient for the emergence of communication regarding the presented information. In this socio-cognitive setting,

caregivers and children must manipulate their attention to each other and to hotspots, thus creating the described intersubjective space (Akhtar & Gernsbacher, 2007).

## 1.3. Gestures

Gestures are usually spontaneous movements involving hands or arms. These are seen when people talk and synchronize with the speech identical to its meaning (McNeill, 1992). Spoken language and gestures are two cultural tools used for communication in shared reading settings. Children not only learn language embedded in shared reading routines for constructing meaning, but they also learn to use different gestures (Carpendale et al., 2014).

Gestures have not garnered much attention in the literature about shared reading, especially regarding electronic books. Gestures are one of the focus of this research because they play important roles in cognitive development and meaning formation in child-caregiver communicative settings (e.g. Tomasello & Farrar, 1986). The use of gestures or gesture-speech combinations to convey meanings to young children help them label objects and build their vocabulary (e.g. Zukow-Goldring, 1996).

Caregivers tend to use gestures spontaneously when talking to their children, and then, mostly in combination with speech (O'Neill, Bard, Linnell & Fluck, 2005; Özçalışkan & Goldin-Meadow, 2006). Caregivers use gestures, such as pointing, for reinforcement (pointing to the bear and saying, "Look at the bear."); clarification (pointing to the bear and saying, "Look at this brown bear"); and supplementation (pointing to the bear and saying, "Can you give it a hug?"). After the age of two, children's understanding and production of gestures increase (McNeill, 2006). Young children tend to imitate their caregivers, and they start to synchronize communication via cultural tools such as gesture and speech to augment communication (Kita & Ozyürek, 2003).

McNeill (1992) suggested a general classification of four main hand gesture types: deictic, iconic, metaphoric, and beat gestures. The present study refers to the most commonly used gestures by caregivers and children - including deictic and iconic

meanings. Other types of gestures that were observed in isolated cases were not defined or coded.

### 1.3.1. Iconic gestures.

Iconic gestures are hand gestures that convey a meaning which resembles the semantic content of the accompanied speech (McNeill, 1992; Namy, Campbell & Tomasello, 2003; Özçalışkan, Adamson & Dimitrova, 2013). An example is cupping one's hands when referring to the ball while talking. Examples of iconic gestures include extending arms to describe the size of an item or raising fingers to show the number of counted items in a set. While iconic gestures usually resemble speech, they can also stand without any associated speech. Children's increased use of iconic gestures synchronized with speech accelerates during preschool years (Sekine, 2009).

Iconic gestures may be important in shared eBook reading because they direct and enhance awareness of the speaker's intentions and supports learning of new concepts.

### 1.3.2. Deictic (pointing) gestures

The act of pointing – extending arm and index finger, with enclosed hand – is an essential social skill (Carpendale et al. 2014). The gesture can replace a deictic word or phrase (i.e. "there" "this thing") or be used jointly with it (McNeil & Duncan, 2000). Communication between the child and the caregiver can be triggered by declarative pointing (Liebal, Carpenter & Tomasello, 2010). Declarative pointing is a common act when a new object suddenly appears on the scene. As a result, the child and the caregiver each direct attention towards this object, which can lead to shared excitement and talk about it (Bates, 1979). Declarative pointing can also be a channel of communication when a familiar object comes to the scene for which the child and the caregiver shared attention, excitement or a conversation when it previously appeared (Liebal et al., 2010). Pointing also provides an estimation on how often children or their caregivers point to focus their own attention in order to keep track of things or to locate things on the screen. In the context of the present study, pointing is expected to be used by children since pointing appeared to be most effective for preschoolers, who are indeed at their learning

counting stage (Saxe & Kaplan, 1981). Pointing helps preschoolers facilitate their counting accuracy through tracking the counted items (Alibali & Dirusso, 1999).

A multi-touch, screen-based environment establishes additional forms of gestures related to actions of the hands on the screen. Saffer (2009, p. 2) defined a gesture in his book *Designing Gestural Interfaces* as: "any physical movement that a digital system can sense and respond to without the aid of a traditional pointing device such as a mouse or stylus." Among different gesture types identified in the literature, two main gesture categories are relevant to the present study - epistemic gestures (Billinghurst & Buxton, 2002) and dynamic gestures (Saffer, 2009).

### 1.3.3. Epistemic gestures

Epistemic gestures refer to the act of reaching out to something on the screen, and activating it, in order to learn through haptic or tactile exploration. In the context of the present research, epistemic gestures refer to tapping the hotspots to activate them.

Since gestures may overlap, it can be difficult to determine whether a person is tapping for the sake of activating the hotspot, or for the sake of pointing to establish joint focus of attention to a specific location on the screen. Pointing is done to track a virtual object on the screen or locate an object on the screen.

### 1.3.4. Dynamic gestures

Dynamic gestures can be a specific form of epistemic gestures that include moving over time, such as drag-and-drop of virtual objects on the screen.

## 1.4. Shared reading of print books with mathematical content

Shared reading can be influential in constructing meaning in unfamiliar domains, such as mathematics, by utilizing an array of communicative tools. Shared reading as a means to promote thinking about mathematical concepts has attracted little attention. Anderson, Anderson, and Shapiro (Anderson & Anderson 1995; Shapiro, Anderson &

Anderson 1997; Anderson, et al., 2004; Anderson, Anderson & Shapiro 2005) pioneered a series of studies to explore the contribution of shared reading activities to mathematics related talk, thinking and learning.[1] A later research was conducted by Hojnoski, Columba, and Polignano (2014).

An early longitudinal case study by Anderson et al. (1995) documented shared reading episodes in home-based settings using a variety of print storybooks that were either familiar or unfamiliar; and those that presented explicit mathematical concepts in both the text and/or illustrations and those with no explicit mathematical content. Audiotapes of shared reading sessions between the authors and their pre-school aged daughter were reviewed to explore the contribution of shared reading on mathematics related meaning construction. The study aimed to explore the child's initiations of mathematics concepts such as counting, addition, shapes, and measurement. Primarily, it sought to explore how the child's initiations were supported by and were an inherent part of the shared reading activity. Findings from the case study provided evidence that shared reading, regardless the context, provided a rich platform for the child to demonstrate an active role in interactive conversation about mathematical ideas rather than being a passive recipient of information. The child's tendency to initiate mathematics talk, construct meanings using mathematics-related ideas and relate them to personal experiences significantly increased when the mathematics-related content was embedded in the illustrations, storyline, or title such as in the storybook *Twelve Elves* (Wylie, 1972). When the child initiated talk about mathematics idea, the caregiver encouraged the child to expand upon initial ideas and engage in reasoning and problem- solving.

Reporting results on only one participant limits the understanding of the diverse ways that children and their caregivers attend to mathematical ideas. In a later study, Shapiro and his colleagues (1997) explored diversity in the mathematical discourse during shared reading. Caregiver-child conversation was the central unit of analysis in the interactions of 12 parents and their four-year-old children during the shared reading of two storybooks. Both storybooks contained references to mathematical ideas and

[1] Learning mathematics content is beyond the scope of the present research, therefore, my synthesis of Anderson et al. 1995 is limited to discussion of the child's talk rather than her learning pattern.

concepts related to counting, size, shape, and estimation. These storybooks were not created with the specific aim of generating mathematical discussion. Analysis of the parents' language elicited during these shared reading sessions showed that illustrations are critical in children's early literacy development. The ratio of attention-to-illustration to attention-to-text was 10:1 for both storybooks. However, parents' attention to mathematics concepts embedded in the text or illustrations differed as a function of the storybook. Particularly, the mathematical content embedded in the illustrations was more explicit in one storybook compared to the other. The storybook with more explicit mathematical content included objects with different sizes illustrated close to each other. These stimulated discussion about the sizes of the objects. The concept of variation was rarely discussed when the caregivers and children examined the book containing illustrations of characters that were the same size. Parents also counted objects with their children for the purpose of clarification or elaboration, thereby extending meaning about numbers.

In a following study, Anderson et al. (2004) investigated shared reading of four parent-child dyads. They videotaped and examined nuanced dyadic patterns of interactions as they constructed mathematical meanings. Mathematical discussion was diverse due, in part, to influences associated with specific mathematical concepts in the narrative (Anderson et al., 2004; Shapiro et. al., 1997), individual cultural practices (Anderson et. al., 2004), and/or the attention paid to the text by both children and caregivers. The researchers examined the latter factor. In two of the dyads, the majority of questions originated with the caregiver, and mathematical questions included both clarifications and knowledge exploration. A third dyad showed both the child and the caregiver initiating discussion about mathematics, and the fourth showed the child initiate the majority. The topics of discussion were diverse in each dyad, representing many paths to mathematical solutions conveyed by themes presented in a book's narrative. Some caregivers used problem-solving as a tool to refocus the child on the mathematical content, while others tried to relate the book to a past experience the child would remember. Some caregivers used the illustrations as a tool to focus the child on the mathematical discussion. The authors concluded that the construction of mathematics

meaning by the child or caregiver is a joint response to illustrations in combination with the narrative.

The considerable heterogeneity in patterns of attention to mathematics in Anderson et al. (2004) led to a subsequent study (Anderson et al., 2005) where Anderson and her colleagues recruited a larger sample of 39 dyads of four-year-old children and their caregivers from culturally diverse backgrounds in a metropolitan area. The study investigated patterns of constructing mathematics related meanings. Analysis of video recordings showed that caregivers mediated discussion of a range of early mathematical-related concepts as they interacted with their children. The amount of talk and the patterns of sharing mathematics related ideas considerably differed across the dyads. Only a few dyads accounted for more than half the total of mathematics related discourse. Even though most of the mathematics related concepts in the story centered on numeracy, size, and shape, not all of these concepts were attended equally by all dyads. Diversity was also noted in the frequency of mathematical discourse turns generated as the dyads shared each storybook, a finding that affirms Shapiro et al.'s (1997) and Anderson et al.'s (2004) findings.

Similar to findings from Anderson et al. (2004) and Shapiro et al. (1997), Anderson et al. (2005) documented the importance of contiguity between illustrations and storyline. Measurement concepts seem to pique the interest of several dyads when illustrations in the storybook prompted the reader to measure something, particularly when the storyline and the illustrations were aligned. For instance, an illustration of a 45 cm long eel aligned with the text "an eel whose tail... too far to remember" encouraged describing the length of the eel and then asking the child to trace it with the finger.

The variation in responses of children and parents while shared reading of the mathematics-embedded print books is also seen in some training studies. In these studies, parents were instructed about mathematics concepts and vocabulary to support their engagement during shared reading sessions (Hojnoski et al., 2014). Engagement with mathematics content did increase as a result of the training, however, not all dyads expressed the same levels of engagement.

In summary, findings from these lines of research show that shared reading has the potential to provoke mathematical discourse and to facilitate the construction of mathematics-related meanings. Illustrations act as descriptors and prompt to help caregivers and children initiate mathematics-related talk within shared-reading literacy sessions. The effect increased when the illustrations and the story script aligned well and represented the same mathematical content (Anderson et al. 2004; Anderson et al. 2005). However, considerable diversity in the frequency with which children and their caregivers attend to mathematics content was observed across dyads and storybooks. Moreover, that illustrations and text are static suggests there is a high probability that the caregivers and children allocate attention to different locations on the page. Locating a point of joint focus and initiating talk about it appears to be led by the caregiver, regardless of being trained or not; however, it is clear that the children are also active agents in the shared reading activities.

eBooks bring a new dimension to a shared reading activity. They can be engineered to stimulate joint attention (Rvachew, Rees, Carolan & Nadig, 2017), sparking discussion of story-relevant mathematic content. eBooks are likely to be the most effective when the design features are aligned with the narrative (e.g. Korat & Or, 2010), or when they bring attention to animations or illustrations that portray mathematics concepts (e.g. clear variations in sizes of objects). Next, these possibilities are discussed in relation to the current research regarding eBooks and shared reading.

## 1.5. eBooks: Multimedia Design Features

eBooks range from non-interactive to highly interactive (Landoni & Gibb, 2000). Non-interactive eBooks are the simplest form of eBooks; they function much like static, printed texts with pages that can be turned using the computer mouse, keyboard, or the touchscreen. Interactive eBooks can function primarily to entertain the child, or to assist their understanding of the text through linking hotspot with either print, animations or spoken explanations. Interactive eBooks can be one of three kinds: (1) eBooks that include automated interactive features that combine features that dramatize the text, such as background music, animations, and audio enhancement; (2) eBooks that require the

reader to explicitly interact with varying multimedia features - through tapping hotspots - to trigger dramatizing features of the text of the illustrations or to start music or animation; (3) a combination of both, automated interactive features and also features that require the action of the reader.

Flat panel displays, such as computers, tablets, or cell phones, are the most popular medium for reading eBooks. Some are web-based and open source while others require commercial applications. Various terms are used to describe eBooks, including, talking books, CD-ROM storybooks, or interactive books (Roskos & Brueck, 2009).

eBooks are increasingly purchased by caregivers of young children (Buckleitner, 2011). Proportionally, the number of children who use a tablet or handheld media device to play video games, watch videos, or use applications, increased from 38% to 72% between 2011 and 2013 (Common Sense Media, 2013). The accompanying increase in eBook sales reflects a change in public opinion and an acceptance that eBooks are a productive learning resource for children (Leseman, Mayo & Scheele, 2009). One possibility is that eBooks have greater potential to facilitate child development due to the entertaining function of the dynamic features, which are thought to both enhance the shared reading activity and sustain the caregiver's and the child's attention to important aspects of the story. Caregivers' confusion about eBooks, however, is not lessened by the growth of the industry. Caregivers may find it more difficult to judge the efficacy of sharing eBooks compared to print literature. Dynamic features in eBooks may function only to entertain children and, as a result, to distract children from focusing on the story content. Further research is needed to establish how dynamic features in an eBook affect children's shared reading practices (Bus, de Jong & Verhallen, 2007). Moreover, social interactions between caregivers and children seem less warm when sharing eBooks compared to print storybooks (Yuill & Martin, 2016). This dip in emotional engagement may have a negative effect on the child's understanding, and engagement (Yuill & Martin, 2016).

Research to date has shown that the engagement of young children in shared eBook readings is closely tied to how caregivers respond to their children's verbal reactions (e.g. Raikes et al., 2006). However, eBooks consisting of all the "bells and

whistles" including loud, fast effects that are unrelated to the story content, tend to distract children's attention away from the storyline (De Jong & Bus 2003). These extraneous design features are considered decorative or incidental multimedia features (Bus, Takacs & Kegel, 2015) and do not usually promote understanding the storyline or highlight related content. Therefore, these features tend to interrupt the caregiver-child interaction and meaning construction during shared reading activities (Korat & Or, 2010).

A "conflict of dual representation" (Tare, Chiong, Ganea, & DeLoache, 2010) may occur when information presented in verbal and visual modes conflict or do not match in eBooks. This may cause interference, hindering engagement with the storyline and disrupting the communication between the child and the caregiver. For instance, a background auditory cue that is not related to the narrated content that is automatically activated may redirect the child's attention, forcing the caregiver to pause in the middle of reading (Parish-Morris, Mahajan, Hirsh-Pasek, Golinkoff & Collins, 2013).

Cases of "conflict of dual representation" are frequent in eBooks. An analysis of digital elements within a corpus of 55 Dutch eBooks published between 1995 – 2002, made for children aged three to seven years, showed that 90% of the hotspots were incidental to the storyline (Bus & de Jong, 2003).

Supplemental multimedia that aligns with the storyline can direct attention to the narrative (Korat & Shamir 2008). Supplemental features include multimedia developments such as background effect, animations, highlighting of text, or hotspots involving words and/or images. These features are intended to set the mood as a way to support understanding the storyline (Pearman & Chang, 2010), direct the child's attention to specific features of the story (De Jong & Bus, 2002; Bus et al., 2015), or increase the child's active involvement and promote understanding (e.g. Korat & Shamir, 2008).

## 1.6. eBooks and shared reading practice

Findings in this area of study are mixed. Research concerning eBooks and their applications in shared reading typically compares the quality and quantity of discussion between the caregiver and the child while reading an eBook with multimedia features to those discourse features while they read a traditional print book (Kim & Anderson, 2008;

Lauricella, Barr & Calvert, 2014). Studies that compare two or more different eBook designs in adult-child shared reading settings are rare. Results are also mixed.

In the study by Parish-Morris and her colleagues (2013), caregivers and their three to five-year-old children were randomly divided into three groups, differing according to whether the adult read a printed storybook, an eBook (touch electronic console) or an eBook with interactive options turned off (control group). The eBook included a typical page-turns, like the print book. However, it also included buttons that the child could press to activate audios of letters or words or background music. The touch electronic console paused the audio text to allow for repeated readings of letters and words, or to count virtual objects by tapping on them. The touch electronic console also included hotspots for animations, music effects, and games. Each eBook included over 60 interactive activities that exclusively aimed to improve literacy skills (e.g. spelling and vocabulary) or problem-solving. Researchers reported that the children were highly engaged with the shared reading activity, a beneficial adult-child dialogue was exchanged, and the children successfully comprehended the content. However, a significant amount of utterances was devoted to managing both the child's interaction and behaviour around the multimedia features of the eBooks. Researchers also noted that the adult-child conversation was enhanced when an eBook functions much like a print text, by disabling the interactive and digital features (Parish-Morris et al., 2013).

Kim and Anderson (2008), facilitated and observed the shared readings of two distinct eBooks. The first was a CD-ROM format that contained interactive features. These controlled the movement of characters, animated illustrations, and control over the pace of viewing. The other, described as a "video-clip" type eBook, in which page turning was not controlled. Findings revealed more conversational exchanges, and more complex and useful communication between the child and the caregiver while sharing the CD-ROM. This was because the CD-ROM offered an open-ended format without time restriction, as opposed to the video-clip format.

Korat and Or (2010) compared the influence of sharing eBooks with interactive features against two print books on the discourse of mothers and their children. The

findings revealed that in comparison with print books, eBooks yielded more initiations from children, and heightened the children's responsiveness to their mothers' questioning. However, it is noteworthy that reading print books yielded more discourse initiated by the mother.

The variation in eBook design features used in each study resulted in mixed findings. In Kim and Anderson's study, multimedia features focussed the readers' attention to narrative features, in turn promoting shared attention. However, the increase of quality among the dynamic features in eBooks from Parish-Morris's study may have divided joint attention between multiple actions and events that did not directly impact the narrative. That peripheral information, in addition to the already present narrative, may have limited the children's ability to recall and construct a coherent mental model of the story.

There is also evidence to suggest that both print and eBooks have the potential to elevate child-caregiver engagement during the shared reading activity. The specific types of interactions, however, differ depending on the presented format (Lauricella et al., 2014). In Rvachew, Rees, Carolan, and Nadig (2017), 28 kindergarteners were read the same storybook and eBook, with adults in multiple one-to-one shared reading settings. The eBooks were designed to support interactive, shared reading by the adult. Findings showed that both the eBook and the storybook supported the children's language and literacy outcomes. However, differences across the conditions were found in attention to print. Sharing the eBook resulted in five times more concept mentioning about the text rather than in the print books. Adults that also shared the eBook tended to talk more about word meaning, due to the eBook's design of highlighting relevant text.

The mixed results in the literature in regards to outcomes of shared reading of eBooks point to the influence of the design on shaping the child-adults dialogic reading exchanges.

## 1.7. The Cognitive Theory of Multimedia Learning (CTML)

Since an eBook's design potentially shapes how children and their caregivers engage with literacy practices, principles associated with multimedia design theories are foundational to guide the construction of eBooks. The Cognitive Theory of Multimedia Learning (CTML; Mayer, 2009) and the closely aligned Cognitive Load Theory (CLT; Sweller, 1988), are used in the present research to design an eBook with dynamic features that appropriately associate with mathematics concepts.

*Cognitive Load Theory* (CLT; Sweller, 1988) provides a theoretical foundation to consider how the design of literacy tools - such as eBooks for children - may impact caregiver-child attention to a mathematics-related narrative. By extension, this can also impact their mathematics related conversations.

The *Cognitive Theory of Multimedia Learning* (CTML; Mayer, 2009) is a theoretical framework cited repeatedly by researcher and designers of multimedia tools for educational purposes. The present study applies principles of CTML as a theoretical base for this study.

Research concerning print books confirms that young children instinctively attempt to match (visual) illustrations with (spoken) text as they navigate a storybook. Verhallen and Bus (2011) found that young children fixate their attention on static illustrations that they feel correlate with the text they are reading. Animated illustrations also help children fixate their attention (Takacs & Bus, 2016).

In the context of the present study, CTML posits that both children and caregivers act on attentional resources in their working memories to keep information in mind for processing that leads to comprehension or reasoning (Baddely, 2010). They also self-monitor a number of variables during a shared reading; these include selection, maintenance, and information organization (Gathercole, Pickering, Ambridge & Wearing, 2004). Yet, compared to adults, research has shown that the working memory capacities of very young children are limited (Gathercole et al., 2004). Therefore

designing eBooks for young children requires managing cognitive load so it does not exceed the child's working memory capacity.

Processing visual and verbal modalities simultaneously rather than contiguously or in a fast-paced presentation may overwhelm the child's working memory capacity and negatively affect attention (Clark, Nguyen, & Sweller, 2006). Therefore, it is recommended to align interactive design features with the overall narrative and accompanying illustrations - especially those that can be pace-controlled.

A cognitive load can also result when the child engages in irrelevant cognitive processing. This distracts from the eBook narrative. If an eBook frequently presents distracting features, such as incidental hotspots, children and caregivers must actively avoid attending to the interfering information to maintain focus on the story (Bus et al., 2015). Control over one's attention to this information reduces temporary storage in working memory of story-relevant information (Sweller, 2005). Directing attention to the narrative supports child-caregiver communication during shared reading (Korat & Shamir, 2004; Korat & Or, 2010).

## 1.8. The Present Research: Aims and Research Questions

The research reported in this dissertation aims to expand upon previous research by exploring the impact of variations in eBook design, specifically hotspots, on children's and caregivers' spoken utterances and gestures about mathematics content during shared reading of eBooks. Variation of hotspots of the same eBook has not been tested previously. For comparison purposes, two eBooks were designed. Each contained the same story and illustrations but one contained hotspots that were directly aligned with mathematics content (i.e. the math eBook) while the second contained hotspots aligned with actions or emotions expressed by characters (i.e. the emotion-action eBook). Mathematics and emotions-actions were chosen to differentiate the two eBooks because the narrative, particularly through illustrations, was intensively depicted by mathematics content, and the emotions and actions of characters.

The CTML theory guided the design of the eBook hotspots and the layout of the eBook along with other theories that guided the story content (to be explained in Chapters 2 and Appendix B). During the shared eBook reading activity, communication between the caregiver and the child is central to how meanings about mathematics concepts are constituted. Therefore, spoken utterances and gestures are critical data to gather and analyze to examine interactivity in this social communication. Socio-cognitive perspectives presented previously in this chapter are foundational to the analysis of spoken utterances and gestures of children and caregivers during the sessions. This research aims to answer the following questions. The first deals with hotspots in both eBook and their influence on the mathematics related communication about the narrative:

1. What is the impact of eBook hotspots (mathematics vs. emotions-actions) on caregiver-child communication about mathematics during shared reading practices?

The second question refers only to the math eBook and deals with the ways math hotspots cue caregivers' and children's attention and impact communication about problem-solving activities related to the embedded mathematics in the story:

2. How does the alignment of hotspots with problem-solving activities in the story narrative affect caregiver-child communications about mathematics?

The following chapters in this dissertation present a description of the literature on the theoretical principles of CTML theory and principles of composing stories with mathematics content for young children (Chapter 2). Then, the mixed methods design and procedures of the research are described (Chapter 3). The results of the mixed methods study follow to explore the use of communication tools to interact around mathematics in each eBook (Chapter 4). This is followed by a discussion of the research findings (Chapter 5).

# Chapter 2.

# Literature Review on eBook Design

The present research employed two eBooks, both including multimedia features that highlighted the same narrative elements and illustrations. Certain animated features and background sounds considered necessary for dramatization were included in both eBooks. The eBooks, however, used the hotspots differently. One contained mathematics-themed hotspots while the second eBook's hotspots pertained to the emotions and actions of characters. In this chapter, the theoretical framework that guided the design of the two eBooks is discussed.

The chapter is divided into three parts. The first section presents the Cognitive Theory of Multimedia Learning (CTML) and its application to eBook construction. The second section reviews literature concerning the construction of children's books, print or electronic. In the third section, an overview of Marston's (2014) framework for evaluating the quality of children's books is presented and discussed in relation to the eBooks' designs.

## 2.1. Cognitive Theory of Multimedia Learning (CTML)

As previously discussed in Chapter one, the Cognitive Theory of Multimedia Learning (CTML; Mayer, 2009) draws upon the Cognitive Load Theory (Sweller, 1988) to guide the design of multimedia features. The theory has three primary assumptions: (a) multiple modalities – auditory, visual, and haptic – are used to process information; (b) information is processed in working memory, a limited capacity executive resource; and (c) in learning, relevant information must be organized and integrated while non-relevant information must be inhibited.

The eBooks in the present study were not created specifically for learning or instruction; rather, they were engineered with the aim of increasing communication between the child and the caregiver. Communication relies on some of the same

principles as learning: attention to relevant information and inhibition of non-relevant material. Therefore the design of the present eBooks was informed by CTML principles and assumptions.

Six CTML principles are discussed below: the multimedia principle, the temporal contiguity principle, the segmentation principle, the signaling principle, the coherence principle, and the personalization principle.

### 2.1.1. The Multimedia principle

The multimedia principle generally suggests that individuals learn more from verbal and visual information in combination rather than either format alone (Mayer, 2009). CTML describes visual and verbal modalities as two separate channels, but information processing during shared readings requires attention to multiple modalities, including haptic information (e.g. turning pages, or touching the screen). The present eBooks adhere to the multimedia principle; as children and caregivers could hear the spoken text – by the interactive feature or caregiver narration – which were aligned with visual, verbal, and haptic design features like hotspots. These hotspots activated illustrations, animations, and other highlighted features that aligned with the narrated content.

### 2.1.2. The Temporal Contiguity principle

This principle posits that when verbal and visual information are presented contiguously instead of simultaneously, working memory load is reduced. Attentional resources can then be distributed effectively, freeing processing capacity for information from multiple modalities (Mayer, 2009).

The temporal contiguity principle was implemented in multiple scenes in the eBooks. For example, in both eBooks, the script “(the little bear) was very happy” was read by the caregiver (verbal information) and then was followed by an animation of the smiling little bear (visual information).

### 2.1.3. The Segmentation principle

The segmentation principle states that breaking animations into shorter segments reduces complexity. This, in turn, helps the viewer/reader to manage working memory load more effectively. Overly rapid change in media animations interferes with effective storage as new information rapidly comes in to working memory (Ayres & Pass, 2007). The eBooks developed for this research recognize this principle. The eBooks design features allowed the caregiver and/or child to control not only how the information was segmented, but also the rate at which information was presented. To support attention to segmented information, the reader activated hotspots to regulate information flow, including access to backward and forward buttons (e.g. Moody, Justice & Cabell, 2010). Control of pace is critical for the child to increase interaction and engagement in the shared reading (Kim & Anderson, 2008). Speed control also allows caregivers to tune the story presentation to the child's reactions and/or needs (Shade & Watson, 1987).

### 2.1.4. The Signaling principle

This principle posits that multimedia features can increase attention to relevant information and decrease attention to distracting information (Mayer, 2009). For example, attention can be drawn to the sequence of animations by zooming to different parts of the screen or using a directional arrow. This design feature can be used to signal important information across the temporal sequence (Mayer, 2009). In the present research, hotspots were signaled by bright colors which cued the children and caregivers as to which hotspot was necessary to activate at particular points in the narrative.

### 2.1.5. The Coherence principle

This principle posits that using multimedia features to articulate information in a coherent way leads to more effective information processing than a system in which design features neglect or mask coherence. The eBooks in the present study were designed to align visual information (images) with the narrative. Unrelated information such as activities, hyperlinks to dictionaries or games, were not included in the eBooks.

### 2.1.6. The Personalization principle

According to the personalization principle, multimedia designs incorporating information that has personal meaning to the user are likely to increase attention to the content. The personalization principle is applied often to multimedia designs for children (Vasilyeva, 2007) through actions such as directly referring to the child with the pronoun "you" instead of using general references (Mayer, Fennell, Farmer, & Campbell, 2004). Personalizing content also increases children's motivation and their willingness to spend more productive time on learning tasks (Pintrich & Schunk, 2002). Making interactions with media relevant to an individual's lived experience potentially helps them consider the material as meaningful opposed to a situation where they are a passive observer (Mayer et al., 2004).

In the present study, the personalization principle was applied by inviting children to choose a name for the lead character, which was a three-year-old bear. The story also often included questions for the children so that they could partake in conversation with their caregivers.

## 2.2. Children's Stories

eBooks that are specifically tailored to a child's developmental readiness, interests and psychological needs are expected to increase the child's engagement and motivation concerning information in the eBook. The eBook "*Let's Catch More Fish"* was designed for the present research with these principles in mind.

Professional literature about writing and illustrating children's stories was reviewed. Print books and eBooks shape shared readings in different manners, but many of the findings from the literature review were helpful for developing eBook drafts and design features. In the discussion below, a review is presented of research on constructing stories and illustrating stories for children. A description of the way these findings influenced the construction of the narrative is also included. The final story *Let's Catch More Fish* is reproduced in Appendix A

### 2.2.1. Constructing the story

#### *Characters*

Children are fascinated by animals. Research has shown that children often prefer a photo of an animal to that of a non-animal, and they prefer faces of infantile animals over human babies (Borgi & Cirulli, 2013). Following these findings, anthropomorphized bears with childlike features were chosen to be lead characters in the eBook story in the present research.

Characters drawn in a minimalist style of details and realism leave the possibility of creative interpretation of characters identities, moods, feelings. A minimalist style (Painter, Clare, Martin & Len, 2013) is among the recommended storybook art styles for very young children. In this style, characters' heads are usually made up of ovals or circles with small circles or dots for the eyes. In most of the scenes involving characters, backgrounds are empty or include minimal elements. Using backgrounds with minimal details directs the child's attention to the main images in the story rather than to peripheral images. For example, when a scene revolved around the actions of the bears, their appearance was salient when positioned in a background that included few additional details.

#### *Plot*

According to Aristotelian narrative structure, plot refers to a set of events linked together so that they progress in order within the story (Chandler & Munday, 2011). The links are formulated through cause and effect, and the effects set into motion a significant change in the characters' goals, plans, and course of action.

A plot is characterized by specific flow across the story involving an escalation of events from balance, creating imbalance, and then returning to balance (Chandler & Munday, 2011). This results in a recognizable, orderly story pattern. A balanced beginning of the story consists of character and event exposition. The middle part of the story is dominated by imbalance created by rising actions from which conflict emerges

which is then resolved, thus restoring balance. In children's stories, the plot includes no more than one conflict (Shepard, 2000).

### *Narrative Genre*

A narrative genre was used to guide construction of the story. At the beginning of the story, characters and settings are introduced (Taylor, 2008). Exposition, rising actions, climax, falling actions, and denouement are the features that keep the story moving from the beginning to the end. Description of these features and their relation to the story developed for the eBooks is presented next.

In the story *Let's Catch More Fish*, the exposition introduces the reader to a little bear who lives with her parents. After introducing the characters, actions take place that demonstrate the little bear's love for fishing. Next, the father bear states, "Let's go fishing." This cues the launch of the primary action – a fishing adventure. This primary action was developed through several events that were chronologically ordered and were presented at a fast pace. The exposition also included the little bear's main goal of catching three fish in total.

Rising action refers to a set of events that develop prior to the climax. They include the development of characters and events and the conflict that interferes with the main character's fulfillment of her goal, which is to catch three fish (Taylor, 2008). In the story *Let's Catch More Fish*, rising action is created with each unsuccessful attempt to catch fish.

The end of the story is characterized by resolution, which is subdivided into climax, falling actions, and denouement or closure (Chandler & Munday, 2011; Taylor, 2008). The climax refers to the dramatic portion of the plot in which the character overcomes the central conflict. After catching a boot and a broken chair instead of fish, the little bear's father suggested that they sing a song to attract the fish. The climax began after singing the song when the little girl bear started catching fish and putting them in a basket.

In contrast to rising action, falling action occurs after the main conflict is resolved (Tayler, 2008). The success of the little bear catching the desired number of fish pushed the plot forward and re-established a stable equilibrium.

Denouement includes the reveal of the final solution and closing off loose ends. Whenever the little bear sang she caught a fish. After three songs she had caught three fish, which was her goal. Then the little bear and her father return home in the evening to share the three fish with the other family members. The eBook ends with the whole family gathering around the table for dinner to eat the freshly caught fish.

### *Themes*

A story theme is a viewpoint or concept developed throughout the storyline (Shepard, 2000). The story's theme/s should be significant, and it is best to have themes not emerge abruptly (Shepard, 2000). The story fostered two themes: a sense of belonging and respecting the environment. The first theme aimed to promote a sense of belonging among children living in an urban area of Western Canada drawing on the activity of fishing that is common in their culture. The second theme aimed to promote respecting the environment through the act of releasing small fish back to the river and keeping just three fish to sustain the fish population in the river.

### *Point of View*

The eBook is written as a third person narration, as recommended for children's stories (Shepard, 2000). As opposed to a first-person view, the third person narration emphasizes emotions in a simpler fashion. This allows the children to consider the bear's perspective separate from their own (Mitchell, 1997), a perspective that may be challenging for young children yet to develop a theory of mind.

### *Vocabulary and Syntax*

The vocabulary and syntax of the eBook were controlled to ensure that language spoken by the caregiver was familiar to children at three years of age. Alternating tenses created two levels of narration within the story. First, the past tense conveyed narration of the fishing journey that took place in the past. The tense to the present switched in the

mathematical activities that were embedded in the story. Switching to a present simple tense was important in creating a context that resembles face-to-face interaction (Kümmerling-Meibauer & Meibauer 2015). Questions in the present tense (e.g. “Can you help (the main character) share the fish?”) prompt engagement with the caregiver to solve the mathematics problem.

***Repetition***

Predictable repeated language patterns, have been reliably shown to support young children's ability to retain information (Hargis, Terhaar-Yonkers, Williams & Reed, 1988). Vocabulary acquisition is also associated with repetition (Darnton, 2001; Horst, 2013). When children encounter a novel word repeated different times in the same story, they are more likely to recognize the word in new contexts (Horst, 2013). The language associated with repeated and predictable actions was central in both eBook narratives. The story included the repetitive action of catching fish, then counting them. It also included a short song the main character sang a few times throughout the story.

## 2.3. Incorporating Mathematics Content in the eBook

Creation of a storybook to facilitate constructing ideas about mathematics concepts in the early years is contingent on incorporating clear and relevant mathematical ideas in both the text and the illustrations (Anderson, Anderson & Shapiro, 2005). Previous findings showed how illustrations play a primary role in increasing children’s attention to the mathematical content beyond the explicit textual meaning presented in the story. Illustrations also helped the children generate more mathematically sophisticated discussion as they were read stories by adults (Van den Heuvel-Panhuizen & Van den Boogaard, 2008).

Marston (2014) claimed that there is little to guide parents and teachers about storybooks with clear and relevant mathematics content. She reviewed 122 storybooks with mathematics content to help parents and teachers select storybooks suitable for introducing mathematics themes to children. Her goal included identifying criteria for future research and policy about storybooks to facilitate the development of mathematical

concepts in young children (Marston, 2010). Features Marston proposed and their applications to the eBooks construction are as follows:

### 2.3.1. Mathematical content

Mathematical content within the text and the illustrations is described by Marston (2010, 2013, 2014) as perceived (mathematical concepts are apparent), explicit (aims to teach or develop particular mathematical concepts) and embedded (concepts purposefully embedded in an entertaining way). The content of the mathematics in the eBooks was embedded in the title, symbols, diagrams, illustrations, and actions. The title *Let's Catch More Fish*, cued the child and caregiver to the quantitative concept of "more", which was also embedded in the story narrative and images. The concepts associated with incremental gains in quantity and/or size were made explicit in repeated actions and language associated with the actions.

### 2.3.2. Integration of mathematics concepts

The eBooks created for this research integrated several mathematics concepts (see Table 2.1 for definitions) such as one-to-one correspondence, cardinality, measurement, and division. These concepts were realized in story content such as when the bears count fish and arrange fish from the biggest to the smallest. Digital features along with the caregiver's scaffolding were used to support how children counted fish and compared their sizes. Cardinality was facilitated when a virtual fish was tapped, the cumulative number of fish was highlighted and the cumulative number of fish was spoken. Measurement was addressed in the design; a fish was highlighted, and the order number was spoken only when it was tapped in temporal order.

### 2.3.3. Mathematical meanings

Mathematical meanings were constructed through the caregiver's and child's discussion of the text and visual images as meanings were embedded naturally and spontaneously in the story's images and narrative. Also, the mathematical content developed gradually throughout the story. The eBooks introduced basic mathematical

concepts at the beginning of the story (i.e. counting to three), followed by addition and subtraction actions, and ending with a mathematical problem-solving activity requiring division.

### 2.3.4. Mathematical problem solving and reasoning

Marston argued the text and images in print stories afford opportunities for children to engage in solving problems, identifying new problems and strategy use, and following multiple paths. Following this criterion, the eBooks created for the present research incorporated questions that facilitated mathematics reasoning and problem-solving in the caregiver-child discussions. For example, a problem was posed in the text of both eBooks: “Can you help (the main character) share the fish?” This activity aimed to encourage communication between the child and caregiver about mathematics. Dividing three fish of different sizes between four bears created space for multiple paths to problem-solving. A pet cat, potentially hoping for leftover fish, was also shown sitting near a window in the background.

### 2.3.5. Affordance for mathematics learning

According to Marston (2010, p. 388), affordances for mathematics learning criterion is explained as “the way the book motivates and engages students in mathematical concepts and activities, promotes an enjoyable atmosphere, and encourages positive attitudes towards mathematics and mathematics learning”. Furthermore, considering this criterion in storybook creation encourages children to perceive mathematics as social, and important for active participation, beyond capacities for reasoning and creativity (Schiro, 1997)

In essence, the eBooks created for the present research aimed to provide children with an enjoyable and motivating experience using mathematics concepts. As both eBooks were designed to be read by adults in shared reading practices, an automatic narration option was not included. The eBook designs aimed to stimulate the child’s engagement through the caregiver’s modeling, questioning, elaborating, and explaining unique content (Marjanovič-Umek, Hacin & Fekonja, 2017).

### 2.3.6. Curriculum content, policies, and principles

According to Marston's classification scheme, the criterion of curriculum, content, and principle in storybooks means that: "the mathematical content is consistent with relevant curricula and reflects policies of gender equity, cultural and socioeconomic diversity, inclusiveness, and environmental awareness" (Marston, 2010, p. 387).

During shared reading practices children were expected to co-construct with their caregivers' new mathematics meanings and concepts through communication centered on the eBook. To increase the likelihood the concepts discussed were at least to some extent unfamiliar to the children, the concepts depicted in the story aligned with the British Columbia Ministry of Education mathematics curriculum for kindergarten aged children (BC Ministry of Education, 2016).

The curriculum content and its application to the eBook story are described in Table 2-1. Curriculum content that was embedded in the eBook were: number concepts, ways to make five, change in quantity (to 10), and direct comparative measurement.

Two additional counting principles not mentioned in the curriculum that were taken into consideration while embedding the mathematics principles in the eBooks - the *abstraction principle* and the *order-irrelevance principle* - were outlined by Gelman and Gallistel (1978). The abstraction principle states that any collection of similar, or different items can be counted as a set. The fish in the eBooks appeared in different sizes and different colours to afford occasion for applying the abstraction principle of counting.

The order irrelevance principle states that the order in which the counting is carried out is irrelevant. Counting could start with any fish and could be done from any direction as long as every object in the set is counted once.

**Table 2-1.** The B.C. Kindergarten Mathematics Curriculum Content and Application to the eBooks' Content

| Curriculum content | Application to the eBooks |
|---|---|
| **Number concepts**<br>Refer to a set of basic mathematics skills of counting and comparing numbers (Chin & Zakaria, 2015). The skills included in the curriculum and the eBooks are the following: | |
| One-to-one correspondence: the assignment of only one number word in correspondence with each item in a counted set (Gelman & Gallistel, 1978).<br><br>Cardinality: the last counted number represents the total number of elements in an enumerated set (Gelman & Gallistel, 1978).<br><br>Stable order counting: the number words must proceed in the same order while counting (Gelman & Gallistel, 1978).<br><br>Conservation: the number of elements in a set remains the same, regardless of the spatial arrangement of these elements (Clements, 1984)<br><br>Sequencing 1-10: refers to the use of number words while counting, creating repeated patterns (Fuson, 2012).<br>Subitizing: the perceptual process of rapid enumeration of small sets (up to five objects) without counting them (Clements, 1999). | The eBooks emphasized counting as language-based through the forward recitation of the numbers between one and three, one and five, and one and ten. Number words were linked to sets of fish or fingers.<br>In the eBooks, there was an emphasis on perceptual subitizing a set of three items. Particularly, in the scene of the little bear holding up three fingers and saying three. Or, at the end when she was holding the basket with three fish as she said three.<br>The fish appear in different physical arrangements throughout the story to emphasize the conservation of quantity. |
| **Ways to make 5**<br>• Perceptual subitizing (e.g., I see five)<br>• Conceptual subitizing (e.g., I see four and one)<br>• Using concrete materials to show ways to make five. | The eBooks referred to the ability to recognize and name, one to five objects at a glance. The eBook included a scene of five fish that can be counted one-by-one by tapping them and activating spoken and visual hotspots. The addition and removal of fish encouraged both perceptual and conceptual subitizing. |
| **Change in quantity (to 10)**<br>• Generalizing change by adding one or two | |

| | |
|---|---|
| • Modeling and describing number relationships through change | A particular scene involved releasing two fish to the river (one by one) and then constructing a new set of three fish. Counting three fish through one-to-one correspondence was repeated in several scenes. Sets are compared with the words "less," "more," and "fewer," as the curriculum highlights |
| **Direct comparative measurement**<br>• Understanding linear height, width, length (e.g., longer than, shorter than, taller than, wider than)<br>• Mass (e.g., heavier than, lighter than, same as)<br>• Capacity (e.g., holds more, holds less) | The eBook encouraged the use of two attributes within the domain of weight and capacity. Corresponding to the curriculum objectives, the eBooks' content invited the child to:<br>Compare weights of different objects using the words lighter and heavier. The story content explicitly used the words "light" and "heavy" to refer to fish and items (the boot and the chair) of different masses.<br>Compare the capacity of various objects using different words such as smaller. The narrative script of the eBooks included comparison words to express the different weights of the fish. |

The following chapter includes a description of the entire program of research, including a description of the mixed methods study to evaluate how children and caregivers engaged with the two eBooks is described in the next chapter.

# Chapter 3.

# Methods

## 3.1. Research Design

The first phase of the research consisted of the eBooks development. The prototypes were the result of an iterative process involving several focus groups including the researcher, programmers, and the illustrator (see Appendix B). The eBook hosting mathematics-aligned hotspots was constructed first. The second eBook, identical in text and illustration, was created with hotspots that related to characters' emotions and actions rather than mathematics.

The mixed method study investigated the impact of eBooks with and without mathematically aligned hotspots on differences in child-caregiver communication about mathematics. A quasi-experimental aspect of the research compared frequencies of communicative tools (i.e. utterances, gestures, tapping of hotspots and responding to them) between the two eBooks. A qualitative aspect involved observing and evaluating patterns of child-caregiver communication in the math condition as they discussed two specific parts of the eBook; where a mathematics problem was embedded. The qualitative analysis resulted in different themes.

The math condition refers to the eBook with mathematically aligned hotspots. The emotion-action condition contained emotions-actions hotspots that were unrelated to mathematics. Both eBooks included the same story script and illustrations and shared 27 automatic animations intended to spark interest in the story. These animations were not aligned with critical events, emotions of the characters or mathematics related actions, e.g., they animated birds flying and chirping, bears blinking, little bear swinging legs, and movement of the surface of the water around the fishing poles.

Additionally, both eBooks featured 46 other animations that were activated by tapping a visually dynamic hotspot. Hotspots in the math condition activated animations aligned with mathematics content in the text and illustrations. Hotspots in the emotion-

action condition activated animations aligned with emotions of the characters or events in the story that advanced the plot but were not aligned with mathematics content. Hotspots in the math eBook were expected to prompt discussion of mathematics-related content while hotspots in the emotion-action eBook were expected to prompt discussion of the actions and emotions of the characters. Both eBooks featured the same number of visually dynamic hotspots with and without auditory feedback, and hotspots that facilitated drag and drop actions. The relative frequency of hotspots in each of these three categories is summarised in Table 3-1.

**Table 3-1. Categorical Descriptions and Frequencies of Hotspots in Each eBook Condition**

| Hotspot categories | Description | Frequency of hotspots in each condition |
|---|---|---|
| **Hotspot activating animations with auditory feedback** | Tapping the virtual object animates the object, highlights it, or changes its position. This change was accompanied by an audible sound or a spoken word. | 35 |
| **Hotspot activating animations without auditory feedback** | Tapping on the virtual object animates the object or changes its position. There was no accompanying sound or spoken word. | 1 |
| **Hotspot activating Drag and/or Drop animations** | Pressing on the virtual object and holding it down while dragging and dropping it to a particular location on the screen. | 10 |

The eBooks also differed on a second dimension: the number of animations related to mathematics. During the development of the eBooks, it became apparent from discussions with focus groups that when only animations not related to mathematics were included in the eBook in the emotion-action condition, the animations generally drew attention away from story events which had a considerable amount of mathematics content. Therefore, seven of the animations in the eBook in the emotion-action condition were made automatic rather than being triggered by tapping a hotspot. These same mathematics related animations were activated by tapping hotspots in the math eBook.

## 3.2. eBook Development

Creation of the eBooks spanned five phases (Appendix B): 1) constructing the story script, 2) highlighting mathematical content through vocabulary and phrases that reflected mathematics concepts, 3) creating a visual storyboard, 4) populating the eBook with illustrations and hotspots related to the narrative, and 5) programming the eBook for a tablet platform.

### 3.2.1. Constructing the story script

As described in Chapter 2, construction of the initial version of the story script involved a comprehensive review of commercially available eBooks for preschool-aged children and research on the topic of writing children's stories.

Following face-to-face meetings and emails with focus groups and members of the Faculty of Education, the final version of *Let's Catch More Fish* (Appendix A) incorporated a narrative schema that included characters, beginning, plot, climax, and denouement. The storyline focussed on a personified little bear who accompanied her father to the river to catch some fish. After they were unable to catch any fish, her father suggested that she sing a song to attract the fish. When she sang, she caught a fish. After three songs she had caught three fish. Soon after that point, the little bear and her father each caught a small fish at the same time, however, they decided to release both fish because they already had sufficient fish to feed the family and did not want to over-fish the river. The little bear and her father returned home in the evening to share the three fish they had caught with the other family members.

***Focus group consultation***

As previously discussed, multiple focus groups were consulted at each phase of development of the eBook prototypes. The discussions in focus groups emphasized the feasibility and promise of the eBook to generate mathematics-related discussion. These collaborative consultations included feedback about mathematics-related actions in the story, writing style, characters, and the adequacy of multimedia features to connect the eBook narrative to mathematics content (see Appendix B).

*Faculty consultation*

Topics discussed with Faculty of Education professors included the way the narrative could be made more relatable to young children, how communication - involving the child, the caregiver and the story on the device - could be facilitated during the shared reading, and how well the narrative matched the illustrations.

*Early childhood educators*

Two educators made up this focus group. Lisa (a fictitious name) was a Ph.D. student in Educational Psychology with 20 years of educational experience with young children. Laurie (a fictitious name) had been in the field of early childhood education for more than seven years. The two educators provided valuable feedback about whether the eBooks had potential to actively engage young children and how the use of action verbs and vibrant colours in illustrations elevate attention and interest of young children.

*Graduate students in educational psychology*

Three graduate students actively researching cognition in young children were also consulted. Specifically, these students studied the way children use tablets to document their interactions with local science exhibits.

*Parents and their children*

Three parents volunteered themselves and their children to pilot and provide feedback about how their children used eBooks. All families used eBooks on a regular basis. The children were Arabic-English bilinguals ranging from three to five years old. This focus group helped to inform whether designs of the eBook were appropriate for such an environment.

### 3.2.2. Designing mathematics-related hotspots.

Designing mathematics-related hotspots in the math condition was strategically considered. As shown in Table 3-2, hotspots in the math eBook aligned with a range of mathematics-related concepts.

**Table 3-2. Hotspot Categories and Examples from the math Condition**

| Hotspots | Mathematical concept | Application to math eBook |
|---|---|---|
| **Visually dynamic hotspot with auditory feedback** | One-to-one correspondence for counting | Each time the virtual fish is tapped, the cumulative number of fish is highlighted. Simultaneously, the cumulative number of fish is spoken. |
| | Subitizing (the perceptual process of rapid enumeration of three objects) | When the little bear is tapped, she speaks her wish to catch three fish, then she raises her hand and shows three fingers. |
| | Cardinality and measurement | Clicking on the fish and counting them from biggest to smallest. The fish is highlighted and the number is spoken only when it is tapped in the right order. |
| **Visually dynamic hotspot with no auditory feedback** | Subitizing | Tapping on the bear's head shows a thinking cloud with a basket and three fish inside it. |
| **Drag and/or Drop** | Subitizing/ one-to-one correspondence/ cardinality | One fish is in a basket and the child is instructed to add fish by dragging and dropping them into the basket until there are three fish in the basket. A row of three fish appeared next to the basket to help the child instantly recognize the number of fish associated with the word "three". |
| | Comparing quantities | The idea that the quantity of three fish is less than five fish could be shown by dragging and dropping two fish to back to the water. |
| | Addition | Dragging "one more fish" to the basket represents addition. |

| | | |
|---|---|---|
| | Subtraction | Releasing the two smallest fish back to the river by dragging and dropping them. |
| | Division | Sharing the fish with members of the bear family by dragging fish to each bear. |

In the emotion-action condition, the hotspots in the eBook directed the attention of the caregiver and the child to actions and emotional responses in the story unrelated to mathematics content. Examples are shown in Table 3-3.

**Table 3-3. Hotspot Categories and Examples from the emotion-action Condition**

| **Hotspots** | **Function** | **Application to emotion-action eBook** |
|---|---|---|
| **Visually dynamic hotspot with auditory feedback** | Emotional expressions | In some scenes, when the little bear is tapped, she smiles (animated). Simultaneously, she giggles (embedded sound) to show happiness.<br>In some scenes, when the father bear is clicked, he opens his mouth. Simultaneously, he said "uh-oh" to express disappointment. |
| | Music effects | When the musical sign is clicked it is animated. Simultaneously, music played in the background. |
| | Actions of the bears | Clicking on the door of the shed to open it. Simultaneously, a cracking sound is heard. |
| **Visually dynamic hotspot with no auditory feedback** | Moving objects | Tapping on a thinking cloud shows animated images of the sun and the moon inside it. |
| **Drag and/or Drop** | Actions of the bears. | Dragging the virtual image of the bears to the river. |

| | | |
|---|---|---|
| | Moving objects | Moving the fishing pole to different directions on the water surface. |

### *Creating the storyboard*

The storyboard, an initial depiction of the sequential scenes of the eBook and illustrations, was created in collaboration with the illustrator. The storyboard portrayed sketched illustrations in a simple form before the final illustration was drawn. When changes were made to a scene or part of it, revisions to the storyboard insured that the new scene integrated well with the other scenes. The placement of the hotspots in both eBooks was carefully considered.

### *Illustration*

The process of creating illustrations began by reviewing research on children's illustrations and by browsing a corpus of published children storybooks. As described in chapter 2, research findings guided decision-making about the physical features of the characters, backgrounds, and colours. Similar to the previous stages of the eBook construction, ongoing interaction with focus groups guided the illustration process.

Constant collaboration among the illustrator, the programmers and myself was essential before the illustrations were finalised. Through a period of fourteen months, bi-weekly meetings and at times, weekly meetings with the illustrator and a programmer took place.

The illustrator was a young artist. She worked for an animation company that specialized in making short, educational animated movies. Two programmers created the eBooks. The first programmer was a fourth-year undergraduate student in Information Technology with a good knowledge of many programming languages and experience in programming several projects. The second programmer was a Ph.D. student in Computer Science with several years of expertise in the computing industry.

In the early stages of the creation of the eBook, separate meetings (sometimes Skype meetings) were held with the illustrator. Later, the first programmer started working simultaneously with the illustrator and myself. On many occasions, the illustrator contacted the programmer to synchronize their work. Focal issues discussed with the illustrator and the programmers are described in Appendix B.

### *eBook programming*

All the hotspots in the math condition were mathematically oriented using a number of eBook design features previously reported. The hotspots were designed to facilitate the unprompted simultaneous presentation of the spoken and animated mathematical content. All hotspots provided visual and kinesthetic cues to assist the child and caregiver to focus attention on the hotspot and to avoid accidentally pressing virtual objects.

### *Cross-platform eBook development*

To enable portability of the eBook across different handheld devices and simplify the development process, web-based programming was employed. Web pages could be stored online and made available to remote users via most web browsers running under any common operating system. The eBook included animations and sounds, and enabled advanced feedback to the user, such as clicks and drags. The two programmers involved in developing the eBook used advanced web-based programming functions to create the eBook.

### *eBook Web-based programming*

Three World Wide Web (WWW) programming technologies were used together by the web developer to design the eBook, these technologies were tightly coupled as follows.

*Hypertext markup language (HTML) version 5 (HTML5)*[2]

The latest version HTML5 as of October 2014, v.5, was used as the skeleton of the eBook. HTML5 is a markup language used mainly to structure and present content in web pages. HTML5 is interoperable with other web development technologies through application programming interfaces (APIs). Combined with other HTML5 elements, such as audio[3], or Canvas[4], these APIs enable the integration of complex functionalities, for instance, page interleaving, text subtitles, animations, audio, clicks, and drags. The *audio* element, for instance, takes audio files as input and the *canvas* elements allow a dynamic scriptable rendering of 2D shapes.

*Cascading style sheets (CSS) version 3 (CSS3)*[5]

CSS3 is a stylesheet language used to describe the presentation parameters of an HTML document. Related to the eBook, the CSS file stores, for instance, the design colors, spaces, element sizes, and locations. The World Wide Web Consortium (W3C) is the CSS regulatory authority of the CSS language.

*JavaScript*

JavaScript is a high-level and dynamic programming language usually used in web development alongside HTML/CSS. JavaScript allowed programming complex scenarios in the eBook storyline, such as emphasizing counting principles.

*Graphical design*

The graphical designs and drawings were stored in three different file types, each with a different image encoding method:

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[2] HTML5 A vocabulary and associated APIs for HTML and XHTML: https://www.w3.org/TR/2014/REC-html5-20141028/.

[3] HTML Canvas 2D Context, W3C Recommendation 19 November 2015: https://www.w3.org/TR/2dcontext/.

[4] Web Audio API, W3C Working Draft 08 December 2015: https://www.w3.org/wiki/HTML/Elements/audio.

[5] Cascading Style Sheets home page: https://www.w3.org/Style/CSS/Overview.en.html.

*JPEG (Joint Photographic Experts Group) images*[6]

JPEG is a compression encoding method used to store digital images, usually photographs. JPEG encoding was used to store the background images in the eBook. Background images were usually large.

*PNG (Portable Network Graphics) images*[7]

PNG is a compression encoding method that allows images to be overlaid on top of other images using transparency. For instance, the fish images in the eBook were stored as PNG images with transparent surrounding. This allowed overlaying the fish images over a static background, e.g. the riverside background, and dragging the fish across the background.

*GIF (Graphics Interchange Format) images*

GIF is also a compression encoding method. GIF images support animation. GIF images were used to display fixed image content in the eBook where user's interaction is not required.

*Test Platform*

The eBook was developed for cross-platform portability to be accessible via any web browser with HTML5/CSS and JavaScript support. The Android 5.0 (Lollipop) operating system designed by Google for touchscreen devices (smartphones and tablets) was utilized as a testing platform.

Instead of a standard web browser, KioWare was used, a kiosk browser developed to run under the Android operating system. A kiosk browser locks down the browser for any activity other than operating the eBook and allows a full-screen display. When KioWare was activated, the eBook was presented in a full screen and the user could not exit the eBook or use the browser in any other way except to browse the eBook.

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[6] The Joint Photographic Experts Group (JPEG) committee Webpage: https://jpeg.org/jpeg/

[7] Portable Network Graphics (PNG), Functional specification: http://www.iso.org/iso/catalogue_detail.htm?csnumber=29581

***Sound effects and audios***

Sound effects encoded in MP3 format introduced background musical effects and other sounds to enhance the realism of the characters' actions. For example, audios were designed to align with a character's dialogue, emotional expressions, and actions. All sound effects in the eBooks were downloaded from the following websites:

- Freesfx: http://www.freesfx.co.uk/sfx/
- SoundBible: http://soundbible.com/
- AudioMicro: http://www.audiomicro.com/free-sound-effects/
- Free Sound Effects: http://www.freesoundeffects.com/

Google translator (https://translate.google.ca) provided audio files for numbers referred to in the math eBook. The sounds embedded in the eBooks were audio files in MP3 formats.

### 3.2.3. Piloting the prototypes.

After the prototypes of the eBooks were completed, a multiple subject pilot case study was conducted with three mother-child dyads to evaluate the eBook, its illustrations quality and intelligibility of the story. Each dyad was observed while sharing the prototype. Analysis of observational data revealed how the dyads interacted with the features of the eBook and provided information about design changes needed to enhance clarity of the mathematical content and increase engagement of the children. Mothers also provided specific feedback about the functionality of the hotspots.

## 3.3. Mixed methods study

### 3.3.1. Design

After the eBook prototypes were finalized, a quasi-experimental study was conducted to compare conversations elicited when participants experienced the mathematical-related hotspot (math) condition compared to those who experienced the emotions, actions related-hotspots (emotion-action) condition. Participants were randomly assigned to either the math or emotion-action condition. Differences in

frequencies were calculated on specific measures of general communication and mathematics-related communication. Two sections of the eBook (mathematics activities) in the math condition were identified for further qualitative analysis of discussions at two points in the story.

### 3.3.2. Recruitment of participants

Approval to conduct the study was obtained through the Research Ethics Board of Simon Fraser University. Written consent for study participation was sought from the caregivers and verbal assent was obtained from the children.

Participant recruitment was done through a letter (see Appendix C) sent home with children attending daycares and preschools in an urban area of Western Canada. Interested parents then contacted the researcher. To qualify, children had to be between three and four years old and score at or above the 25$^{th}$ percentile on the Picture Vocabulary subset of Woodcock-Johnson Tests of achievement, 3rd Edition (WJ—III; Woodcock, McGraw & Mather, 2001).

To determine the sample size needed to address the research questions accurately and increase the power of the study to detect relationships between the dependent and independent variables, a power analysis was conducted. The power analysis was based on Parish-Morris and colleagues' (Parish-Morris, Mahajan, Hirsh-Pasek, Golinkoff & Collins 2013) study in which two versions of an eBook (one with dynamic features and one with muted features) were compared on an outcome measure of total story-related utterances. Alpha level of .05 (the probability of rejecting the null hypothesis when it is true) and .80 for power (the probability of rejecting the null hypothesis when the alternative hypothesis is true) were used for the power analysis calculation. The analysis indicated need for a total of 32 dyads; 16 dyads per group to detect an effect size of $g \geq .80$. Based on this, 35 dyads were recruited to allow for drop outs. Later, three dyads were excluded as children did not meet some of the criteria for participation. The final sample size included 32 child-caregiver pairs, 16 in each condition.

### 3.3.3. Materials

#### *eBook computer*

The eBook was presented on a Samsung Galaxy Tab A tablet computer.

#### *Drawing application*

Children used *Peppa's Paintbox* (Entertainment One, 2015), a drawing application in a warm-up session that preceded the shared reading experience. This application includes several options for digital drawing such as paintbrushes, characters stickers, animated stickers and items that can be dragged or clicked to activate sounds. This application has no direct references to mathematics.

### 3.3.4. Measures

#### *Demographic and home-literacy questionnaire*

A demographic and home literacy questionnaire (Appendix D) presented questions to determine the child's sex and date of birth, the caregiver's level of education and employment status, languages spoken in the home and child literacy practices. Of specific interest was the frequency of shared reading practices with print storybooks and eBooks, and the frequency of engaging in mathematics activities with the child (see Appendix D). All caregivers were the children's parents (29 mothers and two fathers), except for one case where the oldest sister shared the story with her young brother.

#### *Picture vocabulary subtest of Woodcock-Johnson III Tests of Achievement*

Children's receptive English vocabulary was estimated by administering the Picture Vocabulary subtest of Woodcock-Johnson III Tests of Achievement (WJ—III; Woodcock, et al., 2001). In the initial few items, the child is required to point to a named picture. In the majority of the following items, the child is required to name objects, actions or events displayed in pictures. The manual reports test-retest reliability coefficients for children between the ages of three to four as ranging between 0.80 and 0.82.

### *Caregiver satisfaction questionnaire*

The Caregiver Satisfaction Questionnaire (see Appendix E) described the caregiver's perceptions of the eBook, particularly the feasibility of reading eBooks with their children. The questionnaire consisted of 12 statements and used a four-point scale (1: agree, 2: somewhat agree, 3: somewhat disagree, 4: disagree) to indicate agreement with the statements. The statements referred to whether the caregiver deemed the hotspots relevant to their child's attention to mathematics, the hotspots' relevance to the narrative, and if the caregivers would use the eBook as a resource in the future. The Cronbach alpha internal consistency of the questionnaire was 0.84 in the Math-EA condition and 0.79 in the emotion-action condition.

## 3.3.5. Procedures

After the caregivers provided written consent (Appendix C), they were asked to fill out the demographic and home literacy questionnaire (Appendix D). While the caregiver was doing this, the child was administered the picture vocabulary subtest of Woodcock-Johnson III tests of achievement (WJ—III; Woodcock et al., 2001). Children who met criteria for study participation (32 out of 35 that were interested) were randomly assigned to the math or emotion-action condition. Children that did not meet the participation criteria shared one of the eBooks with the caregivers but the videos were not analysed.

The study was conducted in the participant's house ($n$ = 23), a public library ($n$ = 5), an office at SFU ($n$ = 3) or at the childcare facility ($n$ = 1). Caregivers and their children were instructed to read the eBooks as they would at home. Some of the children sat on their caregiver's lap on a sofa. In other cases, the children and caregiver sat at a table on separate chairs and the caregiver propped up the tablet on the table. Other caregivers and children preferred to sit on the floor and use the folding stand on the tablet on the floor.

***The warm-up phase***

Before the shared reading session, the child and the caregiver played with the *Peppa's Paintbox* application. This phase prepared the children and their caregivers to be comfortable holding the tablet and interacting with it. The length of time of this phase was no more than five minutes, and depended on the child's interest in the application. No data were collected in the warm-up phase.

***The shared-reading sessions***

The caregiver was asked to read with the child as he or she would normally do at home. In the shared reading session, the caregiver read the eBook in its entirety to the child. The same instructions were given to all of the participants in both conditions before the reading session, as follows:

> *Please read the eBook story with your child as you normally do at home. The story will be about a little girl bear that goes fishing with her father. On the cover page, you need to ask your child to name the little bear, and you need to type the name here (the researcher points to the empty blank where the name needs to be typed). In some pages, there are flashing lights that will blink around some images. Those are hotspots that you or your child can press or drag as part of the story. Make sure you press them all to proceed to the next page.*

The child chose the name of the main character and typed it with help from their caregiver on the introductory page before the reading session commenced. Choosing and typing the name lasted less than one minute in most cases. Following, the reading sessions commenced and was videotaped by the researcher using a stationary camera. On average, the shared reading activity took approximately 10 minutes. At the end of each shared reading session, the caregiver completed the Caregiver Satisfaction Questionnaire (Appendix E) as the child played with the *Peppa's Paintbox* application. This took approximately five minutes.

### 3.3.6. Data analysis

The analysis of the caregiver-child communication focussed on story-related spoken utterances, iconic gestures and pointing that occurred during communication

beyond the verbatim reading of the story text (see Table 3-4). Each coding category referenced a variable to describe the spoken utterance, iconic gesture or pointing, whether mathematics related or not.

### *Spoken utterances*

Transcriptions of all videos were made. The unit of analysis was a spoken utterance made by a speaker during the shared reading activity. An utterance is defined here as a segment of speech by one individual which satisfied two criteria (Chaparro-Moreno, Reali, & Maldonado-Carreño, 2017): (a) there was a clear pause or silence of at least two seconds before speech began again and (b) words spoken formed a syntactically complete sentence even when just a single word was spoken. Caregiver utterances were coded separately from child utterances even if they spoke at the same time.

### *Mathematics related spoken utterance*

A spoken utterance was coded as mathematically related when its content included reference to: counting, abstract quantity, lack of quantity (e.g., zero), the whole, some or few items, manipulation in sets such as adding fish or subtracting fish from a set of fish, partitioning (e.g. half or part), subjective judgment about size, or comparing sizes. Examples of mathematics-related utterances are provided in Table 3-5.

### *Deictic (pointing) gestures*

A deictic gesture is pointing to indicate a task-related object. Pointing is typically defined as an extended arm and index finger with an enclosed hand. A deictic gesture can replace or be used simultaneously with deictic spoken words and phrases such as “here” or “this one” (McNeil & Duncan, 2000). Pointing, whether accompanied or not accompanied by speech was coded.

Although tapping a hotspot may include the intention of pointing, in this study tapping a hotspot was not considered a deictic gesture. However, any pointing to the hotspot location before or after tapping was coded as pointing.

### *Mathematics-related pointing*

A pointing gesture was coded as mathematically related when it clearly accompanied, resembled, or was shortly followed by a mathematics-related spoken utterance; or when the pointing was accompanied with a phrase such as “here” or “this one” that immediately followed a mathematics-related utterance. Examples of mathematics-related pointing can be found in Table 3-5.

Pointing not accompanied by speech was coded mathematically related when it clearly related to mathematics content, such as pointing used to track counted objects without saying the numbers.

### *Iconic Gestures*

Iconic gestures are hand movements that convey semantic content regardless of whether the gesture is accompanied by speech (Namy, Campbell & Tomasello, 2003). An iconic gesture, for instance, includes extending both arms laterally to describe the size of an item or raising fingers to represent the number of items counted in a set.

### *Mathematics-related iconic gestures*

An iconic gesture was coded as mathematically related when it accompanied or resembled a mathematics-related spoken utterance. When an iconic gesture was not accompanied by speech, it was considered mathematically related when it clearly described or delivered meaning related to counting or reference to: abstract quantity, lack of quantity, whole, some or few items, manipulating members in sets such as adding fish or subtracting fish from a set of fish, portions (e.g., half or part), subjective judgment about size, or comparing sizes. Examples of mathematics-related iconic gestures can be found in Table 3-5.

### *Epistemic and dynamic gestures*

Epistemic and dynamic gestures in this study refer to tapping the hotspots and to the drag and drop operations in an eBook. Each eBook included 36 touch-based hotspots and 10 drag and/or drop hotspots. All 46 hotspots in the math eBook concerned content related to cardinality, subitizing, one-to-one correspondence, addition, subtraction, and

division (more details are in Table 3-2). Hotspots in the emotion-action eBook related to characters' emotions or actions, such as the bears or moving the fishing pole.

Since the number of hotspots was equivalent between the two eBooks, but all hotspots in the math eBook were mathematics targeted, the setting was inadequate for comparing the dyads' tendency to use epistemic and dynamic gestures vs. mathematics-related epistemic and dynamic gestures. Therefore, hotspot activation was not coded in this study for epistemic and dynamic gestures.

Multiple taps on the same hotspot or multiple drags were coded as one hotspot tap for two main reasons. First, some participants had to tap more than once or drag the item multiple times after the initial activation of a hotspot. The instances observed of multiple taps were due to too light press on the screen, tapping beyond the hotspot's location, or other possible reasons that could be related to repeating the counting procedure while repeating the tapping, or multiple taps to explore the hotspots.

The following conversation between Jackson (a fictitious name) and his caregiver exemplifies spoken utterance, iconic gestures and pointing (deictic gesture) coded as mathematically related.

> ***Jackson**: [pauses and scans the fish with his eyes]. Two [points to the green fish], three [points to the pink fish], four [while pointing to the red fish], five [while pointing to the orange fish].*
>
> ***Caregiver:** Ok. How many fish in total? [Makes a circle-gesture in the air around all the fish]. [pauses and waits for an answer]. Can you count again?*

This example shows that even though Jackson verbalised several words that represent numbers, they were clustered into one utterance because there was no clear pause as he said the numbers. Therefore, one utterance was coded for Jackson's speech. However, since there was a clear pause following the caregiver's first utterance, two utterances were coded for her speech.

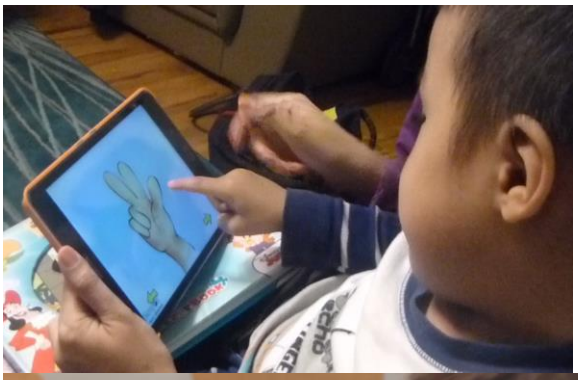
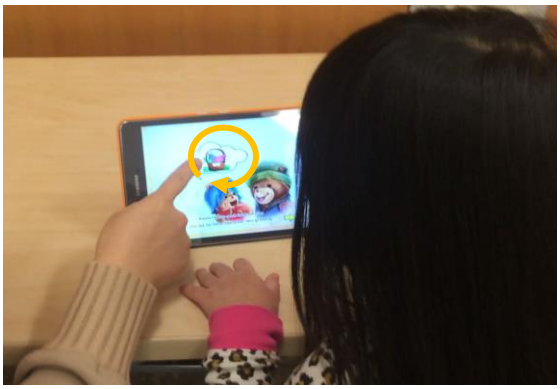
One iconic gesture that was mathematically related was initiated by the caregiver. Four mathematically related pointing gestures initiated by Jackson were coded.

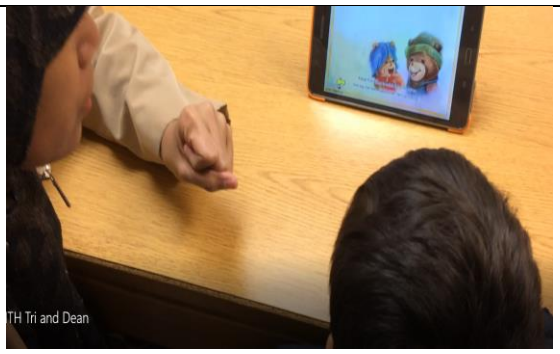
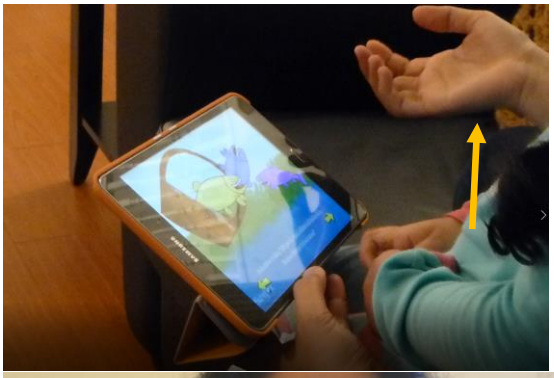
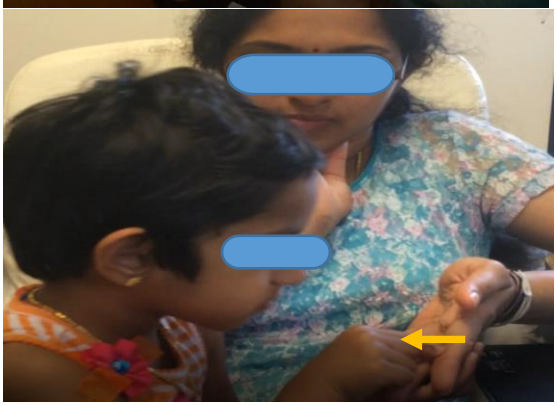
**Table 3-4. Framework for Coding the Children's and the Caregivers' Communication and examples of Mathematics-Related Spoken Utterances during Sharing the eBooks**

| Mathematics references | Examples of mathematics-related Spoken utterance |
|---|---|
| **Counting**<br>The child or the caregiver refers to the quantity of a counted set by counting (not necessarily an accurate counting) | "I can count them, one, two, three." |
| **Subitizing**<br>The child or the caregiver refers instantly to the quantity of a small set of objects without counting them. | "They caught two fish at the same time." |
| **Abstract reference to quantity**<br>The child or the caregiver refers to abstract numbers or quantities. | "She is three years old like you." |
| **Using All/Everyone/Everything**<br>The child or the caregiver refers to the whole quantity of a counted collection. | "Can you please press all the blinking fish and see what will happen." |
| **Using None/nothing/zero/no more**<br>The child or the caregiver refers to quantifier zero. | "They are waiting but no fish so far." |
| **Using some/few**<br>The child or the caregiver refers to quantifier some. | "Look at all the colourful fish; some are big, and some are small." |
| **Using less/minus/more/plus**<br>The child or the caregiver refers to changes/ manipulations. | "Let's see if the girl can catch one of the fish when she tries again." |

| | |
|---|---|
| In the counted amount (addition and subtraction). | |
| **Using ordinal numbers**<br>The child or the caregiver refers to the order of a counted item. | "Which one is the fourth?" |
| **Using half /part**<br>The child or the caregiver refers to the action or outcome of sharing the fish. | "The little bear and her brother can share this big yellow fish." |
| **Subjective judgment about the size**<br>The child or the caregiver describes the size of a fish (or any other object) individually without making any comparisons with other fish (or other objects). | "This fish is little we need to put it back." |
| **Size – comparison**<br>The child or the caregiver describes the size of a fish (or any other object) in comparison to other fish (or objects). | "This fish is smaller than the blue fish." |

**Table 3-5. Framework for Coding the Children's and the Caregivers' Communication and examples of Mathematics-Related Iconic Gestures and Pointing during Sharing the eBooks**

| Mathematics references | Mathematics related iconic gestures | Mathematics related pointing | Image |
|---|---|---|---|
| **Counting** | | Pointing to the virtual image of each of the three fingers while counting. |  |
| **Subitizing** | Holding up three fingers simultaneous to a scene of three fish | |  |
| **Representing All/Everyone / Everything** | After pointing to the fish, the caregiver uses hand circle-gesture around a group of fish to emphasize the whole amount. | Pointing to the virtual image of three fish in the basket while saying "a total of three fish" |  |

| | | |
|---|---|---|
| **Representing None/ nothing /zero /no more** | A closed palm gesture simultaneous to the words “ no more fish” |   |
| **Representing less/ minus/ more/plus** | Raising hand gesture simultaneous to the words “ grow some more” |  |
| **Representing half /part** | Opening one palm (by the caregiver) and moving the finger (by the girl) over the palm to show cutting the fish into two halves. |  |

| | | |
|---|---|---|
| **Subjective judgment about the size** | Palms facing each other in a distance to illustrate big sized fish |  |

***Initial responding to hotspots***

This study explores how eBook hotspots prompt communication between the caregiver and child. Therefore, one level of analysis focussed on the immediate responses of the caregiver and/or the child immediately following activating a hotspot and before tapping the next hotspot or resuming oral reading of the story. The variables that described these immediate responses were: repetition, description, high-cognitive or low-cognitive questioning, explanation, emotional reaction, compliment, request, and gesture. Each response was identified as related or not related to mathematics. Entries in Table 3-6 describes each type of response and two examples, one linked to mathematical content and one independent of mathematics content.

**Table 3-6. Categories of Immediate Responses that Followed Activating the Hotspots.**

| Immediate response | Description | Non-Mathematics Content | Mathematics-Related Content |
|---|---|---|---|
| **Questioning (Low Cognitive)** | Seeking an answer that is perceptually available in the story (more details following this table). | "Where are they walking?" | "How many fish are there?" |
| **Questioning (High Cognitive)** | Seeking an answer that is not perceptually available in the story (more details following this table). | "How does the father feel?" | "Where did the orange fish disappear?" |
| **Explanation** | Explaining content related to the hotspot or the story. | "The little bear is laughing because she caught a boot." | "They are putting them back to the river so they can grow." |
| **Description** | Providing a description of the changes that result from activating the hotspot. | "They walked to the river." | "These fish are tiny." |
| **Emotional reaction (e.g. happiness)*** | Expression of any kind of emotions. | [laughter] | |
| **Compliment /agreement** | Compliment or agreement that follows tapping the hotspot dragging or dropping an item. | "Good job." | "Fair sharing." |
| **Repetition** | Repeating the sound that results from activating the hotspot. | "Oh-oh." | "Three." |
| **Request** | A participant requests something from the other. | "Can you please help them walk to the river." | "Can you drag the second one please." |

| | | | |
|---|---|---|---|
| **Gesture** | The participant makes an iconic, arbitrary or pointing gesture without making any verbal response | [waving hand after hearing the word "hi"] | [holding up one finger after hearing the word "one"] |

*Note: emotional reactions were not linked specifically to mathematics.

Questions defined as high in cognitive demand are identified if the respondent answers with information that is "not perceptually present" in the story (Mcginty et al., 2012, p. 1041). Questions high in cognitive demand were coded when the response included one or more of:

- Arranging or counting a set of objects in a given way.
- Problem-solving.
- Making predictions.
- Inferring the feelings of a character.
- Giving an opinion.
- Explaining cause-effect relationships

Questions defined as low in cognitive demand led to a response involving one or more of these characteristics:

- Repeating words or short phrases from the test just read.
- Locating a highly visible object on a page.
- Describing highly visible features or actions of the objects (including counting objects)

***Reliability of coding***

Having two independent assessors code at least 10% of the data was deemed essential to assess the reliability of the coding procedures used in the research (Yin, 2009). In the present study, four videos were randomly selected from the 32 videos available for analysis. The reliability of transcribing spoken utterances and gestures displayed in the video, expressed as percentage agreement, was calculated as the number of agreements / (agreements + disagreements). The same procedure was used to calculate the percentage agreement for each code that represented a communication variable. As shown in Table 3-7, the percentage agreement between two raters for the accuracy of transcription for spoken utterances was 87 % and for gesture 89%. Percentage agreement

for coding of the spoken utterances/gestures and other variables ranged from 78% to 100%.

**Table 3-7. Reliability of Transcriptions and Coding of Communication Variables**

| Transcription | *N* | Agreements | Disagreements | Percentage Agreement |
|---|---|---|---|---|
| **Spoken utterance** | 311 | 270 | 41 | 87% |
| **Mathematics related spoken utterance** | 176 | 160 | 16 | 91% |
| **Gestures** | 122 | 108 | 14 | 89% |
| **Mathematics related gestures** | 99 | 80 | 19 | 81% |
| **Pointing** | 103 | 82 | 21 | 80% |
| **Mathematics related pointing** | 89 | 69 | 20 | 78% |
| **Frequencies of tapping the hotspots among caregivers** | 19 | 17 | 2 | 89% |
| **Frequencies of tapping the hotspots among children** | 23 | 20 | 3 | 87% |
| **Frequencies of hand-on-hand tapping** | 4 | 4 | 0 | 100% |
| **Initial response to hotspots** | 93 | 84 | 9 | 90% |
| **Initial response to hotspots (range across categories)** | 3 - 44 | 3 - 35 | 0 - 9 | 80% - 100% |
| **Initial response to hotspots - mathematics (range across categories)** | 0 – 26 | 0 – 21 | 0 - 5 | 81% - 100% |

***Quantitative analysis***

In the quantitative analysis, scores were examined for missing data, outliers and normality. Descriptive statistics for all variables were calculated. A series of one-way analyses of variance (ANOVA) was used to check whether differences could be detected between the math and emotion-action conditions on communication outcomes.

***Qualitative analysis***

The qualitative analysis focussed on general patterns of interaction within dyads as they engaged with two specific activities within the eBooks*;* the Strategic Counting activity and the Fair Shared activity.

For the Strategic Counting activity, a scene showed a scattered array of fish with an overturned basket nearby (see Figure 3-1). This scene was accompanied with the following text: "Let's start counting from the biggest fish and end up with the smallest fish." A hotspot was activated each time one of the five fish was tapped in order of size, from largest to smallest. The emotion-action condition did not include hotspots.


**Figure 3-1. The Strategic Counting activity as it appears in the math condition when two hotspots are activated**

As illustrated in Figure 3-2, the Fair Share activity showed a scene where a member of the family shows up (i.e., the brother) and the little bear realizes her one-to-one correspondence strategy for sharing three fish in her basket with three family members (mother, father, herself) is no longer appropriate. The narrative text associated with this scene is: “Here is my brother too. How are we going to share the fish now? Can you help (the main character) share the fish?


**Figure 3-2. The Fair Share activity as it appears in the math condition**

***Thematic analysis***

Each transcript of the mathematics activities – utterances, and gestures - in the math condition was analysed by applying a thematic analysis approach. Data were reduced to themes resembling key ideas or principle concepts (Harding, 2013). While reviewing the Fair Share and the Strategic Counting transcripts, patterns in the data emerged that were consistent across dyads. Excerpts from the transcript highlighted the complexity of communication that emerges, particularly when a dyad interacted with mathematics aligned hotspots. Those patterns were later generalized under three key themes as explained in the Results chapter.

# Chapter 4.

# Results

Here, the analysis will be presented regarding child/caregiver communications generated while sharing the math eBook or emotion-action eBook. Quantitative data describing caregiver and child are analyzed using analysis of variance methods. Analysis of both the child and caregiver's reactions to hotspots will also be presented. Thematic analysis of qualitative data will be presented regarding the examination of children and caregivers discussion of mathematical content. This chapter concludes with a summary of the caregivers' perception of the feasibility and benefits of the eBook, and of sharing it with their children.

## 4.1. Sample Description

All children in the study were three or four years of age, Canadian born, and performed above the 25$^{th}$ percentile on a measure of expressive English vocabulary. None had been diagnosed with learning disabilities. Caregivers (females $n$ =30; males $n$ = 2) were fluent in spoken English and were able to read the eBook effortlessly. As reported in Table 4-1, one-way multivariate analysis of variance (MANOVA) did not detect differences in children's age and English vocabulary across the groups, $F$ (2,29) = 0.35, $p$ = 0.706, Wilk's $\Lambda$ = 0.97. No statistical differences across the two groups were detected in the caregivers' level of education, $\chi 2$ (9, $N$ = 32) = 0.57, $p$ = 0.75.

**Table 4-1. Sample Description of the Math and the Emotion-Action Conditions**

| | **Math** ***n* = 16** | | **Emotion-Action** ***n* = 16** | | ***F* / $\chi 2$** | ***p*** |
|---|---|---|---|---|---|---|
| | ***M (SD)*** | | ***M (SD)*** | | | |
| **Children (*n* = 32)** | | | | | | |
| Gender | 8 females | | 8 females | | | |
| Age in Months | 44.40 (6.83) | | 44.60 (5.66) | | 0.06[b] | .96 |
| English Vocabulary | 107.06[a](9.23) | | 104.44[a](9.72) | | 0.78[b] | .44 |
| **Caregivers (*n* = 32)** | | | | | | |
| Gender | 15 females | | 15 females | | | |
| **Level of Education** | | | | | 0.57[c] | .75 |
| High-school | 2.0 | (12.5%) | 2.0 | (12.5%) | | |
| BA or equivalent | 8.0 | (50.0%) | 6.0 | (37.5%) | | |
| Graduate degree | 6.0 | (37.5%) | 8.0 | (50.0%) | | |

[a] Standard scores based on age-norms from the Picture Vocabulary subtest of the English version of the *Woodcock-Johnson Tests of Achievement, 3rd Ed.* [b] *F*-test, *df = 2,29* [c] $\chi 2$ test, *df = 9*

## 4.2. Sample Characteristics

While all caregivers spoke English with their children at home, 8/16 (50%) caregivers in the emotion-action condition and 9/16 (56%) caregivers in the math condition reported that they spoke languages in addition to English with their children. Non-English languages spoken by caregivers with their children in each condition were: Arabic, Cantonese, Filipino, German, Indonesian, Kurdish, Malayalam, Mandarin, Persian, and Telugu. Before they participated in the study, caregivers confirmed their children understood spoken English and were able to comprehend a storybook read to them in spoken English. Caregivers also affirmed that shared-reading of stories written in English was a literacy practice in their home and at their child's childcare centre.

The majority of caregivers in each condition – emotion-action: 15/16; 94%, and math: 13/16; 81% - reported frequent mathematics literacy practices in their children including counting objects, comparing quantities, and identifying shapes. Most caregivers also reported a regular shared-reading schedule at home using print books – emotion-action: 15/16; 94%, and math: 14/16; 88%. Caregivers in both conditions – emotion-action: 12/16; 75%, and math: 13/16; 81% - reported their child requested more shared reading activities.

All the children and caregivers regularly engaged with print literature far more than with eBooks. A majority of caregivers in both conditions – emotion-action: 11/16; 69%, and math: 10/16; 63% - reported they did not regularly, if at all, read eBooks with their children. About 18% of emotion-action condition children and 30% of math condition children looked at eBooks on their own at least once a week.

Sample characteristics were statistically indistinguishable between the two groups (see Appendix F for more details).

## 4.3. Missing Data, Outliers, and Distributions

### 4.3.1. Reading Time

Reading time was assessed by Shapiro-Wilk's test for normality at skewness and kurtosis $\leq \pm 2$ (George & Mallery, 2010). Also, visual inspection of histograms, boxplots, and Q-Q plots revealed no outliers for this variable.

Differences in reading time between groups were examined using an independent sample *t*-test, $t\ (29) = 1.62$, $p = 0.11$. This indicates that no statistically significant difference in reading times between math and emotion-action conditions were detected (Table 4-2).

**Table 4-2. Differences in the Average Reading Time across Conditions.**

| Math | | | Emotion-Action | | | | |
|---|---|---|---|---|---|---|---|
| ***M*** | ***SD*** | **Range** | ***M*** | ***SD*** | **Range** | ***t*** | ***p*** |
| 12.47 | 0.67 | 8.5 – 18 | 11.07 | 0.53 | 6.5 – 15 | 1.62 | .116 |

### 4.3.2. Frequency data

Transcribed data were coded into six mutually exclusive categories: *spoken utterance, mathematics-related spoken utterance, iconic gesture, mathematics-related iconic gesture, pointing,* and *mathematics-related pointing.* There were no missing data. Box-plots marked deviant scores (values > 1. 5 SD) but these were not considered outliers because other data of those specific cases were not atypical. All the variables were normally distributed with skewness and kurtosis values $\leq \pm 2$.

### 4.3.3. Immediate Responses to Tapping Hotspots

Further analysis centered on the immediate reactions of the caregivers and children after activating the hotspots. The variables that described immediate responses to clicking the hotspots included: *repetition, description, high-cognitive and low-cognitive questioning, explanation, emotional reaction, compliment, request*, and *gesture*. No outliers were identified.

## 4.4. Quantitative Data Analyses

Given moderate to high correlations among the frequency outcomes between spoken utterances, gestures and pointing within the groups of caregivers and children and also between caregivers and children outcomes within each condition (values of $0.44 \leq r \leq 0.92$); a MANOVA was computed with the groups as an independent variable (math eBook vs. emotion-action eBook) and the frequency data to compare communication during shared reading as the 12 dependent variables (i.e. *utterances, mathematics related*

*utterances, gestures, mathematics related gestures, pointing, mathematics related pointing*; independently for caregivers and children).

The results of Levene's test of equality of error variances were satisfied for *mathematics-related gestures of caregiver, mathematics related gestures of children, utterances of caregivers* and *utterance of children*; however, it was not satisfied for the remaining eight variables ($p \leq 0.05$). Therefore, a strict alpha level of 0.005 was used, and since the *p*-value for all violated variables was less than 0.001, the violation was not a concern (Allen & Bennett, 2008). Moreover, since the two groups are equal, the MANOVA becomes robust against the violation (Allen & Bennett, 2008).

A statistically detectable difference was observed across the groups, multivariate $F = 8.87$, $p < 0.001$, Wilk's $\Lambda = 0.191$. Univariate ANOVAs were evaluated using the alpha level of 0.005 to protect type *I* error. Results are outlined in Table 4-3, Table 4-4, and Table 4-5 and explained in the following sections.

### 4.4.1. Spoken utterances and mathematics-related utterances

Notably, all caregivers and children engaged in social communication, albeit to different extent, about mathematics through *spoken utterances* during the shared reading sessions.

Overall, the dyads in the math condition generated 2291 *spoken utterances*, 1273 (55.6%) of these were *mathematics related spoken utterances* as they highlighted mathematics principles in the narrative and/or illustrations. This is very much greater than the emotion-action condition, where dyads generated 1087 utterances, 371 (34.1%) of these were aligned with mathematics principles reflected in the narrative and/or illustrations.

As shown in Table 4-3, caregivers in the math condition generated more *spoken utterances* in communication, ($M = 99.19$, $SD = 34.36$) than their peers in the emotion-action condition, ($M = 46.63$, $SD = 22.93$), $F(1, 30) = 19.46$, $p < 0.001$. Caregivers in the math condition also generated more *mathematics-related spoken utterances* in communication, ($M = 54.06$, $SD = 15.45$) than their peers in the emotion-action condition, ($M = 13.50$, $SD = 6.61$), $F(1, 30) = 29.28$, $p < 0.001$.

As shown in Table 4-3, children in the math condition generated more *spoken utterances* in communication, ($M$ = 44, $SD$ = 29.71) than their peers in the emotion-action condition, ($M$ = 21.31, $SD$ = 5.55, $F$ (1, 30) = 8.99, $p < 0.005$. Children in the math condition also generated more *mathematics-related spoken utterances* in communication, ($M$ = 25.50, $SD$ = 16.23) than their peers in the emotion-action condition, ($M$ = 9.69, $SD$ = 8.64), $F$ (1, 30) = 11.83, $p < 0.001$.

### 4.4.2. Caregiver-child differences in spoken utterances

In order to detect whether the children or the caregivers were leading the shared reading process through initiating more utterances, analysis of caregiver-child differences in use of *spoken utterances* and *mathematics-related spoken utterances* were conducted. A series of paired $t$-test comparisons showed that on average caregivers in the math condition generated more *spoken utterances* ($M$ = 99.19, $SD$ = 34.36) than their children ($M$ = 44.00, $SD$ = 29.71 ), $t$ (15) = 11.62, $p < 0.001$.Within the emotion-action condition, caregivers also used more *spoken utterances* ($M$ = 46.63, $SD$ = 22.93) than their children ($M$ = 21.31, $SD$ = 5.55), $t$ (15) = 6.83, $p < 0.001$.

Statistical comparisons also showed that on average, caregivers in the math condition generated more *mathematics-related spoken utterances* ($M$ = 54.06, $SD$ = 15.45) than their children ($M$ = 25.50, $SD$ = 16.23), $t$ (15) = 7.71, $p < 0.001$.Within the emotion-action condition, caregivers also used more *mathematics-related spoken utterances* ($M$ = 13.50 , $SD$ = 6.61) than their children ($M$ = 9.69, $SD$ = 8.64), $t$ (15) = 2.70, p = 0.017.

**Table 4-3. Frequency of Occurrence of Spoken Utterances in the Math and the Emotion-Action Conditions**

| | Math ($n$ = 16) | | Emotion-Action ($n$ = 16) | | | |
|---|---|---|---|---|---|---|
| | ***M*** | ***SD*** | ***M*** | ***SD*** | ***F*** | ***p*** |
| **Utterance** | | | | | | |
| Caregiver | 99.19 | 34.36 | 46.63 | 22.93 | 19.46 | .001 |
| Child | 44.00 | 29.71 | 21.31 | 5.55 | 8.99 | .005 |
| **Mathematics-related Utterance** | | | | | | |
| Caregiver | 54.06 | 15.45 | 13.50 | 6.61 | 29.28 | .001 |
| Child | 25.50 | 16.23 | 9.69 | 8.64 | 11.83 | .001 |

In summary, the important results from the analyses on the use of *mathematics-related spoken utterances* are: a) all caregivers and children attended to and discussed, albeit to different extents mathematics related content in the story narrative; b) approximately one-half of *utterances spoken* by dyads in the math condition and approximately one-third of *spoken utterances* in the emotion-action condition were related to mathematics principles compared to non-mathematics related themes or events in the story; c) use of spoken utterances that aligned with the mathematics content in the story occurred more frequently in the math compared to the emotion-action condition; and d) on average, caregivers in both the math and emotion-action condition used *spoken utterances* as well as *mathematics-related spoken utterances* more frequently than children.

### 4.4.3. Iconic gestures and mathematics-related iconic gestures

All children and caregivers used *iconic gestures* at least once as they engaged in a shared reading of their eBooks. All of the *iconic gestures* made by caregivers and almost all of those made by children were accompanied by speech. Overall, the dyads in the

math condition made 151 *iconic gestures*, 139 (92%) of these gestures highlighted mathematics related content in the story narrative. In the emotion-action condition, dyads made 77 *iconic gestures*, 66 (85.8%) were aligned with mathematics principles reflected in the narrative and illustrations.

The frequency of *iconic gestures* differed between the math and the emotion-action conditions. As shown in Table 4-4 the frequency of use of *iconic gestures* was higher among caregivers in the math condition ($M$ = 5. 80, $SD$ = 1.31) compared to the emotion-action condition *(*$M$ = 2.63, $SD$ = 1.06); $F$ (1, 30) = 20.42, $p < 0.001$. Similarly, *iconic gestures* among children in the math condition ($M$ = 3.63, $SD$ = 1.82) were higher than their peers in the emotion-action condition, ($M$ = 2.19, $SD$ = 0.69); $F$ (1, 30) = 8.18, $p < 0.001$.

**Table 4-4. Frequency of Iconic Gestures Use in the Math and Emotion-Action Conditions**

| | **Math (*n* = 16)** | | **Emotion-Action (*n* = 16)** | | | |
|---|---|---|---|---|---|---|
| | ***M*** | ***SD*** | ***M*** | ***SD*** | ***F*** | ***p*** |
| **Iconic gesture** | | | | | | |
| Caregiver | 5.80 | 1.31 | 2.63 | 1.06 | 20.42 | .001 |
| Child | 3.63 | 1.82 | 2.19 | 0.69 | 8.18 | .001 |
| **Mathematics-related iconic gesture** | | | | | | |
| Caregiver | 4.71 | 2.88 | 2.00 | 3.52 | 29.89 | .001 |
| Child | 3.95 | 2.35 | 2.13 | 3.50 | 9.94 | .004 |

The frequency of *mathematics-related iconic gestures* also differed between the math and the emotion-action conditions. As shown in Table 4-4 the frequency of use of *mathematics-related iconic gestures* was higher among caregivers in the math condition

(*M* = 4.71, *SD* = 2.88) compared to the emotion-action condition *(M* = 2.00, *SD* = 3.52); *F* (1, 30) = 29.89, *p* < 0.001. Similarly, *mathematics-related iconic gestures* among children in the math condition (*M* = 3.95, *SD*= 2.35) were higher than their peers in the emotion-action condition, (*M* = 2.13, *SD*= 3.50); *F* (1, 30) = 9.94, *p* < 0.005.

Results outlined in the table also show that the majority of *iconic gestures* of caregivers and children in both the math and the emotion-action condition aligned with the mathematics content in the story narrative.

### 4.4.4. Caregiver-child differences in the use of iconic gestures

Within-condition analyses showed that differences in the use of *iconic gestures* between caregivers (*M* = 5. 80, *SD* = 1.31) and children (*M* = 3.63, *SD* = 1.82) that shared the math eBook were not detectable; *t* (15) = 0.70, *p* = 0.49. Similarly, the differences in use of *iconic gestures* between caregivers *(M* = 2.63, *SD* = 1.06) and children (*M* = 2.19, *SD* = 0.69) that shared the emotion-action eBook were not detectable; *t* (15) = 0.98, *p* = 0.34.

Within-condition analyses showed that differences in the use of *mathematics-related iconic gestures* between caregivers (*M* = 4.71, *SD* = 2.88) and children (*M* = 3.95, *SD*= 2.35) that shared the math eBook were not detectable; *t* (15) = 0.08, *p* = 0.94. Similarly, the differences in use of *mathematics-related iconic gestures* between caregivers condition *(M* = 2.00, *SD* = 3.52) and children, (*M* = 2.13, *SD*= 3.50) that shared the emotion-action eBook were not detectable; *t* (15) = -0.43, *p* = 0.67.

Taken together, a) The frequencies of *iconic gestures* and *iconic gestures aligned with the mathematics* content were higher among caregivers and children in the math compared to the emotion-action condition; b) caregivers and children in both conditions used *iconic gestures* and *mathematics related iconic gestures* to the same extent c) most of the gestures used by caregivers or children in both conditions were mathematics related.

### 4.4.5. Pointing and mathematics-related pointing

Pointing was observed to estimate how often children or their caregivers drew the attention of one another to single out specific elements on screen as they shared the eBook. Pointing was also observed to estimate situations when caregivers or children pointed to focus their own attention in order to keep track of things, or to locate things on the screen.

All children and caregivers pointed at least once as they engaged in the shared reading of each eBook. The majority of pointing used by children and caregivers in both conditions aligned with illustrations or animations that highlighted mathematics principles in the story (in rare cases to their hands or each other's hands as they raised up fingers). Specifically, 419 (83%) of the total frequency of pointing in the math condition, and 117 (73%) of the total frequency of pointing in the emotion-action condition referred to mathematics-related content mainly in the illustrations and animations. Pointing to the text occurred rarely, as expected in a caregiver-child shared reading context (Evans et al., 2009), and therefore, no analyses of pointing to the text were conducted.

Results in Table 4-5 show that the frequency of pointing to illustrations and animations differed between the math and the emotion-action conditions. The frequency of *pointing* was greater among caregivers in the math condition ($M$ = 17.88, $SD$ = 10.97) compared to caregivers in the emotion-action condition ($M$ = 5.06, $SD$ = 1.12), $F$ (1, 30) = 18.72, $p < 0.001$. Results also show that the frequency of *mathematics-related pointing* of caregivers in the math condition *(*$M$ = 14.22, $SD$ = 7.15), was greater than among caregivers in the emotion-action condition ($M$ = 3.00, $SD$ = 1.54), $F$ (1,30) = 15.71, $p <$ 0.001.

**Table 4-5. Frequency of Pointing in the Math and Emotion-Action Conditions.**

| | Math (*n*=16) | | Emotion-Action (*n*=16) | | *F* | *p* |
|---|---|---|---|---|---|---|
| | ***M*** | ***SD*** | ***M*** | ***SD*** | | |
| **Pointing** | | | | | | |
| Caregiver | 17.88 | 10.97 | 5.06 | 1.12 | 18.72 | .001 |
| Child | 13.87 | 2.08 | 6.00 | 5.55 | 10.37 | .003 |
| **Mathematics-related Pointing** | | | | | | |
| Caregiver | 14.22 | 7.15 | 3.00 | 1.54 | 15.71 | .001 |
| Child | 11.98 | 1.39 | 5.06 | 3.01 | 10.07 | .001 |

The frequency of *pointing* of children in the math condition *(M* = 13.87, *SD* = 2.08) was greater than pointing of children in the emotion-action condition (*M* = 6.00, *SD* = 5.55), *F* (1,30) = 5.53, *p* = 0.003. Similarly, the frequency of *mathematics-related pointing* of children in the math condition *(M* = 11.98, *SD* = 1.39) was greater than of children in the emotion-action condition (*M* = 5.06, *SD* = 3.01), *F* (1,30) = 10.07, *p* < 0.001. Results also show that the majority of caregivers' and children's *pointing* in both conditions were mathematics-related.

### 4.4.6. Caregiver-child differences in the use of pointing

Analysis of caregiver-child differences in use of *pointing* showed that in the math condition, differences between pointing of caregivers (*M* = 17.88, *SD* = 10.97) and their children *(M* = 13.87, *SD* = 2.08) were not statistically detected, *t* (15) = 1.6, *p* = 0.13. Similarly, within the emotion-action condition, differences between caregivers (*M* = 3.00, *SD* = 1.54), and their children (*M* = 5.06, *SD* = 3.01) in use of *pointing* were not statistically detected *t* (15) = -0.59, *p* = 0.56.

Analysis of caregiver-child differences in use of *mathematics-related pointing* showed that in the math condition, differences between caregivers ($M$ = 17.88, $SD$ = 10.97) and their children *(*$M$ = 13.87, $SD$ = 2.08) were not statistically detected, $t$ (15) = 1.64, $p$ = 0.12. Similarly, within the comparable emotion-action condition, differences between caregivers ($M$ = 3.00, $SD$ = 1.54), than their children ($M$ = 5.06, $SD$ = 3.01) in use of *mathematics-related pointing* were not statistically detected $t$ (15) = -1.73, $p$ = 0.104.

Taken together, the results show that caregivers and children in the math condition pointed more often to mathematics-related illustrations and animations that highlighted mathematics-related content than their peers. Despite the discrepancy between the conditions, the majority of total pointing that occurred during shared reading among caregiver and children in both conditions was aligned with illustrations or animations with mathematics-related content. Within the two conditions, caregivers pointed in general, and to mathematics-related content to the same extent as their children.

### 4.4.7. Tapping the hotspots

Within math and emotion-action condition comparisons were made to detect who took the lead in activating the hotspots, the children or the caregivers. A series of paired-samples $t$-tests were conducted to compare the frequency of activating the hotspots by children and their caregivers. Results suggested that in the math condition, children activated hotspots more frequently ($M$ = 29.63, $SD$ = 15.97) than their caregivers ($M$ = 12.44, $SD$ = 13.29), $t$ (15) = -2.48, $p$ = 0.025. However, in the emotion-action condition, difference in the frequency of activating hotspots between children ($M$ = 19.44, $SD$ = 14.60) and their caregivers ($M$ = 24.88, $SD$ = 14.38), $t$ (15) = 0.75, $p$ = 0.463 was not statistically detectable.

### 4.4.8. Immediate responses to tapping the hotspots

An immediate response indicates the first action, defined broadly as a spoken utterance or a gesture (iconic or pointing) made by the child or the caregiver following

activating the hotspot and before tapping the next hotspot or resuming with oral reading of the narrative.

Nine categories of response to the hotspots were coded: *repetition, description, high-cognitive* and *low-cognitive questioning, explanation, emotional reaction, compliment, request,* and *gesture*. Descriptions of these categories/dependent variables of analysis can be found in Chapter 3, Table 3-5.

Table 4-6. Frequency of Immediate Responses of Caregivers and Children to Activated Hotspots.

| | **Math (*n* = 16)** | | **Emotion-Action (*n* = 16)** | | | |
|---|---|---|---|---|---|---|
| | ***M*** | ***SD*** | ***M*** | ***SD*** | ***F*** | ***p*** |
| **Immediate response** | | | | | | |
| Caregiver | 27.50 | 8.74 | 13.68 | 9.13 | 11.55 | .001 |
| Child | 9.56 | 6.45 | 2.25 | 1.73 | 7.57 | .006 |
| **Mathematics-related immediate response** | | | | | | |
| Caregiver | 20.52 | 5.45 | 0.44 | 0.73 | - | - |
| Child | 6.54 | 4.12 | - | - | - | - |
| **Repetition** | | | | | | |
| Caregiver | 7.69 | 6.31 | 2.38 | 3.10 | 10.03 | .005 |
| Child | 7.30 | 6.11 | 0.19 | 0.40 | - | - |
| **Mathematics-related Repetition** | | | | | | |
| Caregiver | 7.69 | 6.31 | - | - | - | - |
| Child | 7.30 | 6.11 | - | - | - | - |
| **Description** | | | | | | |
| Caregiver | 5.50 | 2.37 | 3.31 | 3.61 | 7.40 | .007 |
| Child | 1.50 | 2.19 | 0.63 | 0.89 | - | - |
| **Mathematics-related Description** | | | | | | |
| Caregiver | 5.00 | 2.13 | 00.13 | 0.34 | - | - |
| Child | 0.19 | 2.29 | - | - | - | - |

*Note.* Missing data (-). Statistical tests are not calculated for variables that show a floor effect for at least one of the two comparison conditions.

A total of 593 and 255 immediate responses to hotspots were made by children and caregivers together in the math and emotion-action conditions, respectively. The proportion of immediate responses to hotspots in the math condition that was mathematics related was 433/593 (73%) and in the emotion-action condition, 51/255 (20%).

Given weak correlations between the dependent variables, ANOVA was computed to compare means across the groups. As shown in Table 4-6, caregivers within each dyad made more *immediate responses to hotspots* in the math condition *(M* = 27.50, *SD* = 8.74) relative to the emotion-action condition *(M* = 13.68, *SD* = 9.13), *F* (1,30) = 11.55; *p* = 0.001.; and children made more *immediate responses to hotspots* per dyad in the math condition *(M* = 9.56, *SD* = 6.45) relative to the emotion-action condition (*M* = 2.25, *SD* = 1.73), *F* (1,30) = 7.57; *p* = 0.006. *Mathematically related, immediate responses to hotspots* per caregiver (*M* = 20.52, *SD* = 5.54) and child condition (*M* = 6.54, *SD* = 4.12) in the math condition exceed those of caregivers (*M* =0.44, *SD* = 0.73) and the children (none was found) in the emotion-action condition. Since a floor effect was detected statistical comparisons were not calculated.

*Repetition* refers to the act of repeating the sound that was heard once the hotspot was activated; whether it was a spoken word (e.g. "seven") or an emotional reaction of a character (e.g. laughter). All of the spoken words that were heard after a hotspot was activated in the math condition were numbers, while all of the spoken words associated with activated hotspots in the emotion-action condition were emotional expressions. As reported in Table 4-6, repetitions among caregivers in the math condition were more (*M* = 7.69, *SD* = 6.31) than caregivers in the emotion-action condition, *(M* = 2.38, *SD* = 3.10); *F* (1,30) = 10.03; *p* = 0.005.

*Description* refers to the verbal explanation that occurs after activating a hotspot; e.g., as a caregiver drags a virtual fish to the river, she describes the appearance of the fish to her child. Caregivers in the math *(M* = 5.50, *SD* = 2.37) and the emotion-action condition *(M* = 03.31, *SD* = 3.61) differed in their use of description in response to hotspots, *F* (1, 30) = 7.40; *p* = 0.007. Floor effects were found on the distributions of

description among children in the math condition (*M* = 01.50, *SD* = 2.19) and children in the emotion-action condition, *(M* = 0.19, *SD* = 0.40). Taken together, the results suggest that caregivers, rather than children, in both conditions provided descriptions of actions that occurred after the activation of the hotspot.

Table 4-7 showcases the remaining responses that occurred after hotspot activation. All the response variables demonstrated a floor effect in at least one of the two conditions. *High-level questioning, low-level questioning, complimenting*, and overall *gestures* that were used among caregivers in the math condition had floor effects on these variables were found among caregivers in the emotion-action condition. In contrast, emotional reactions to hotspots were frequent among caregivers in the emotion-action condition relative to the floor effect observed among caregivers in the math condition.

Caregivers in both conditions rarely provided *explanations* to support understanding of the themes in the story following the tapping of hotspots. For instance, only three caregivers in the study explained to their children that dragging the smallest fish to the river was a benefit to the fish and to conservation efforts: *"they are putting them back to the river so they can grow bigger".* Additional analyses of the variability in the immediate responsiveness to hotspots among caregivers in the math condition showed that in total 119 questions were posed, 80 were high- and 39 were low-level cognitive questions. Caregivers' questions prompted children to engage in one-to-one correspondence and counting (e.g., *Can you count the fingers?*"). Caregivers' questions also probed children about making a judgment regarding size comparison (51/119, 43% of total questions): for example. *"Which one is smaller than the yellow fish?"* Sharing the fish was the focus of 28/119 (24%) of total questions (e.g. "*How are we going to share this fish with brother?"*). Caregiver questions low in cognitive demands most often concerned identifying the colours of the fish (39/119 questions; 33%).

As previously described, the *emotional response* was a common immediate response of caregivers and children in the emotion-action condition to a hotspot. Laughter was the most common emotional reaction of caregivers and children in this condition (72 out of the 107 emotional reactions; 67%).

**Table 4-7. Frequency of Immediate Responses to Hotspots among Caregivers and Children in the Math and Emotion-Action Conditions (n = 32).**

| Responses | Math ($n$ = 16) | | Emotion-Action ($n$ = 16) | |
|---|---|---|---|---|
| | ***M*** | ***SD*** | ***M*** | ***SD*** |
| **High-level cognitive questioning** | | | | |
| Caregiver | 5.01 | 3.11 | 0.87 | 1.31 |
| Child | 0.19 | 0.54 | - | - |
| **Low-level cognitive questioning** | | | | |
| Caregiver | 2.43 | 2.02 | 0.50 | 1.50 |
| Child | 0.25 | 0.48 | - | - |
| **Explanation** | | | | |
| Caregiver | 0.56 | 0.71 | 0.19 | 0.75 |
| Child | - | - | 0.13 | 0.34 |
| **Emotional Reaction** | | | | |
| Caregiver | 0.44 | 0.73 | 5.56 | 4.21 |
| Child | - | - | 1.13 | 1.71 |
| **Compliment** | | | | |
| Caregiver | 3.13 | 2.90 | 0.44 | 0.73 |
| Child | - | - | - | - |
| **Request** | | | | |
| Caregiver | 1.31 | 2.12 | 0.48 | 0.63 |
| Child | - | - | - | - |
| **Gesture** | | | | |
| Caregiver | 0.81 | 0.91 | 0.19 | 0.40 |
| Child | 0.50 | 1.03 | - | - |

*Note.* Missing data (-). Statistical tests are not calculated for variables that show a floor effect for at least one of the two comparison conditions.

Taken together, the results show that children in the math condition tapped hotspots more often than children in the emotion-action condition; whereas caregivers in

the math condition tapped hotspots less often than their peers in the emotion-action condition. Within the math condition, children tapped hotspots more frequently than their caregivers. Within the emotion-action condition, differences between the frequency of children and caregiver's tapping of hotspots were not statistically detectable. Caregivers in the math condition responded to hotspots by asking high and low-level questions, by repeating what is heard, and by providing descriptions to the children. In the emotion-action condition, caregivers and children both reacted emotively to the hotspots.

### 4.4.9. Analysis of mathematics activities

The eBook narrative (in both conditions) included two activities, the Strategic Counting activity, and the Fair Share activity. The activities encouraged dyads to engage in mathematical-related conversations. Each activity was integral to the context of the story, In the Strategic Counting activity, the text invited the child to count a scattered array of fish from the biggest to the smallest. In the Fair Share activity, the text invited the child to help the little bear with sharing three fish in her basket among four family members (mother, father, brother, and herself) and probably the cat. In the math condition hotspots allowed dragging the virtual fish indefinitely to new locations on the page to indicate how the fish would be divided. Those were drag-and-drop hotspots not associated with audio files. Hotspots in the emotion-action condition aligned with actions of the characters such as sounding out *hello* once tapped or allowing dragging the virtual image of the brother bear to visualize the action of his entry to the room.

A dichotomous scoring system was used to indicate whether the child or the caregiver responded to the activities. A score of 1 was coded when at least one spoken utterance, or gesture related to the activity was made by the caregiver or the child, and 0 when no response related to the activity was observed. As shown in Table 4-8, results of chi-square analyses revealed differences in the number of dyads who responded to each activity. Namely, a greater number of dyads engaged in the math condition compared to the emotion-action condition in the Strategic Counting activity; $\chi 2$ (1, $N$ = 32) = 4.57, $p$ = 0.041; and the Fair Share activity $\chi 2$ (1, $N$ = 32) = 24.50, $p < 0.001$.

Only one dyad in the emotion-action condition responded to the question about sharing the fish compared to 15 dyads in the math condition. The remaining 15 dyads in the emotion-action condition tapped the hotspots that activated actions of the bears (e.g. sounding "hello" when a bear is tapped) and responded to them by either repeating the spoken word they heard or by reacting emotively (e.g. by laughing) and proceeding to the next page.

**Table 4-8. Number of Dyads that Engaged in the Strategic Counting and the Fair Share Activities across Conditions**

| Task | Math | Emotion-Action | *df* | $\chi 2$ | *p* |
|---|---|---|---|---|---|
| | (*n* =16) | (*n* =16) | | | |
| **Strategic Counting** | 15 | 10 | 1 | 4.57 | .041 |
| **Fair Share** | 15 | 1 | 1 | 24.50 | <.001 |

## 4.5. Thematic Qualitative Analysis

In order to further highlight the experience of caregivers and children with the eBook in the math condition, a thematic analysis of the interactions of the dyads during these two activities was conducted.

As children and their caregivers in the math condition interacted with hotspots embedded within the activities, several clear themes began to emerge. In many instances, caregivers took lead, positioning themselves generally as an aid for their children's construction of knowledge. This is referred to as scaffolding; giving assistance to support higher levels of acting and/or thinking during the shared reading then withdrawing it as children's skills improved (Whitehurst et al. 1988). Sometimes children and their caregivers constructed ideas together, particularly while exploring the mathematic hotspots.

The themes that highlight the process of accessing mathematical thought are scaffolding of mathematics ideas, caregiver-child co-construction, and seeking self-agency of the child.

### 4.5.1. Scaffolding of Mathematical Ideas

The following illustrates how the hotspots present in the math condition of the strategic counting activity influenced the scaffolding of mathematics ideas. Raju's (a fictitious name; 48-month-old male) caregiver reinforced tapping the first fish (which was associated with a hotspot) in the correct order by affirming Raju's response to it. The caregiver affirmed that the yellow fish was the "largest" fish. She also expanded Raju's knowledge about the hotspots' mechanics. It went from something he simply tapped, to something that can be tapped to elicit a verbal response from the eBook, as if the text was an active participant in the conversation. Raju's caregiver directed his attention to the interactive features within the eBook and she guided his overall experience. Below is an excerpt from their shared reading activity.

> ***Caregiver:*** *[reads the text] "Let's start counting from the biggest fish and end up with the smallest fish". [After Raju's caregiver finished reading, she looked at Raju and with a slight nod to indicate to the child for the next steps in the eBook.]*
>
> ***Raju:*** *It is this one? [Raju asks as he points to the yellow fish and he looks up at his caregiver]*
>
> ***Caregiver:*** *Yes, this is the largest fish [Raju's caregiver turns to him, nods and says with a pleasant voice]. You have to tap it honey; it blinks.*
>
> ***Raju:*** *[taps the fish. Upon tapping it, the eBook "speaks" the number one and the yellow fish is highlighted. Raju had a surprised look on his face].*
>
> ***Caregiver:*** *It is talking to you! And it is highlighted. Let's move to the next one [points to the yellow fish and then turns to Raju with a smile and pretended to be surprised as well].*

In the next excerpt, Raju's caregiver scaffolded him by encouraging him to activate the fish and repeat the verbal responses generated by the eBook. Furthermore, she indicated which hotspots had already been activated to better help Raju discover the fish not yet tapped and numbered. Apparently, Raju was able to understand the pattern and could activate the next fish in the correct order without his caregiver's aid.

***Raju:*** *two [with a bright and loud voice, Raju repeats the word "two" to his caregiver].*

***Caregiver: "****Two" means it is the second fish [touches the second big fish and repeats the number "two" that is spoken, and the fish is highlighted]. The purple fish is the second fish.*

***Raju:*** *Three [touches the pink fish, which is the third fish in size and repeats the number "three" that is sounded out, and the fish is highlighted]. The pink fish is the three fish.*

***Caregiver:*** *The third fish. Good job!*

### 4.5.2. Co-constructing Knowledge

These interactions highlight how Raju's and his caregiver's co-construction of knowledge about tapping the fish in the correct order became routine as they continued to respond to hotspots. Raju initiated some actions, and the caregiver initiated others. Moreover, Raju and his caregiver responded in kind to each other, taking into account the perspective of the other person. This is a key aspect of co-constructing knowledge (Tomasello, 2003). When Raju stated his comprehension of an idea, his caregiver expanded on the process; she used the word "third," rather than "three," to introduce the correct words associated with the order. Notably, she repeated the same sentence structure as the child, which focussed the child's attention on the word embedded in a familiar phrase pattern.

Pointing and gesturing actions facilitated the process of co-construction of knowledge. For example, in the math condition, the act of touching the fish was used almost solely to count them. This activated the hotspots relating to the fishes' sizes. The hotspots focussed the child and the caregiver on the number of fish counted vs. the fish that had not been counted. The following excerpt shows Elsa (a fictitious name; 40-month-old female) and her caregiver using these tools in a problem-solving space.

***Caregiver:*** *how are you going to share with the brother? [asks when pointing to the brother's image].*

***Elsa:*** *mm.. [with a long thoughtful look on the screen]*

***Caregiver:*** *which one do you want to give to brother? [Points to the brother's virtual image and then to each one of the fish]*

***Elsa:*** *[again looks thoughtfully on the screen]. Blue fish [with excitement]*

Elsa was not able to find a way to share the fish and her caregiver did not provide a direct solution. Rather, the caregiver initiated co-construction by engaging her with pointing, and then waiting for her to respond. Elsa's caregiver validated her responses by demonstrating how to drag the blue fish to the brother.

***Caregiver:*** *[as he taps and drags the blue fish to the image of brother] this could go to brother. How about the mum?*

***Elsa:*** *[again looks thoughtfully on the screen but now talks with hesitance] pink fish.*

***Caregiver:*** *[holds Elsa's finger and helps her drag the pink fish to the mother bear's image.*

The following excerpt shows that although multiple options were available for sharing, Elsa's caregiver valorizes her response, which encourages her to continue finding ways to share the remaining fish:

***Elsa:*** *[with a smile on her face, holds the yellow fish and drags it to the father bear's image].*

***Caregiver:*** *Great! How about Dora (the name given to the little bear)?*

***Elsa:*** *[immediately drags the pink fish from the mother bear to the little bear's image]*

***Caregiver:*** *the pink one is already with the mum. Can you think about other option? [turns to Elsa with a caring look]*

***Elsa:*** *mm.. [with a puzzled look on the screen]*

At this point, Elsa was not able to solve the problem, so her caregiver provides a possible strategy to share the fish. Through added gesturing, he indicates that a big fish might be shared among all the family members.

***Caregiver:*** *You are almost there [with a supporting voice]. You only need to choose a fish that is big enough to share [make a hand circle-gesture around the whole page]*

### 4.5.3. Seeking Self-discovery and Agency

Marjanovic-Shane, Connery, and John-Steiner (2010) characterize self-discovery and emerging agency in children as "what they must need to know next through self-initiated problem-solving and implicitly drawn connections through self-discovered meaning making" (p. 66). Through this process, a child will utilize available resources in their immediate environment, including adults and materials. They will initiate interactions with these sourses until they have created a space for self-discovery.

Hotspots in the math condition were meant as attentional resources to interact with creating a discovery space for the children. In this way, the hotspots were communicative tools intended to help children self-monitor their attention. The support and scaffolding of the caregivers when children were activating these hotspots showed the children a pattern; activating the hotspots yielded important mathematics information.

Caregivers used more tools than just the hotspots to facilitate the children's self-discovery. The following excerpt shows how Pedro (a fictitious name; 50-month-old male) and his caregiver navigated hotspots; his caregiver reinforced the hotspots to raise her child's level of engagement. She begins by explaining the problem that must be solved - the division of fish among family members – and Pedro responds with heightened interest.

> ***Caregiver:*** *Oh. That is a tough one [deep "pretend" serious tone]. How are you going to share the fish? Who gets what?*
>
> ***Pedro:*** *what? [With a puzzled look on his face he looked intently at the screen]*
>
> ***Caregiver:*** *Are we going to drag them? Or what are we going to do? Who's going to get which fish, what do you think? [Asks with intonation as if she is trying to engage Pedro]*
>
> ***Pedro:*** *She is going to get that [laughs and points to the mother bear's virtual image and then to the purple fish on the screen with excitement]*
>
> ***Caregiver:*** *The mum is going to get the little one? [Turns to Pedro with a curious look and a smile]*
>
> ***Pedro:*** *Yes, because it is purple hair and purple fish [points to the mother bear's virtual image and then points to the purple fish intently and nods]. So let's put the purple fish with the mum [holds the fish and drags it to the mother bear's hands]*

***Caregiver:*** *Ok [laughs out loud]. That is very creative [gently strokes Pedro's shoulder as if to indicate acknowledgment and pride].*

Pedro wanted to discuss the colors of the fish, even when his caregiver tried to direct his attention to the varying fish sizes. She respected this inclination of his own meaning-making, and he began to match the colours of fish to different hair colours; i.e. the purple fish went to the mother with purple hair and the blue fish to the brother with blue hair. She also reinforced his actions with positive laughter and complimenting his abilities.

After colour matching most of the family with fish that matched their hair colour, Pedro encountered a problem: the last fish did not match the last family member's hair color. The excerpt below highlights the issue.

The following excerpts show that when Pedro had no more fish to share with a family member, his caregiver directed his attention to the issue. Pedro responded by suggesting that the largest bear and the smallest bear share the largest fish by attempting to find a "dynamic solution" by dragging the yellow fish back and forth between both bears. His caregiver validated this method of problem-solving and reinforced Pedro's capabilities to construct his own knowledge.

***Caregiver:*** *Ok what about papa bear? [Pedro's caregiver turns to him and asks with incline tone of voice suggestive of a question]*

***Pedro:*** *He is going to share [whispers to his caregiver's ear and smiles].*

***Caregiver:*** *He is going to share. With whom? [turns to her son with affectionate look and a smile]*

***Pedro:*** *[Points to the brother bear with his right index finger. He then taps and drags the yellow fish back and forth between the father and the brother with a smile on his face]*

***Caregiver:*** *[holds the yellow fish and drags it to the middle distance between the two bears]*

***Pedro:*** *Yeah [with a loud clear voice as he watches his caregiver with a big smile on his face when the fish is dragged.].*

***Caregiver:*** *Oh that is very fair [deep "pretend" serious tone]. Because he gets the biggest he gets to share with little brother [turns to her son with affectionate look and turns page].*

## 4.6. Caregivers' Impression of the eBook

The caregivers' impression of eBook for use in shared reading practices was investigated by asking caregivers to complete the *Caregiver eBook Satisfaction Questionnaire* (see Appendix E). A four-point Likert scale (1: agree, 2: somewhat agree, 3: somewhat disagree, 4: disagree) was used to indicate the level of caregiver agreement with 12 statements that described features that defined the quality of their experience using the eBook. Since the Likert scale is an ordinal scale (Jamieson, 2004), the non-parametric test of Kruskal-Wallis *H* test was conducted to determine differences in the caregivers' attitudes across the conditions. Please refer to Appendix F for the mean ranks, the Kruskal-Wallis *H* test results, and *p*-values.

Perspectives of caregivers about the quality of their eBook experience often differed, depending on the eBook they shared with their children. Caregivers in the math condition agreed that the hotspots were important to maintain the child's attention to the story; however, on average, caregivers in the emotion-action condition reported that they somewhat agreed with this statement. The differences in caregiver ratings were statistically detectable $H$ (2) = 6.608, $p$ = .01, with a mean rank rating of 1.56 for the math condition, and 2.31 for the emotion-action condition.

On average, caregivers in the math condition reported they strongly disagreed with the statement that hotspots were distracting for their children or themselves. Similarly, on average, caregivers in the emotion-action condition also reported they disagreed that the hotspots were distracting for their children. However, math and emotion-action differences in caregivers' agreement with the statement that the hotspots were distracting for their children were statistically detectable, $H$ *(1)* = 7.107, $p$ =.009; with a mean rank of 3.81 for the math condition, and 2.94 for the emotion-action condition. Differences in caregiver's ratings of agreement with the statement about the distractibility of the hotspots for themselves between math and emotion-action conditions were also statistically detectable, $H$ (1) = 8.805, $p$ = .003, with a mean rank of 3.62 for the math condition, and 2.63 for the emotion-action condition.

Moreover, on average, caregivers in the math and emotion-action conditions strongly agreed (math) or somewhat agreed (emotion-action) that their child's engagement with the eBooks was high (with mean ranks of 1.0 and 1.63, respectively). Differences in these between condition ratings were statistically detectable, $H$ (1) = 8.55, $p$ = 0.003.

Caregivers in both conditions agreed that they would continue the practice of reading eBooks to their children in the future, $H$ (1) = 3.593, $p$ = .058, with a mean rank rating of 1.38 for the math condition, and 1.94 for the emotion-action condition.

All caregivers in both conditions strongly agreed their children enjoyed sharing an eBook, with a mean rank of 1 for each condition. Moreover, the caregivers in both conditions uniformly agreed that the content of the eBook was appropriate for their children's developmental stage, $H$ (1) = 2.067, $p$ = 0.151, with a mean rank rating of 1 for the math condition, and 1.13 for the emotion-action condition. Notably, caregivers in both conditions agreed that the mathematical content in the eBooks was clear to them, $H$ (1) = 0.89, $p$ = 0.345, with a mean rank rating of 1.12 for the math condition, and 1.31 for the emotion-action condition. Caregivers in both conditions also agreed on the adequacy of the clarity of content to their children as well, $H$ (1) = 1.24, $p$ = 0.266, with a mean rank rating of 1.38 for the math condition, and 1.81 for the emotion-action condition.

Caregivers in both the math and emotion-action conditions reported that they somewhat agreed that the eBooks could potentially help their children improve their mathematical thinking, $H$ (1) = 0.22, $p$ = 0.642, with a mean rank rating of 1.75 for the math condition, and 2.06 for the emotion-action condition. Finally, caregivers in both conditions agreed that they felt actively engaged with the child during a shared reading activity. , $H$ (1) = 0.996, $p$ = 0.318, with a mean rank of 1.13 for the math condition, and 1.37 for the emotion-action condition

Overall, relative to readers of the eBook in the emotion-action condition, readers of the eBook in the math condition were more likely to agree that their children were actively engaged with the hotspots and that the hotspots supported directing their child's attention to the story rather than distracting attention while sharing the eBook.

Finally, the analysis of the caregivers' impression showed that caregivers perceived the mathematics-related hotspots as more positive to engage their children and maintain their attention through the shared reading activity.

In Chapter 5, which follows, the findings described in this chapter are discussed at length in light of the research questions that guided the research, previous findings in the literature, and study limitations and implications.

# Chapter 5.

# Discussion

This study explored the influence of the design of eBook hotspots on caregiver-child communication about story content during shared reading practices. Specifically, this study examined how eBook hotspots designed to guide joint attention to mathematics influence caregivers' and children's communication about mathematical concepts highlighted in the hotspots, text, and illustrations.

The Cognitive Theory of Multimedia Learning (CTML; Mayer, 2009) guided the design of hotspots in the eBooks specifically with respect to managing cognitive load on working memory through increasing joint attention directed to relevant information. Theoretically, the eBook designs aimed to increase communication between caregivers and children about actions, events, illustrations or dialogue in the story.

For example, according to the CTML signaling principle (Mayer, 2009), blinking hotspots in the eBooks focus the joint attention of the caregiver and the child to specific locations on the screen and, once activated, the hotspots animate or highlight events in the eBook narrative. The highlighted event also aimed to focus joint attention between the caregiver and the child to those locations on the screen. Drawing on the signaling principle, physical interactions with hotspots in the eBooks prompt joint attention and communication about the characters' actions, illustrations, or different mathematics related content. For instance, a hotspot associated with a blinking fish directed the joint attention of the child-caregiver dyads to the screen, which then prompted them to activate the hotspots. Upon tapping, the blinking fish was permanently highlighted and, simultaneously, the cumulative number of fish was spoken by the eBook.

In the comparison eBook, the signaling principle used blinking hotspots to focus caregiver-child attention to locations on the screen that presented the character's emotions and actions to the reader. For example, character emotional expressions were activated by tapping the character, which showed the little bear smiling and giggling, expressing an emotion of joy.

Another design characteristic is the CTML's segmentation principle (Mayer, 2009). The segmentation principle was used to design the presentation of the hotspots. It was important to keep the hotspot activation separated from each other to allow the caregiver and child to activate them at their own pace, with the intention of supporting joint attention to segmented information about mathematics actions. For instance, dragging the two smallest fish back to the river was segmented. When one fish was dropped into the river the child and the caregiver could pause, and discuss the events on the screen before dragging the second fish back to the river.

Findings from this research addressed two research questions, which are discussed at length in this chapter. The first research question concerned the impact of eBook hotspots on the mathematics-related communication of children and their caregivers. Math hotspots, as well as emotion-action hotspots, were expected to impact the mathematics communication in different ways. The second research question explored how hotspots designed to cue caregivers and children's attention to mathematics problem-solving activities embedded in the story influence caregiver-child communication during this activity. This question dealt only with the math eBook and particularized the two mathematics problems embedded in the narrative.

The chapter concludes with a summary of research contributions to the extant literature, limitations, and implications for future studies.

## 5.1. RQ 1: What is the Impact of eBook Hotspots (math vs. emotion-action) on Caregiver-Child Communication about Mathematics during Shared Reading Practices?

The joint attention of caregivers and children to the unfolding story was found to be influenced by story narrative, illustrations, automatic animations, and eBook hotspots. In the context of this study, "mathematics-related communication" refers to speech and gestures about content related to mathematics appearing in the eBooks. For instance, the utterance "this fish is smaller than the blue fish" was used to compare the sizes of fish mentioned in the text, depicted in illustrations or activated in hotspots.

Spoken utterances were considered the main medium caregivers and children used to construct meaning about, around, and beyond the text. Utterances often centered on actions or emotions, beliefs, and perspectives of characters that emerge as the story unfolds.

Children's and caregivers' iconic gestures - hand gestures that convey a meaning that resembles the semantic content of the accompanied speech - were also frequently used to facilitate discussing mathematics related attributed (such as size) presented in the story. Iconic gestures were specifically used to facilitate finger counting, represent different sizes (e.g. palms facing each other in different distances to illustrate different sizes of fish), or represent parts (e.g. by opening the palm and moving the pointer over the palm to represent cutting the fish).

Deictic (pointing) gestures were also considered in the analysis since children and caregivers used them frequently in order to establish a joint focus of social attention (e.g. Özçalışkan, Adamson & Dimitrova, 2016). Pointing was usually used jointly with a deictic spoken phrase such as "that thing" or "here". In other cases, it was used without using any simultaneous phrase.

Prior to examining the effect of hotspots on children's and caregivers communication during the shared reading of the eBooks, a discussion is presented about design elements other than hotspots that also may have influenced communication. This serves to provide the context for further discussion of the role of hotspots.

### 5.1.1. The impact of eBook design components other than hotspots on communication about mathematics

***Illustrations and script***

Findings showed that regardless of which eBook the caregivers and children shared, each dyad discussed counting sets of one, two or three objects (fish/fingers), whole quantity, parts, the quantifier zero, changes in manipulations, varying sizes of the fish, or possible options of sharing the fish among the bear's family members at least once during the reading session.

Caregivers and children in both groups also used gestures to represent mathematics operations as they talked or pointed to the screen at least once during the shared reading session. For example, the child or the caregiver referred to the quantity of a counted group of five fish by counting them one by one while pointing to them on the screen. Then, the child or the caregiver referred to changes in manipulations by referring to the original set of five fish while raising up five fingers and then discussing the subtraction of two fish by explaining that two fish were released back to the water while bending two fingers and keeping three fingers up.

These findings affirm previous studies showing caregiver-child discussions about mathematics concepts occurred during the reading of storybooks with mathematics content displayed in the story script and illustrations. Storybooks that directed attention to the mathematics concept of size through the story script increased the tendency of children and caregivers to refer to size during shared reading practices (Shapiro, Anderson & Anderson, 1997). Additionally, in shared reading of print storybooks that included illustrations of objects with different quantities and sizes, caregiver-child discussion about mathematics was more likely to occur (Anderson, Anderson, & Shapiro, 2004; Anderson & Anderson, 2005). Specifically, it was demonstrated that illustrations play a central role in attracting attention to counting (Anderson et al., 2004) or size (Anderson & Anderson, 2005) while adults read to children, prompting relevant conversation.

Van den Heuvel-Panhuizen and Van den Boogaard (2008) found that storybook illustrations promoted mathematics-related thinking, as evidenced in the children's questions and comments while the book was read to them by an adult. In their study, when the adult read the story to a young child; the child generated a considerable range of utterances that were mathematically oriented, and most of the utterances were centered on the illustrations. This finding was detected despite the fact that the storybook the researchers used did not aim to prompt mathematics thinking in the first place.

### 5.1.2. Responsiveness to the eBook hotspots

***Activating the hotspots***

Whether caregivers or children activated hotspots was influenced by whether the hotspots activated animations or audios related to mathematics or to another content. Children who shared the math eBook activated hotspots more frequently than their caregivers. In contrast, children and caregivers reading the emotion-action eBook participated equally in hotspot activation.

Provided that children had scaffolding from their caregivers in the shared reading sessions, a possible explanation of these findings is that caregivers sharing the math eBook tended to grant their children permission to activate hotspots. Presumably, those caregivers perceived the content and locations of the hotspots to serve as "hands-on" tools for binding the content activated by the hotspots with the mathematics targeted narrative, and to engage their children in understanding mathematics content. For instance, dragging the virtual fish by the children in the Fair Share activity was possibly perceived by caregivers as essential for their children's understanding of the action of sharing three fish among four or five characters.

On the contrary, Labbo (2009) reported that in order for the child to take a leading role in activating the hotspots in shared eBook practices, repetitive exposure to the eBook is needed. However, the current study shows that the content activated by hotspots also determines who takes the lead in activating them. The distinct findings across the two studies may be explained by the level of experience of the children in the different studies. The child in Labbo's study did not have previous experience with eBooks, and therefore, he possibly needed more exposure time and competence to engage in taking the lead in deciding which hotspot to activate. Children in the current study had previous experience with using tablets to play games or read eBooks (see Appendix F).

In comparison, caregivers who shared the emotion-action eBook may have perceived the hotspots to create a playful context for exploring actions and exciting emotions of the eBook's characters. Therefore, they took equal turns activating the hotspots as a form of playful engagement.

***Responses to activated hotspots***

Communication between the child and the caregiver was influenced by the content associated with hotspots such as the animations, audios, and illustrations.

The most common immediate responses from children and caregivers were *repetition* and *questioning* as they tapped the hotspots in the math eBook. In the comparison condition, the most common response of caregivers and children was *emotive reaction.*

*Repetition*

Repetition is defined here as the act of repeating sounds that resulted from activating a hotspot. Repeating the audios of the sequential numbers of counted sets of objects (fish/fingers) was the most frequent, immediate response of caregivers to mathematics related hotspots. This occurred in 40% of immediate responses to hotspots. The shared reading literature concerning eBooks does not offer findings of responses to hotspots. However, in a 2013 study, Liu and his colleagues found that repetition of narrated scenarios was the most used strategy by caregivers as they read eBooks to their children. Repeating scenarios prompted young children to directly follow their caregivers' narration, and to understand the story content with more depth (Liu, Tseng, and Wu, 2013). This assumption is reflected in the act of repeating audios of sequential numbers in the present study. Presumably, through repetition, caregivers aimed to prompt the understanding of one-to-one correspondence regarding sequential number counting while engaging their children in routine practices of counting along with the audios (hotspots mostly activated this type of content). One-to-one correspondence is effective for learning counting (Gelman & Gallostel, 1978).

The present study goes further with this principle. Children immediately repeated the audios at the same extent as their caregivers. From the lens of the socio-cognitive perspective, the children's engagement with repeated audios could be an outcome of their caregivers' routine practices of repetition (Carpendale et al., 2014).

In comparison, the emotions and actions hotspots did not prompt a high frequency of repetition (i.e. 15% of the time), because they mostly included audio such as "aha" or

"yeah" or a sneezing sound. Repeating these audios did not emphasize verbatim narration. Instead, caregivers and children usually reacted to them with laughter. Going back to the research question, it can be concluded that the content activated by hotspots determines whether repetition occurs, and thus how eBook design can support rehearsing information.

*Questioning*

Questioning children about events in the story was the second most frequent caregiver response to mathematically aligned hotspots. This finding also matches Liu and his colleagues' (2013) finding that questioning was amongst the most used strategies in shared reading practices. They explained that maintaining engagement of children triggered caregivers to use this strategy (Liu et al., 2013).

In the present study, most caregivers' questions required information not explicitly present in the eBook (i.e. high cognitive questioning; Mcginty et al., 2012), such as making a prediction about a number of objects in changing sets of fish or linking the story to the child's personal experience of fishing. Smeet and Bus (2012) found this kind of questioning during shared reading important for promoting children's active engagement and deep processing of information.

Most questions were asked as the dyads discussed the embedded mathematics activities (the Fair Share activity and the Strategic Counting activity). For example, caregivers' questions probed mathematics thinking about comparing different fish lengths by asking "which one is smaller than the yellow fish?" Other questions prompted thought about different possibilities of sharing the fish such as, "How are we going to share this fish with brother?" This finding provides evidence that the content and placement of hotspots within the eBook support the strategy of questioning in shared reading settings.

In comparison, questioning as an immediate response to hotspots in the emotion-action condition was rare and never prompted thinking about mathematics. Since the content was simple and direct, the caregivers did not tend to use questions to engage children in an additional talk that requires processing information about actions or emotions (Korat & Shamir, 2004). However, hotspots that triggered mathematics content

required processing the mathematics meaning, which is also important to understand subsequent scenes (e.g. returning the two smallest fish back to the river and later going back home with less fish).

*Emotive responses*

An emotive response is defined here as an expression of any kind of emotion when the dyads shared the eBook. Emotive responses were the most frequent immediate responses to hotspots in the emotion-action eBook. They facilitated emotional engagement between the child and the caregiver concerning the story. ,

Laughter was the most common emotional reaction; observed as an expression of shared enjoyment around the story (Labbo, 2009). Again, this finding provides further evidence that communication between the child and the caregiver is influenced by animations, illustrations, and audio-files activated by hotspots. In this condition, hotspots supported emotions and actions in the narrative, evidence that eBooks design can promote laughter and bonding with a child while reading an eBook.

***Quantity and quality of communication***

Quantity and quality of communication between the children and the caregivers were observed not only in direct responses to hotspots but also during the entire shared reading activity. The caregiver-child communication included a review of eBook-related spoken utterances, iconic gestures and pointing that occurred during communication beyond the verbatim reading of the story text.

Findings showed that moderate to high correlations were detected between the different communication outcomes. First, these correlations are expected based on that the caregiver's and the child's use of speech, gestures or pointing are related in shared reading contexts. In light of the social-cognitive perspective, dyadic communication is a recursive process in which the caregiver and the child jointly contribute to the meaning construction and react to each other (e.g. Carpendale & Lewis, 2004; Brinck, 2008). Second, correlations between speech and gestures frequencies of the same person are also natural based on that gestures and pointing are spontaneously used in combination with speech (O'Neill, Bard, Linnell & Fluck, 2005; Özçalışkan & Goldin-Meadow, 2006).

*Spoken utterances*

Verbal engagement is an indicator that attention is paid to a shared reading activity (Son & Tineo, 2015). Caregivers and children in both groups discussed counting sets of one, two or three objects (fish/fingers), whole quantity, part of a whole quantity, or quantifier zero, changes in manipulations, varying size of the fish, or possible options of sharing the fish among the bear's family members at least once. However, caregivers and children who shared the math eBook engaged in this kind of discussion about mathematics more frequently compared to their peers who shared the other eBook.

Mathematics hotspots prompted caregivers and children to engage in richer and more condensed talk about mathematics in the story narrative as opposed to the emotions-actions hotspots in the comparative eBook. The finding replicates a previous study reporting that hotspots drew shared attention of caregivers and children to elements in a story narrative or illustrations and promoted engagement (Moody, Justice & Cabell, 2010).

The gap in the number of spoken utterances between the two conditions about mathematics can be attributed to how hotspots matched the text. The mathematics related hotspots were well aligned with the mathematics content in that hotspots activated audios of accumulating number of the fish and that was related to the storyline (e.g. The age of the little bear, her wish to catch three fish, or three fish inside the basket). This hotspot-text matching supported the construction of meaning associated with the meaning of the quantity three in the narrative.

The match between hotspots and text prompted discussion in regards to changing quantities of sets as a result of adding fish or releasing fish from different sets. For example, when a child tapped a hotspot that allowed dragging a fish back to the river; that supported discussion of the previous set and the new set of fish; five versus three. The hotspot-text matching is important when this matching supports the plot and subsequent of events. For instance, discussing the new set of three fish was an important component for constructing the meaning of the sequence of events in the story; in this case by showing the mother bear upon arriving home that there were three fish in the basket. In comparison, there was less in mathematics talk among the dyads that shared

the emotion-action eBook - despite that mathematics was made explicit in the narrative. Since content available on interacting with the hotspots in this condition focussed attention to emotions and/or actions of characters and did not directly support understanding the plot, caregivers and children were less likely to engage in extended mathematics discussion.

To conclude, an important addition of this research to literature is that increasing attention to text through aligning hotspots activations and the text (i.e. Korat & Shamir, 2008) is not sufficient for relevant and rich discussion to take place in shared reading settings. The hotspots further need to support understanding the storyline and the connection of the sequenced scenes within it as in the case of the mathematics aligned hotspots.

*Gestures*

General and mathematics related gestures (i.e. accompanying and resembling mathematics utterances), whether iconic or pointing in nature, were more frequent among caregivers and children who shared the math eBook. Dyads gestured for different purposes, such as conveying perceptual information about objects in the eBook (e.g., length or amount). They gestured less to convey information about actions (e.g., to express the virtual bears walking to the river). The use of iconic gesture is tied to simultaneous speech (Namy, Campbell & Tomasello, 2004) which in turn aligns with the richer and more diverse mathematics related talk observed among dyads that shared this eBook.

Findings also show that when reading both eBooks, the frequency of iconic gestures was statistically indistinguishable between caregivers and children. This is important for conceptualizing the adults' influence on the children through gestures during a shared reading activity. As in previous studies, such as Özçalışkan and Goldin-Meadow (2006), where it was noted that children were more likely to produce gestures when they watched their teachers using them. It seems children in the current study were following their caregivers' lead.

Producing gestures is important for directing attention and enhancing awareness of the speaker's intentions during communication (Alibali & Kita, 2010). Nava, Rinaldi, Bulf and Macchi Cassia (2017) further argued that proprioceptive cues (referring to the child's awareness of their hands in space) influence children's construction of the internal representation of numbers. The internal representation of the number, in this case, may have prompted more mathematics-related gestures among caregivers and children sharing the math eBook compared to caregivers and children in the comparison condition.

The increased use of gestures can also relate to the discussion of the mathematics activities; this discussion was more evident among the dyads who shared the math eBook. The Fair Share activity was carried out by the dyads that, generally, used more gestures. Therefore, the use of gestures increased when engaging in problem-solving. This finding matches a study by Kirk and Lewis (2016) that the use of gesture further increases when discussing content that is not easily conceptualized, such as a problem-solving. This holds true in the context of the Fair Share activity which was meant to challenge young children. Through the use of iconic gestures, caregivers helped children cognitively engage in the construction of this "complex information" (Alibali & Kita, 2010). This was prompted through the Fair Share activity; such as the facilitation of divergent paths of thinking (Kirk & Lewis, 2016).

*Pointing*

Children and caregivers in both conditions pointed to different illustrations, animations, and/or hotspot locations on the screen, drawing attention to them. Whether the pointing was mathematics related, such as pointing to the basket with three fish while saying "three", or whether the pointing was directed to objects on the screen that highlighted the actions of the characters, such as pointing to the bears as they walk to the river - these kinds of pointing occurred in both conditions.

However, pointing to illustrations and animations was recorded more while sharing the math eBook. Similar to iconic gestures, this finding was expected based on since more talk in general, and more mathematics related talk, in particular, was generated in one condition. Thus, the use of pointing gestures is usually synchronised to

simultaneous speech (Namy, Campbell & Tomasello, 2004); more talk typically is accompanied by more pointing.

Since hotspots in the math condition prompted the act of counting or dragging fish, pointing (and particularly mathematics-related pointing) was used seemed to help children and caregivers focus their own attention in order to keep track in the current study of counted objects, or in order to locate objects on the screen. Pointing then seemed to help the children keep track while counting and coordinate their tagging of counted items through one-to-one correspondence (Alibali & Dirusso, 1999). Pointing helped to track with the finger the act of moving the fish (the drag-and-drop hotspots) on the screen in order to share them among the bears. That was less likely to happen in the emotion-action condition that included different hotspots.

Alibali and Dirusso's (1999) ideas may explain observations from this study. Pointing while touching items to tag and track the counted items is more effective for counting accuracy than pointing without touching the items; or virtual items in the eBook context. Therefore, hotpots in the math eBook facilitated pointing while touching the screen because children needed to touch the screen in order to activate the hotpots. Even though activating the hotpots (i.e. epistemic and dynamic gestures) was not recorded in this study, it was apparent that these hotspots prompted pointing while counting, either before or after tapping the hotspots.

### 5.1.3. Engagement with the Fair Share activity

Findings showed a gap in the tendency to engage with the Fair Share activity when different hotspots were embedded within the activity. In the math eBook, the Fair Share activity included hotspots that allowed dragging and dropping the virtual fish from place to place to facilitate sharing them among the family members. After activating the hotspots, 15 out of 16 dyads that shared the math eBook generated spoken utterances and gestures that related to solving the Fair Share problem. Comparatively, the Fair Share activity in the emotion-action eBook included hotspots that activated audiovisual animations of bears saying "hello" as they entered their home and then the option of

dragging the brother bear into the scene. This eBook resulted in less engagement with the Fair Share activity among these dyads.

Differences across the condition in the dyads' tendency to discuss the Fair Share activity suggest that different content of the hotspots seems to account for differences in engagement with the embedded activities. When hotspots aligned with mathematics content, dyads were cued to engage in communication regarding the content prompted by the hotspots, especially for those hotspots that provided supplemental information to assist in problem-solving of how to share the fish.

In the math eBook, the drag and drop hotspots associated with the Fair Share activity visualized the action of dividing the fish. These hotspots seem to invite a range of diverse solutions and to facilitate multiple paths of mutual discussion about the Fair Share activity. Activation of drag-and-drop hotspots allowed flexibility such that the fish could be virtually held, dragged, and dropped indefinitely as the child facilitated sharing them.

Not only the content matters but also the pace of tapping the hotspots. The design allowed controlling the pace of activating the hotspots to be coordinated with the dyad's discussion. According to the segmentation principle from the CTML theory, breaking animations into shorter segments through allowing tapping the hotspots on the reader's pace reduces multimedia complexity. In the current study, this design feature seemed to help the caregivers and children to better manage working memory load through managing the attention shift from the script to the hotspots, and subsequently solving the mathematics problem.

Comparatively, sharing the emotion-action eBook resulted in extremely low engagement with the Fair Share activity. After activating the hotspots, only one out of the 16 dyads that shared this eBook engaged with the narrative regarding the activity. The other 15 dyads did not discuss the activity at all despite the explicit request in the script inviting them to help the main character share the fish. Following activating the emotion-action hotpots, they either responded by repeating the spoken word they heard or by reacting emotively and proceeding to the next page.

Aliagas and Margola (2015) noted a reduced engagement level in shared reading of interactive eBooks can be caused by particular content activated by a hotspot. In their research, they observed a child browsing pages quickly with the intent of reaching the hotspots that provided playful feedback. These hotspots led to a reduced engagement with the shared reading activity because the child was distracted from attending to the narrative. In their case, hotspots gave rise to the pursuit of entertaining aspects of the story rather than providing support for engaging with the shared reading activity. Their finding explains why most dyads in the present research, who shared the emotion-action eBook, skipped the Fair Share activity after tapping hotspots that directed their attention to the entertaining aspects of the eBook.

## 5.2. RQ 2: How does the alignment of hotspots with mathematics problem-solving activities in the story narrative affect the caregiver-child communication about mathematics?

In comparison to reading print storybooks with mathematics related content, eBooks seem to invite additional forms of communication in which caregivers and children utilize the design features within the eBook as a focussed frame of reference for joint attention and social exchange about mathematics activities.

Thematic analysis deepens the understanding of caregiver-child shared reading practices as they pertain to interactive features, particularly mathematics related hotspots. The themes, *scaffolding of mathematical ideas* of the caregiver, *knowledge* as well as *seeking self-discovery and agency* among the child, explicate the child-caregiver communication as they discussed the Strategic Counting and the Fair Share activities and, particularly, as they communicated around the associated hotspots. All of the themes point to the impact of the interplay between the hotspot and the eBook's narrative about the dyads' communication about mathematics.

The first theme refers to the caregiver's *scaffolding* the child's knowledge construction about mathematics**.** While sharing eBooks, caregivers practice their main role as agents for their children's meaning construction of the narrative (Kucirkova,

Messer, Sheehy, & Flewitt, 2013). eBooks present space for caregivers to utilize the hotspots presented in the eBook, allowing them to adjust their scaffolding role accordingly. In the context of the present study, this theme shows that a great part of interaction dynamics, specifically through scaffolding the child's interpretation of the problems is shaped by the mathematics related hotspots. The hotspots facilitated the caregiver's modeling for the child; utilizing these interactive features supported meaning-making of the mathematics problems. That was apparent in different examples, such as when one caregiver reinforced her son's mathematical thinking by affirming his response regarding the largest fish. Then she modeled further counting steps when the child was not sure about them by directing the child to tap the fish in the order of decreasing size.

The second theme refers to *co-construction of knowledge* as the child and the caregiver interact around the hotspots and jointly construct meaning about the activity. For instance, the interaction highlights how the caregiver and the child co-constructed actions around the hotspots that became routine as they continued using the hotspots to solve the mathematics problems. Strategically embedded hotspots in a problem-solving context can be used as a feature for fostering opportunities for the caregiver's and the child's co-construction of meaning when reading an eBook (Labbo, 2009). Indeed, the current study's findings showed that co-construction was facilitated by the mathematically linked hotspots. Co-constructing mathematics meaning was apparent in different examples, such as when the child was confused about sharing the fish, the caregiver asked a question that triggered attention and thinking of a child such as through pointing to one bear and asking which fish shall be dragged to this bear? That way, the caregiver interacted with the child through co-construction of the meaning of "sharing with" rather than scaffolding the child's knowledge construction or modeling to him.

The third theme refers to *seeking self-discovery and agency of the child*. The child's search for self-discovery and agency was a distinct form of interaction while attending the mathematics activities**,** especially around the interactive features (Aliagas & Margolla, 2015). Self-discovery and agency constitute the initiation of actions around the hotspots, and the progressive acquisition of autonomy around these hotspots. Activating hotspots in the math eBook revealed animations that led to solving the mathematics

problem. The hotspots aided in solving the mathematics problems by supporting the child's knowledge construction, especially when the child was not sure about the mathematics solution. In the Strategic Counting activity, the animations that resulted from tapping the hotspots led to correct answers. Namely, tapping the fish in the correct order only resulted in highlighting the fish and activating audio announcing the cumulative number of the fish. An example of the occurrence was when one child tried tapping the hotspots while not being sure about the next fish in order. In this case, the caregiver supported his/her child's self-discovery and agency to figure out the solution through the hotspots. To conclude, self-discovery and agency can be added to our understanding of how strategically embedded hotspots can promote children's agency for their own meaning construction in literacy practices such as shared reading of eBooks.

## 5.3. Caregivers' perceptions of the eBooks

Differences in caregivers' perceptions appeared to be influenced by features of the eBook they shared with the children. Caregivers who shared the math eBook reported more positive perceptions of the eBook than their counterparts who shared the emotion-action eBook. The gap was calculated from the *Caregiver eBook Satisfaction Questionnaire* (Appendix E). Caregivers indicated that the mathematics-related hotspots captured both their attention and their children's attention. Perceptions were rated higher than those of caregivers who shared the comparison eBook. Although hotspots in both eBooks were designed to draw the joint attention of caregiver and children to them by following principles from the CTML (Mayer, 2009), differences in the caregivers' perceptions were detected. These findings seem to be related to the level of engagement in the shared reading activity around the hotspots. Specifically, the dyads' higher rates of immediate responses to those hotspots in the math eBook compared to their counterparts may have shaped their perspective around the hotspots as attention-grabbing features to them and to their children.

The difference in caregivers' perceptions about the hotspot can be linked to another finding derived from the questionnaire, which is the perception about the influence of hotspots on their children's active role in the shared reading session. The

caregivers sharing the math eBook rated their children as more active than those that shared the other eBook. A relation between the level of engagement of caregivers in the shared reading activity of eBooks and their perception of their children's level of engagement was also detected in Cheng and Tsai (2014). They noted that parents who were actively engaged in the reading activity tended to perceive the shared eBook reading activity motivating and engaging for their children.

Moreover, caregivers who shared the math eBook reported it featured a strong mathematical presence, more than caregivers who read the comparison eBook. It can be deduced that hotspots play a substantial role in shaping the caregiver's perception about the main topic the eBook aims to deliver. To some extent, this finding confirms a work by Cheng (2017) that mothers tend to perceive the interactive features of an eBook as important when these features emphasize and elaborate on information delivered through the text.

The various findings from the questionnaire provide evidence for a potential association between dyadic level of communication (such as the amount of talk or gestures) and the perceptions that caregivers hold about eBooks. Caregivers who believed in the potential of eBooks to promote meaning-making about mathematics generated more communication and were more likely to help their children to physically engage with the hotspots activation. They may have also perceived that the activation of hotspots by children enhances the child's attention.

However, caregivers in the comparable condition were less likely to perceive the eBook as a tool to promote their children's understanding of mathematical content. This can partially explain why they discussed the mathematics content less often and were less likely to encourage the children to take the lead in activating hotspots. These findings shadow Cheng and Tsai's (2016), who detected a positive relationship between the parent's beliefs concerning eBooks, and their resulting behaviors during the shared reading activities. Cheng and Tsai found that parents who were concerned eBooks may decrease their children's involvement with shared reading practices tended to communicate less often during the reading activity.

This study also took steps toward investigating a possible association between the facilitative roles of hotspots strategically aligned with narrative (i.e., the mathematics targeted hotspots) and the way caregivers perceived them as an affordance or challenge to their children's participation and attention.

## 5.4. Conclusion

The salience of mathematics ideas presented through the eBook narrative provides foundations for the discussion and engagement about mathematics through shared reading practices. However, multimedia features and ways they are used also influence whether attention is focussed on specific components about mathematics or broad components of the narrative. eBooks that draw attention to the eBook mathematics-related content appear to be more conducive to supporting meaning-construction of mathematics.

The ways in which hotspots are designed, in turn, seem to influence how communications were enacted and who responded, child or caregiver. The nature of discussion elicited during the shared reading activity in this study supports the claim that hotspots emphasizing main mathematics themes in the eBook, and also support understanding the storyline can support joint attention and meaning construction about those mathematics-related themes. Shared access to knowledge afforded by hotspots seemed to prompt caregivers to scaffold discussion about mathematics through cognitively demanding questions.

The placement of hotspots can shape engagement within the shared reading activity. When the mathematics hotspots were strategically embedded in eBook mathematics activities, they tended to prompt diverse forms of involvement about these activities. For instance, the caregiver provided a constructive base for the child's understanding of the mathematics activities; and also engaged in the co-construction of mathematics meanings. Moreover, these hotspots shaped the caregiver's perception about the eBook as a medium for shared reading. Caregivers believed hotspots increased

narrative clarity about mathematics, encouraged active child participation, and worked to create a more favorable impression for both the child and the caregiver.

## 5.5. Limitations

The eBook design poses a challenge in relation to the cognitive theory of multimedia learning (CTML). Despite the CTML's prevalence in multimedia instructional designs, the theory lacks support from empirical evidence relating to its efficacy in designing eBooks to facilitate supportive shared reading with children. There is increasing interest among researchers to examine the validity of the CTML among young participants (Plass, Heidig, Hayward, Homer & Um, 2014).

The selection of two equivalent groups was key to contrasting eBook conditions. However, since only those interested participated, the selection was not completely random. Caregivers interested in shared reading activities might be more predisposed to participate. Moreover, heterogeneity across participants may have sampled traits (such as cultural differences or different shared reading habits) that remained unexamined in the study and which may have unknown interactive effects, such as arising from the caregivers' pre-existing reading habits.

Regarding the procedure, one-time exposure to the eBook revealed a great deal about the impact of hotspots on dyads' communications during shared reading. Yet, the single reading session represents a further limitation. Previous studies show that repeated reading of the same storybook yields different patterns of communication over time (e.g., McDonnell, Friel-Patti, & Rollins, 2003). Also, repeated exposure to the same eBook can help children understand the novelty of the multimedia features and pay more attention to the story narrative (Rvachew, Rees, Carolan & Nadig, 2017).

The analysis of the video data could be extended to include a more nuanced description of social interaction. For example, considering that this study was driven by socio-cognitive theories, the analytic perspective focuses weakly on the reciprocal interaction between the caregiver and the child around question asking. For instance, the

data related to caregiver's questioning but not to how the child responded to the caregiver's questions.

Lastly, a generalization of findings is limited. Although children were selected from an expanded catchment area to create a representative sample, the scope of generalizing research findings to other populations is limited. For instance, selected children obtained at least an average score for their age group on the standardized vocabulary test; thus, generalizing the findings to children with lower linguistic skills may be limited. The single eBook used in this research further limits generalizing findings. The eBooks in this study were designed exclusively for the research and were enriched with supplemental hotspots for targeted testing. Therefore, results may not generalize to other eBooks these children may read with their caregivers at home (Smeet & Bus, 2012).

## 5.6. Implications

Findings from this research raise implications for future designs for eBooks. The research points to the impact of the eBook design to foster discussions between caregivers and children in shared reading activities. Moreover, eBook features used in the current study appeared to prompt the children's participation in discussions and in operating the interactive features of the eBook. These findings may encourage specialists to increase awareness among caregivers about selection criteria for choosing eBooks and to develop strategies that balance attention between the child and the eBook in order to maximize participation in the shared reading activity.

Additionally, the design process behind the production of the eBooks illustrates the importance of collaborative work between educators and eBook designers. Successful collaborations can inform thoughtful and functional eBook designs at every stage of the construction procedure (Roskos & Brueck, 2009). eBooks need to support children's developing literacy by integrating educational components and presenting these in an engaging manner to enhance enjoyment and increase motivation and related discussions (Roskos & Brueck, 2009).

Findings from this research also open new avenues for research. Due to the widespread use of eBooks and some caregivers' interest in finding ways to efficiently utilize these resources with their children in the home setting (Labbo, 2009), there is a need for extended research in this area. The existing literature in this field is limited, and, as such, there is a lack of evidence regarding how levels of interactivity in eBooks impact how children and caregivers engage in the shared reading activity and construct meaning from eBooks during shared reading. Quantitative and qualitative studies are needed to develop more nuanced findings around how and which features of eBook designs elicit more productive and/or more enjoyable shared reading experiences.

Longitudinal studies involving repeated exposures to the same eBook should be undertaken to assess the efficiency of eBook content and design. Repeated reading should provide insights into how the communication around the eBook and discussion change over time or support children's linguistics and cognitive development. These kinds of research will mitigate the threat to validity caused by one-time or minimal exposure to the same eBook (Liu et al. 2013), as in the current study.

The caregiver's and child's propensity to effectively engage in shared eBook reading can be related to the literacy skills of the child, previous experience with the eBooks, gender differences and motivation (Kucirkova et al., 2013). These factors should be added to future research agendas. The pursuit of these further research ideas will have a positive impact on eBook design, encouraging the creation of thoughtful eBooks for children with a wide variety of needs, capabilities, and interests; thus, making child-caregiver shared eBook reading an enjoyable bonding mutual activity.

Finally, with an increased media focus on excessive screen time, caregivers who lack confidence in working with eBooks are given further reason to refrain from using eBooks as a shared reading tool. It is hoped that this research will provide caregivers with a means to choose to use technology with their child with confidence. If technology is to be an increasing part of the lives of children, providing caregivers with considered recommendations of eBook designs can help them navigate technology productively with their children.

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## Appendix A. Story Script of *Let's Catch More Fish*

| Page number | Script |
|---|---|
| 1 | _____[8] is a little bear who lives by the river. |
| 2 | _____ likes to catch fish in the river.<br>One day, her father said to her, "Let's go fishing." |
| 3 | _____ was very happy! |
| 4 | _____ and her father walked to the river. |
| 5 | "I hope we catch some fish."<br>_____ responded excitedly to her father, "I hope we catch 3 fish!" |
| 6 | "Why 3 fish?" her father asked.<br>"Because I am 3 years old." |
| 7 | They waited and waited. |
| 8 | Suddenly, _____ felt something light tug on her pole. "Oh no! It's a boot." |
| 9 | Again, she felt something heavy tug on her pole. "Oh no! It's a chair". |

[8] The child and the caregiver chose a name and typed it before sharing the eBooks.

10 _____ and her father waited some more.

Finally, _____'s father asked, "Why don't you sing a song for the fish?"

11 _____ sang,

"1, 2, 3, 4. I wait and wait and wait some more.

One or two fish is all I ask for."

12 _____ felt something tug on her pole.

It's a fish! The fish is big and blue.

13 "Let's count! How many fish?"

14 "Why not sing a song for the fish again?" _____'s father asked.

"1, 2, 3, 4. I wait and wait and wait some more.

One or two fish is all I ask for."

15 _____ felt something tug on her pole.

"It's a fish! This fish is small and pink."

16 "Let's count! How many fish?"

"Let's sing a song for the fish again!" exclaimed _____.

"1, 2, 3, 4. I wait and wait and wait some more.

One or two fish is all I ask for."

17 _____ felt something tug on her pole.

| | |
|---|---|
| | "It's a fish! This fish is enormous and yellow!" |
| 18 | "Let's count! How many fish?" |
| 19 | Finally, _____'s father felt something tug on his pole.<br>"It's a fish. This fish is tiny and green." |
| 20 | "Let's count! How many fish?" |
| 21 | Dad said to _____, "My fish is so small, let's put it back in the river. It needs to grow some more." |
| 22 | "Let's count again!"<br>"1, 2, 3, just like me!" |
| 23 | "Let's go home," _____ said to her father. |
| 24 | "Hi, mom. Look at the fish!<br>One for you, one for dad and one for me. There are three, just like me." |
| 25 | Here is my brother.<br>How are we going to share them now? |

# Appendix B. eBook Construction

In this appendix, the process of eBook construction is discussed in five phases: writing the story narrative; highlighting mathematics concepts in the narrative and illustrations; storyboarding; illustrating, and programming the eBook. A flowchart for each phase of the process is summarized in five figures. Each phase is independent, yet the phases could occur simultaneously in the production process. More detailed descriptions of each phase in this process follows.

## First Phase: Writing the Story Narrative

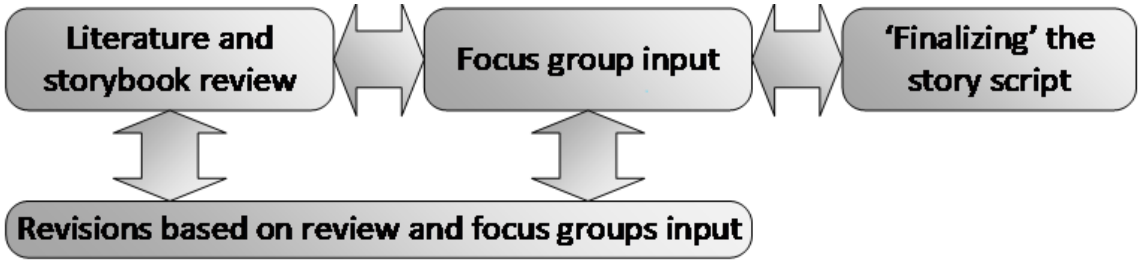


**Figure B-1. First phase: Writing the story narrative.**

### Storybook review.

As discussed at length in Chapter 2, a review of the literature on the art of storytelling for children was conducted. Key findings were applied in the story *Let's Catch More Fish* (Appendix A) by: following a simple narrative structure including exposition, rising actions, climax, falling actions and denouement; choosing the main character as little personified animal, bringing themes young children can find engaging; writing in a third-person narration; controlling the vocabulary and syntax to be familiar to young children; and incorporating repetitions of vocabulary.

As part of the consultative process, a review of children's storybooks was also conducted to determine the genres, the topics of interest, and the language common in present-day children's literature. A brief summary of findings from the storybook review is presented here.

***Genres.***

The corpus of random storybooks reviewed here found the books were typically written using a narrative genre. These storybooks included adventures, fairy tales, general fiction, and interests and activities relating to young children. Expository storybooks, including concept and science books, were also used; poetry books were rare in the reviewed collection.

***Topics of interest.***

Recurring topics in children's storybooks were diverse and revolved around young children. Topics included but were not limited to: family, daily activities, feelings, manners, friendship, pets, growing up, the alphabet, and counting. Some stories revolve around a central character – young children and personified animals are most common – that children are fascinated with, such as dogs, cats, bears or dinosaurs. A limited number of storybooks reviewed contained personified numbers or shapes, the exception being stories written for the purpose of introducing number or shape content.

The integration of activities or riddles in the storybooks was rare. Rather than using the activities as an integral portion of the narrative, activities were mainly added to margins or added after the end of the story.

***Language.***

The storybook narratives found in the review were typically constructed from a single main clause (e.g., I see) or the main clause with a sentential complement (e.g., “I see a yellow duck looking at me”) and included action verbs rather than static verbs. The use of repetitive sentence structures and repetitive vocabulary was common in the children’s storybooks collection.

The first draft of the story narrative was written using this information, combined with the information available from the literature review in Chapter 2. The story was then distributed to members of a focus group for further discussion and input regarding whether the book was engaging; whether the topic, characters, plot and/or setting would

appeal to a young audience; and whether the vocabulary and/or syntactical structures were age-appropriate.

## Focus group input

The main focus group at this phase consisted of early childhood educators. The meetings aimed to discuss in greater depth how the findings of the literature and storybook review informed the construction of the story for the eBooks

### *Story topic*

To maintain interest and engagement, children must be able to identify with the story topic. The focus group agreed that children would be able to connect and understand the topic of fishing. The activity of fishing and sharing the fish later with the family members was agreeable among the group members to foster two themes among the participating children: a sense of belonging and respecting the environment.

### *Sense* of *belonging*

I noted that children within the target age range in the region of Canada where the research was conducted seemed to enjoy fishing as a common activity. Children in this region of Canada have a wide range of activities that engage them with watching fish in the rivers during hatchery season; having tours where they watch people fishing in the rivers; and taking part in fishing derbies where they try fishing themselves with their families. Based on these reasons, the discussants agreed that the fishing activity can promote a sense of belonging to their cultural group among the participating children.

### *Respecting the environment*

The story included instances where respecting the environment was highlighted. When the little bear and her father caught two small fish at the same time, they decided to release both fish because they were still small and they wanted to sustain the fish

population in the river. Also, they were pleased with three fish that were sufficient to feed the family.

### Identifying with the main character

The focus group agreed that the lead character should be someone with whom young children can identify. Since findings from the literature review showed that children prefer faces of animals (Kellert, 1985); and children books often use animals as lead characters, the lead character in the present eBook was chosen to be an anthropomorphized bear.

## Vocabulary

Since the story was written specifically for this study's target group of preschoolers, the language of the storybook script was controlled to ensure that vocabulary and conceptual knowledge was routine and familiar to typically developing children at this age. However, members of the focus group encouraged the develop to adjust parts of the narrative to make it more accessible to young children. They suggested that some sentences need to be more focussed on the actions of the story and to eliminate details that may be redundant to the narrative.

Discussions with the focus group members were efficient for choosing actions verbs and figurative adjectives to make the story more appealing for the young children that will take part in this study.

Focus group members discussed the importance of using language structures that were familiar to the child in promoting caregiver-child social interaction in shared reading practices. For example, they discussed how the use of mathematical language or novel vocabulary in the context of a common sentence pattern allows the child to make predictions about the meaning of the vocabulary and therefore, both the child and adult can contribute to discussion and construction of meanings.

## Simplifying the syntactical structure

It was suggested that a simple noun-verb phrase structure may be easier for young children to comprehend. The children use this format to communicate, and thus the reading would be more familiar to them. For example, the sentence "(the main character) and her father walked to the river singing their favorite songs" in the first draft was adapted to " (the main character) and her father walked to the river" in the second draft.

Furthermore, the group suggested that multiple perspectives and/or interpretations could arise from the use of syntactically familiar structures and illustrations. For example, the more explicit sentence: "She was very happy and hurried to find the fishing poles" was replaced with a more ambiguous sentence "She was very happy" which was coupled with the illustration of the main character searching for fishing poles. The ambiguity serves as a prompt for caregiver-child discussion to establish why the child was happy.

## Adding humour

Focus group members pointed out that children at a young age like funny things. One discussant noted that children like fishing and catching funny things instead of a fish, or catching fish with funny colors (e.g. dotted polka fish).

According to Klein, (1992):

> Humour plays an important role in alleviating stress and supporting children's emotional, social and cognitive development. What better format for humour than children's literature! Through illustration and amusing tales, humorous storybooks give children a dual message: life is not as complicated as it seems and learning is fun. (p. 213).

In response to focus group input, changes to the script included the following: action verbs were used more frequently; syntax of the text was controlled so that children would be familiar with the use of these structures; greater use of repetitive syntax and vocabulary led to predictable language patterns in the song and text; humour was embedded in the story by adding events that were surprising and unexpected (e.g., rather than catch a fish, the child first catches a boot and a broken chair and rather than the

father catching the large fish, the child catches the fish); a personal attachment was created in that to the main character, the child was permitted to name the main character before starting the activity of reading the eBook.

## Second Phase: Infusing Mathematical Content

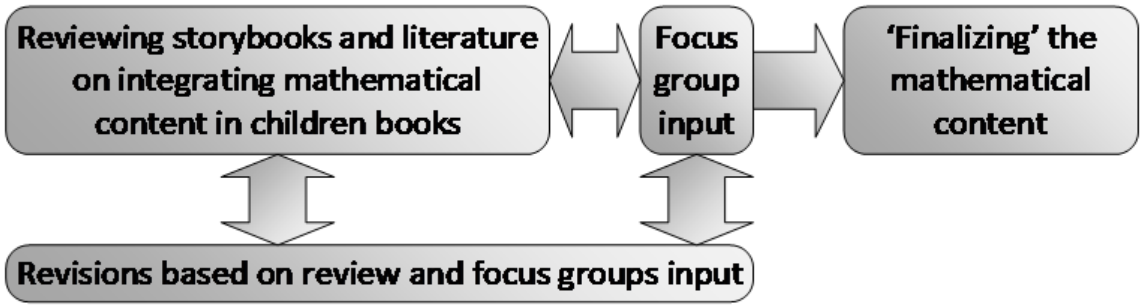


**Figure B-2. Second phase: Infusing mathematical content.**

### Reviewing storybooks and literature on integrating mathematics in storybooks.

An examination of research-based literature concerning the importance of mathematical integration in children's storybooks (see Chapter 1) and a review of the literature on the art of integrating mathematics in storybooks (see Chapter 2) were conducted. As part of the consultative focus group process, an informal review of children's books was performed.

Members of the focus groups (the early childhood educators and three mother-child dyads) discussed the mathematical content of the story as it is presented in the narrative text, particularly with respect to the adequacy of the mathematical content for children in the targeted age range, or whether the presentation of mathematics content was appealing to children. They discussed, based on their own experiences, how they would expect children between the ages of three and four years to interact with the mathematical language incorporated.

The members in the focus groups also discussed whether the mathematics problem solving and reasoning was challenging, but not cognitively overwhelming for the child or the caregiver. They also suggested alternative ways mathematic concepts

could be emphasized in the narrative. The following topics were discussed, and resulted in modifications:

## Focus group input.

### *Adding an array of mathematics content*

The initial draft of the story included the actions of adding up one fish that the single bear catches or two fish that the two bears catch at the same time, and adding them to what they already have. The story also included the actions of subtracting one or two fish from small groups (up to five fish) through the act of losing the fish immediately after catching them, or by releasing them back in the water. The first draft of the storybook included a total of eight actions of this kind.

Some members of the focus groups suggested that the repeated action of catching and releasing fish created multiple opportunities to engage with mathematics. The discussants later agreed that rather than repeatedly catching and releasing fish, the addition of actions representing diversity in mathematics would be helpful and encourage dyads to engage in different communication about other mathematics concepts. One idea was to incorporate the concept of measurement (size) into the story, specifically using adjectives to highlight variation in fish-size (e.g. small or enormous).

The discussants acknowledged that caregivers would likely initiate a conversation about mathematics in response to explicit cues that aligned with mathematics content. One suggestion was to use morpheme variants of words to demonstrate size comparisons between fish as in “This fish is pink and smaller”.

### *Stimulating mathematical thinking*

The initial draft also included the act of dividing three fish among three family members. The focus group members suggested that mathematical thinking should be more complex and cognitively demanding than was present in the first draft of the story. Specifically, rather than encouraging the children to solve a problem that had involved one-to-one correspondence (e.g., giving one fish to each family member) they suggested

encouraging more divergent forms of thinking and communication around sharing the fish. Sharing six fish with the family members was one suggestion.

On the one hand, the discussants agreed that the mathematics content should be challenging for children. However, they also suggested preventing any potential frustration for children (or the caregivers) that could arise if the problem to be solved was not explicit. A decision was made to revise the original script from a situation where three fish were divided among three family members (the little bear, the mother and the father), to a scenario in which the three fish divided among four family members (the little bear, the mother, the father, and the brother, who had unexpectedly entered the room).

Another suggestion involved having the child guess how many more fish were needed in order to reach a specific number. The discussants agreed that this sort of modification would not only increase child interest in the story but also encourage caregiver-child discussions about multiple paths to problem-solving. The original script was revised from a question of how many more fish were needed in order to catch a total of three fish, to a script including additional scenes that invited the dyads to make a guess after catching one fish.

To prompt more mathematics discussion, actions were included where two tiny fish that the bear and her father caught were dragged to and concealed in a basket, then the child was prompted to guess the total number of the fish inside the basket (two concealed fish and three visible fish).

***Personalizing the Fair Share activity***

Piloting the eBook with its current script showed concerns regarding the way the three mother-child dyads attended to the Fair Share activity. Two mothers skipped the Fair Share activity by reading the script without referring to the problem and later explaining that the activity might be hard for the children. The third caregiver tried to explain a potential solution for the same division problem; her child tended not to react to the mother's efforts to engage her. Since two dyads did not attend to the activity at all,

my concern was that the script was not sufficient to encourage communication about this activity.

Members of the focus group agreed that adding a direct question to narrative text; “Can you help (the main character) with sharing the fish?” in alignment to the Fair Share activity should encourage attending to the activity by the participants. They agreed that posing questions to the child within the shared reading practice is a recommended way to increase the child’s interest in the story and as a result increase social-interactions around mathematics ideas.

Using the word “you” in the question is a form of personalizing the request. According to the Personalization principle suggested in the Cognitive Load Theory (Sweller, 1988), personalized content is likely to increase attention more than the non-personalized content.

Revisions based on review and focus groups input included: adding greater diversity in mathematics content by incorporating an additional concept of measurement to the story narrative; stimulating mathematical thinking and caregiver-child social interaction about mathematics through adding scenes that require making some guesses and counting fish in the order of decreasing size; revising the Fair Share activity to include four family members instead of three that will share a total of three fish; personalizing the Fair Share activity through adding a question to the narrative “Can you help (main character) with sharing the fish?”.

## Third Phase: Storyboarding

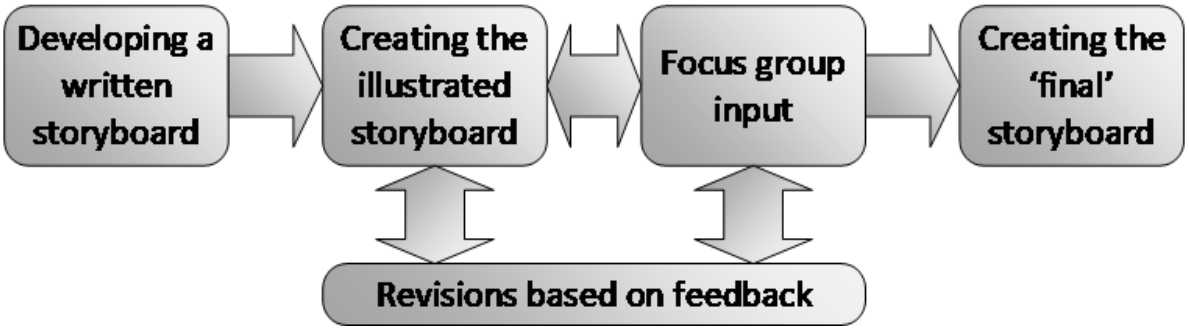


**Figure B-3. Third phase: Storyboarding.**

"Storyboarding is not just a translation of the script into a series of visual images. It is more like a new rewrite of the story now using the flow of images to show instead of words that tell" (Glebas, 2009, p. 72).

The storyboard was the initial outline of the sequence of the visuals in the story put together in the script sequence. It allowed me to track the progression of the story, and think about the placement of the object on the page layout with the corresponding script (Taylor, 2008).

The storyboard was written before meeting with the illustrator. It was later recreated in collaboration with the illustrator. Simultaneously, the storyboard was discussed with participants during the routine discussions.

In developing the storyboard, transparency between the script and the corresponding illustrations (sketches and stick figures at this stage!) were portrayed in two ways: first, the illustrations fully portrayed the narrative script. Second, the illustrations extended the textual meaning by adding more details that were not literally portrayed in the narrative script. These techniques were essential to blur gaps between contextualized and de-contextualized meaning. For example, in one scene, my plan was to illustrate the little bear raising three fingers as she talks about her desire to catch three fish. However, the act of holding up three fingers was not portrayed in the text. Similarly, in most of the scenes, the characters' emotions were eliminated from the narrative text of the story but were displayed in the static or animated illustrations.

Regardless of which way was used to match the illustration with the script, managing cognitive load was always considered. Storyboarding starts with breaking down the script into small units (Glebas, 2009); and in my case presenting one or two actions on one scene was chosen. Actions were presented in small chunks as an application of simplifying the eBook structure and managing cognitive load of the content.

Here is one example of a written text with a storyboard that resembles it.

- Background: The river and the big rock the bears are sitting on.
- Characters: The little bear and her father.
- Actions: They are sitting on the rock; each one is holding a fishing pole.
- Animations (in a temporal sequence):
    - The surface of the water moves around the hook.
    - The pole bends a bit.
    - The little bear smiles.
    - The father shows excitement.

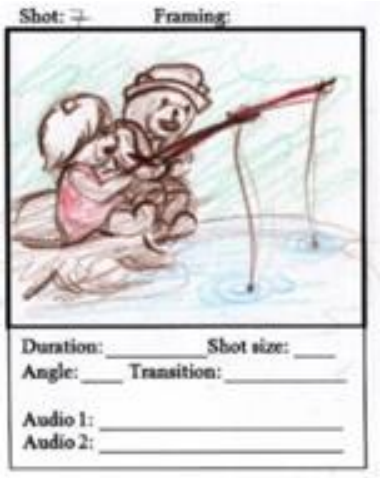


**Figure B-4. An example of a storyboard (animated scene).**

The illustrated storyboard was created in collaboration with the illustrator. Finding a qualified graphic illustrator was challenging because of the special requirements the project dictated. The requirements included: previous experience with children's paintings, long-term commitment to the eBook project, being accepting and

patient throughout the progressive process of revisions and accepting to work on a limited budget.

## Creating the storyboard with abstract figures

The idea of creating three different backgrounds or settings: the living room, the river and its surroundings, and at the outdoor of bear's family house was discussed with the illustrator. The characters' actions and how these actions fit in the different backgrounds were also considered and created.

Discussions with the illustrator were driven by the written description (and some sketches) of the storyboard. The storyboard was discussed in detail, and then the structure was co-constructed. The illustrator created examples for each scene (see Figure B-5 as an example).

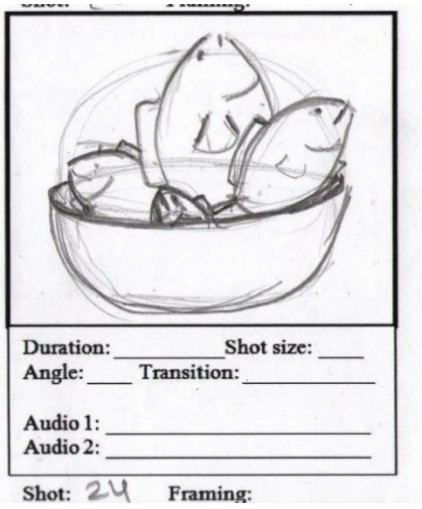


**Figure B-5. An example of the storyboard scribbled in a meeting with the illustrator.**

The illustrator contributed her professional experience. For example, she recommended an alternative way of illustrating the scene of the little bear opening the shed and finding the fishing poles. The written and sketched storyboard initially prepared suggested showing the little bear's back and the inner of the shed to present the fishing tools inside it. The position that the illustrator suggested was more expressive. It showed

the bear's facial expressions and the items inside the shed at the same moment as the viewer was capturing the view from inside the shed (see Figure B-6).

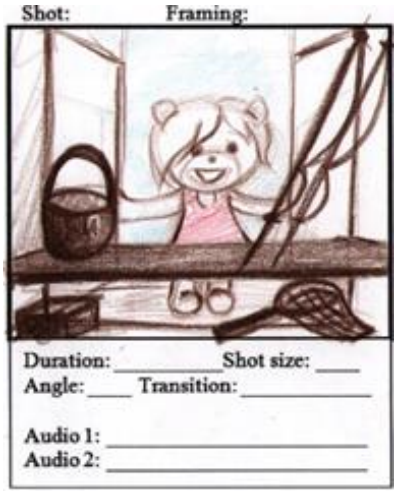


**Figure B-6. A scene taken from the final storyboard.**

Additional meetings and email messages were exchanged with the illustrator. Upon that, we focussed on detailed increments of the storyboard.

## Use of Multimedia Cognitive Load Theory.

Principles from Multimedia Cognitive Load Theory (see Chapter 1 and 2) guided the design of hotspots, the illustrations and the deletion of extraneous details unimportant to the main content. Discussion focussed on backgrounds and the number of details portrayed in them. When a background was not necessary or conflicted with the main content, we decided to have a blank background, such as in the scene with the script "*one day her father said to her: let's go fishing*." That scene depicted the bears with an empty background.

Figure B-7 presents two examples of initial backgrounds. All of the backgrounds were simplified. We agreed that eliminating some of the details, such as the trees in the background would simplify the setting and decrease distractions for the young children sharing the story with their caregivers.

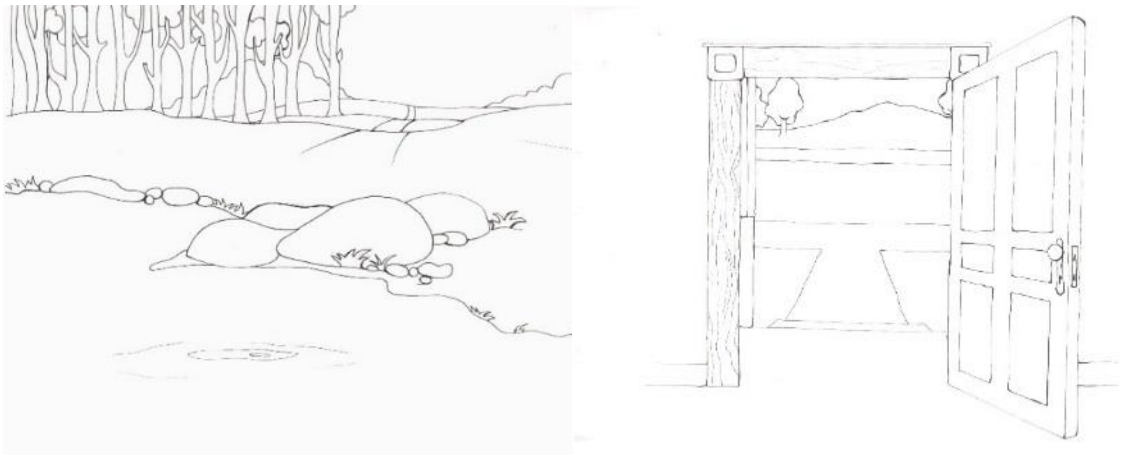

**Figure B-7. Examples of backgrounds (with unnecessary details) taken from the initial storyboard**

## Focus group input

Creating the initial storyboard using abstract figures, along with the written description of the storyboard, were important for eliciting early feedback; this also encouraged quick subsequent revisions with the discussants. Improving pictorial-textual flow and managing the cognitive load of the pictures and the text in each shot were the focal points of the discussions.

In discussing the initial storyboard with some group members, they noticed scenes where the images and scripts were not fully comparable and suggested rethinking them. After further conversations, it was agreed to integrate slight changes for a better overall pictorial-textual flow. For example, in the first scene – in which the little bear and her mother sitting in the living room - there was a visible background of the river through the large window. This image was associated with the following script: "(the main character) was a little bear. (Main character) likes to catch fish in the river." In further discussion, it was agreed to modify the script to the following: "(the main character) was a little bear who lives by the river." The line "she likes to catch fish in the river," was moved to the next scene.

Members of the focus groups encouraged emphasizing content that needs to stand out to assist the reader to pay attention to it – namely mathematics related content. For

example, one discussion was regarding emphasizing the measurement concept by illustrating the fish so that the size differences become very distinctive.

Another idea was magnifying the little bear's fingers to draw attention to counting (Figure B-8 demonstrates this modification in the storyboard). Additional modifications were added such as illustrating the three fingers in the separate page; as described in a sample taken from the final storyboard (see Figure B-8).

Features that were agreed upon as being not essential and probably distractive to the mathematics content were deleted. One example of details that were deleted was a scene with other bears fishing near the river.

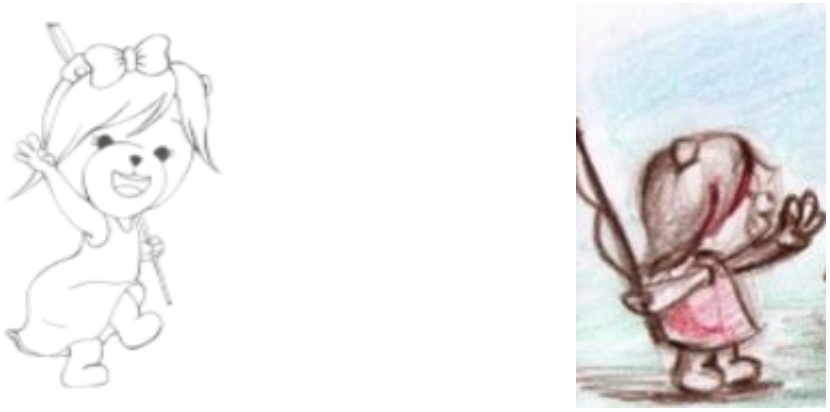

**Figure B-8. Samples taken from one of the initial storyboards (left) and from the final storyboard (right).**


**Figure B-9. Samples taken from the final storyboard.**

Revisions based on feedback from the illustrator and the focus groups included: re-arranging some shots and modifying some scripts in order to improve the pictorial-textual flow of the content; managing cognitive load of the content and increasing attention to the mathematics content by minimizing details in the illustrations and deleting extraneous details that are not related to mathematics and magnifying some mathematics related illustrations in order to increase attention to them.

## Fourth Phase: Illustrating

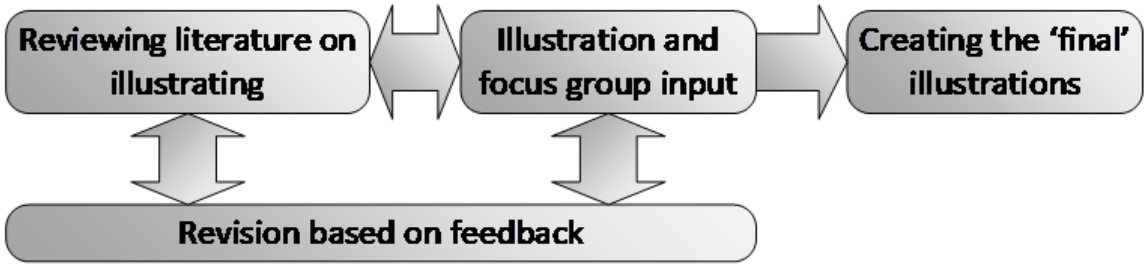


**Figure B-10. Fourth phase: Illustrating**

### Reviewing literature on illustrating

Pictorial representations of the narrative are essential for engaging children in storybook reading, and in enhancing their attention (Van den Heuvel-Panhuizen & Van den Boogaard 2008; Strouse & Nyhout & Ganea, 2018). In the process of developing the present eBooks, images were continually adjusted or alternated to meet the theoretical standards that guide constructing storybooks with a potential to draw children's attention to mathematical principles in the story.

Even though the illustrator naturally used her personal style, there was an effort to maintain standards, suggested in the referenced literature. Theoretical guidelines regarding details and use of colours were presented and discussed with the illustrator. One foundation agreed upon was clear facial features of the fish - as a way to increase attention to them - since most of the mathematics actions revolved around the fish in the story. Also, the use of saturated colours was consistent with the literature as being appealing to preschoolers (Painter, 2008).

Reviewing the literature did not stop once the illustrator started painting the storybook. Additional review was done when decisions about illustrating or colouring were controversial.

## Illustration and focus group input

### *Engaging children in the story*

Illustrating the images aimed to meet young children's preferences. Engaging children refers to increasing their attraction and attention to the story.

### *Illustrating the bears*

Sketching started with the lead character - the little-anthropomorphized bear (in Chapter 2, the choice of a bear is explained). At the early stages, the illustrator created a few sketches to choose from. Two "virtual" friends of the author that both work to promote children's books were consulted for their professional opinions. Each recommended a different sketch. The first friend recommended sketch number one (see Figure B-11); she explained that in children books, big eyes symbolize friendly and delightful characters, while small eyes symbolize evil characters. The second friend chose sketch number four as the most appropriate sketch; she explained that the round and infantile facial features could be more appealing to children at a young age.

Simultaneously, a resource that explained the "minimalist style" in young children's illustrations (Painter, Clare, Martin & Len, 2013) came to light. The shapes of characters heads, and eyes, were an example of the author's recommendation of the minimalist style; the style suggests using ovals or circles to illustrate the heads, and small circles or even dots to stand for the eyes. Based on minimalist style, and in alignment with a suggestion made by one of the "virtual" friends, the fourth option – that of Figure B-11 - was confirmed as the most applicable sketch of the little-personified bear. The same style was used to illustrate the other characters in the eBook.

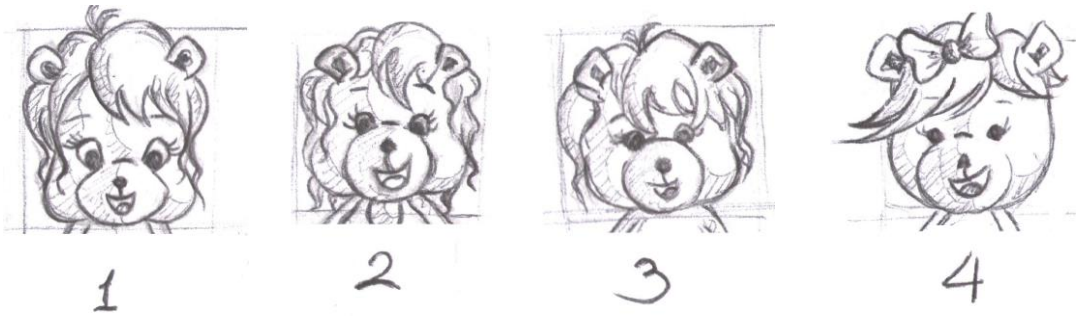


**Figure B-11. Different sketches of the little-anthropomorphized bear.**

***Illustrating the fish.***

Since almost all of the mathematics actions in the story revolved around fish, it was important to illustrate them to draw the attention of the children (and the caregivers) as they share the eBook. Several samples of painting the fish were presented by the illustrator. The different samples were discussed with participants during the routine discussion. A decision was made to choose the one with the happy facial expression. They mentioned that the very big smile on the fish's face will definitely attract the children.

***Colouring the images.***

Setting the atmosphere, the tone, the emotions, and the familiarity depicted in the storybook were significantly determined by the colours (Painter 2008). Discussion in the focus groups revealed some ideational constituents regarding colours. Concerning the general use of colouring style in the eBook; participants in a focus group pointed to instances where bold colour should be used, and how they could become notable within a natural and calm background - such as the background of the river. Another idea was about using bright colours to make illustrations bright that young children can pay attention to them.

The different perspectives about colours were taken into consideration. Primary colour - especially nature colours such as red, blue, yellow, and green- and bold colours such as pink and orange, all served different purposes in the eBook. Aqua hues were used for the sky or any other empty background. Green and blue were also dominant in the backgrounds. The choices for using these colours (aqua, green and blue) aimed to create a

gentle feeling among children; those natural colours are all classified as tones that work to create a pleasant atmosphere. Other objects, such as the hair colours of the personified bear and her mother, were chosen to be bright, attractive and unusual (blue and purple); this, in turn, was through to increase children's attraction to them. The fish in the story were all painted in bold colours such as pink, orange, and yellow. Bold colours were exclusively used for painting the fish, to increase the child's attention when the fish comes out of the water.

The images in the eBook were filled with crayon-based colours, as opposed to typical homogenous colours seen in most cartoons. The illustrator suggested that crayons were ideal for painting with saturated colours; saturated colours that appeal to preschoolers (Painter, 2008). Crayon colours are also ideal for painting different hues of the same colour, as recommended to increase familiarity with the pictures. Below are two figures with different colouring styles. The first (Figure B-12) was suggested before finalizing the storyboard or colour style, while the second (Figure B-13) was taken from the final eBook.

**Figure B-12. An example of colouring style that was suggested by the illustrator in the early stages of illustrating the eBook**

**Figure B-13. The final colouring style.**

In response to focus group feedback, the following revisions were made: drawing the bear characters with infantile face and minimal details; drawing the fish with obvious facial expressions to increase attention to them; using crayons to paint the eBook for saturated natural and bold colours.

## Fifth Phase: Programming

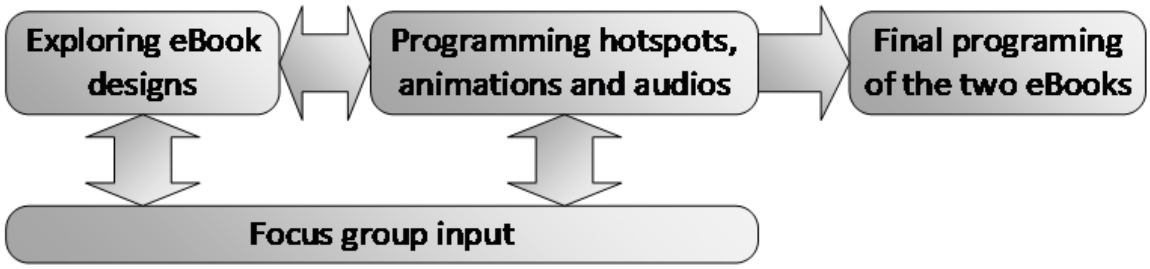


**Figure B-14. Fifth phase: programming.**

### Exploring eBook Designs

An analysis of eBooks was conducted as a primary vector for the present research. The analysis aimed to explore hotspots of different young children's eBooks with mathematics related content. The analysis helped grow an idea about the design-content interface of 30 eBooks - that contain early mathematical concepts. The main finding was

that, although the majority of the eBooks included hotspots, the hotspots' congruence with mathematics content - whether it was in the text or the pictures- was not sufficient. Specifically, congruence between the narrative and content activated by the hotspot was found only in less than half of the total hotspots. Even when this congruence existed, it was not a general trend seen in all the hotspots within the same eBook. Most of the hotspots in the eBook activated content that was not related to the narrative; in many cases, they were not aligned with the content.

This preliminary analysis had important implications for the design of the two eBooks. Compensation for design gaps in the eBooks in those studies relied on design features that were adopted from the Cognitive Theory of Multimedia Learning (CTML). For example, the aim of the eBooks design was to facilitate attention to the story narrative and to avoid the inclusion of distracting features that could potentially compete with this focussed attention. Also, in both eBooks all the results of activating the hotspots were congruent with the narrative; either with the mathematics operations in one eBook (i.e. in the math condition), and with the emotions and actions of the characters in the second eBook (i.e. the emotion-action condition).

## Programming Animations, Audios and Hotspots.

The work with the programmers was conducted through directness and clear instruction. For instance, the programmer was provided with two files of detailed instruction - one for each eBook. Each file included precise written descriptions of all the features that were to be programmed. Those features were of three sorts:

### *Automatic animations*

There were two types of embedded animated scenes. Those that were automatic, meaning activated automatically and those that were the same in both eBooks. The second type was animations that can be activated as a result of tapping a hotspot. Those were different across the two eBooks but balanced in number and function. Instructions given to the programmer were mainly around the locations of the animations within the eBook designs.

### *Audios*

Different audio files were sent to the programmer to be embedded. The sounds included audio recordings of numbers, background effects (such as chirping birds, musical background, or a sound of opening a door), and human expressions. The audios were sent to the programmer along with explanations detailing the way audios should be linked to hotspots or animation and the duration each sound effect should have once it was activated. This was emphasized when the sound effect was continuous, such as in the musical backgrounds, or the chirping birds in once scene in the background.

### *Hotspots*

The files included details of an image map of each hotspot, hence, the area that was clickable on the images and the result of each activation. Those were different across the two eBooks. The files sent to the programmer included descriptions of a total of 46 hotspots in each eBook. Two major considerations guided programming the hotspots, the audios and the animations: adhering to the principles of CTML in both eBooks and activating either mathematical content (for the eBook in the math condition) or emotional content (for the eBook in the emotion-action condition).

### *The multimedia principle*

The multimedia principle acted as the overarching and informing principle when creating hotspots that activated information in auditory, visual and haptic modalities in both eBooks. As the children heard the text narrated by their caregiver, hotspots activated audios and animations that either contained identical or complimentary information. In both eBooks the narrative text “they waited and waited” was associated with the images of the bears sitting on the tree trunk, waiting for their fishing hooks to move. The automatic animation associated with this scene included a gentle movement of water around the hooks, indicating a disruption in surface tension, and the child shaking her legs, indicating that she is waiting. The following scene included the narrative text “suddenly (the main character) felt something very heavy tug on her pole.” In both eBooks, the automatic animation associated with this narrated text included a sharp bend of the hook, and the bears showing their excitement through facial expressions.

***The temporal contiguity principle***

The programmer was given specific instructions about the animations that were presented contiguously with the spoken text. In both the math and emotion-action conditions, an animation of the little bear and her father walking to the river was activated automatically, two seconds after turning the page with the text "[main character] and her father walked to the river." This allowed temporal proximity between the verbal modality of reading the sequence "walked to the river," and visual modality of watching the bears walking to the river. The activation of the hotspot was cued by highlighting the location two second after turning the page; this allowed adequate time for reading the sentence. The animation was programmed to be linked with the word walking in the text. Details regarding the hotspots cues are explained later in this phase.

The temporal contiguity principle was used to guide the construction of hotspots in the math condition, where hotspots aligned with mathematics vocabulary, concepts or actions. For example, a virtual image (finger or fish) in the math condition was highlighted with a distinct color, indicating that it was now an active hotspot. When children activated the hotspot, they instantly heard a number spoken aloud that reflected the cumulative objects they had counted.

***The segmentation principle***

According to this principle, the individual scenes in the eBook did not progress rapidly; instead, the narrative was broken down into shorter segments. This allowed for greater control of the information that was presented for processing. Tapping hotspots in both eBooks was carried out at the dyads' chosen pace; backward and forward buttons allowed the caregiver and/or child to regulate the speed at which information was presented.

***The signaling principle***

Signaling with hotspots aimed to avoid arbitrary taps on the screen. In both eBooks, the locations of the hotspots were programmed to become highlighted in order to draw attention to the location of the hotspots on the screen. For example, in the math condition, highlighting counted object was used to cue the reader to tag an object that

would activate a spoken numeral and remain highlighted until a series of similar objects was counted in order. This procedure cued the reader that some objects had already been counted, and that the last spoken or counted number represented the total number of objects that had been tapped.

***The coherence principle***

Like the multimedia principle, the narrative and the visual modalities in both eBooks were programmed to be entirely constructed by maintaining this overarching principle. That indicated that the narrative and the images of the eBooks were coherent and not links that were not related to the content were presented. For instance, no activities, hyperlinks to dictionaries or games were included. All the activities and the questions were directly related to the content and supported the coherence with the eBooks.

***The personalization principle***

The Personalization principle was used through the activity of naming the little bear. Both eBooks were programmed so the children provided a name of their choice for the lead character, a three-year-old personified bear. That was programmed in a way that once the name was entered on the *screen* (the cover page of the eBook), it was used throughout the eBook.

## Hotspots aligned with mathematics-content

Hotspots that activated mathematics related content required further detail in order to maintain counting principles and other mathematics operations. While programming the math eBook, counting principles were embedded and highlighted (Gelman & Galistel, 1978) as discussed in Chapter 2.

***One-to-one correspondence***

This principle was accomplished by assigning only one number word to be sounded out for each object counted. Partitioning and tagging were also based on this principle; the counted item was permanently highlighted once it was tagged. A permanent

highlight around the object was an indication of transferring the object to the "counted" category.

### *The stable-order principle and order irrelevance principle*

This principle guided the use of words associated with the counted objects in their correct stable order: one, two, three, four… ten (the maximum number included in the eBook). The order irrelevance principle guided the programming of hotspots so there was no restriction on the start or end of counting, and the reader could progress in any order. However, the auditory numerical advancement would progress in the correct order.

### *Mathematics operations*

Cardinality was emphasized in a scene where the child was asked to count the five fish, starting from the biggest and ending up with the smallest. The programming allowed the fish to be highlighted and sounded out only when it was pressed in the right order.

The math eBook invited the child to physically interact with different objects, emphasizing basic mathematical skills such as simple addition, subtraction, and division. The addition was practiced by dragging the fish from the pole and dropping it into the basket. Subtraction was practiced by dragging the fish from the grass and dropping it back into the river. The division was practiced by dragging the fish to the family members to help with sharing them.

## Programming-illustrating collaboration

The illustrator was in constant communication with the programmer while the scenes were being painted. Collaboration through email and video meetings was essential for maintaining an accurate design of the eBook. The collaboration became more frequent as the hotspots and other animated features of the eBook were designed.

An example of the illustrator-programmer collaborations around hotspots was the Strategic Counting scene in which five fish were counted after flipping the basket. Tapping the fish was associated with visual hotspots (by highlighting the fish) and spoken hotspots (sounding out the order number). When this scene was first programmed, the fish overlap that occurred there was confusing, because it limited the image-map of

the fish - or the area of the fish that can be clicked to activate the hotspot. Some young children found it challenging to successfully tap the fish at the pilot stage of the eBooks. To deal with this confusion, the illustrator painted separate images of each fish, instead of having them painted altogether on one page. Later, the programmer re-situated the fish on the page in a way that allowed more flexibility with programming.

Animated scenes that included manipulative features within the hotspots were examples of programming-illustrating collaboration. The illustrator used a GIF animator software to create the animated scene of the little bear pulling the hook with a boot stuck on it. She illustrated a series of several images showing the gradual motion of raising the hook from the water and the changing facial expressions of the bears. Later, the programmer coded all the additional features that include: programming a flashing light on the pole where the glowing indicated a hotspot's location; writing codes to activate the animation once a hotspot was clicked; embedding all the audio that will be activated along with the animation (water splash and laughter).


**Figure B-15. An animated scene completed with programmer-illustrator collaboration.**

## Focus group input

The focus groups that discussed programming included early childhood educators, Educational psychology graduate students, and three mother-child dyads. Discussions

with the members on several occasions promoted the programming process. Discussions were mainly about increasing easiness of using the eBooks by the caregivers and the children. Observations from three dyads using the eBooks and discussions within the focus groups suggested revisions to programming different design features within the eBooks, especially those related to increasing the ease with which the hotspots were activated.

Hotspot cues draw the viewer's attention to locations on the screen that can be clicked; hotspots cues also help to avoid arbitrary clicks on the screen. Based on the analysis of 30 eBook; most eBooks do not use cues or use cues that may be too distracting from the story, such as a big arrow pointing to the location of the hotspot. In the early stages of designing the eBooks for the study, the programmer added little glowing dots on the locations of hotspots. That glowing remained active for two seconds. It aimed to draw attention to the hotspot locations.

One view was that adding hotspot cues could mean adding external elements that were not related directly to the story content, and this could be distracting the children. One graduate student suggested allowing a few random taps for the dyads to learn about the locations of the hotspots; because there is a repeated pattern with tapping the hotspots. She further suggested informing the participants beforehand about those locations:

> *This has to be taught once (meaning, the random clicking of the screen to activate the hotspots that are not visible), and then they will figure it out without having the cue appear on each hotspot. Or you can tell the child or the parents beforehand that this need to happen when you click some locations on the screen.*

The discussants later agreed that excluding cues may negatively affect attention to the screen because this could lead to random taps and a search for any potential hotspot. One mother suggested a clue:

> *I wonder if you can just have a hand pointing, like something indicating that you touch the hotspots. Or how about adding something that can come up, like a little pointer, or adding a little instruction like "touch the bear.*

The discussants were also asked about the drag and drop features that were not associated with any cue (such as in dragging a fish and dropping it in the basket). One of the early childhood educators suggested that adding instructions could be a good idea: "You can put something down here like drag and drop the fish to the basket in parentheses or something." A graduate students added, "or you can have a pointer to the fish and then a pointer to the basket."

In a subsequent meeting, the discussants were asked about an idea that was embedded for signaling the hotspots, which as a light that glows on, or around the object, to indicate the hotspot's location. The discussants agreed with the idea; they assumed that these cues did not resemble any potentially distracting external features, such as a pointer, an arrow, or a written instruction to tap the hotspot. Since the duration of the cue needed more research; the programmer was asked to include cues with different durations: two seconds, four seconds, and constant.

Reactions to short cues, or cues that were too long, were noted as mothers read to their children in a pilot study. All the dyads tended to miss some of the hotspots for short cues, namely when a short blink disappears after two seconds; they tended to miss the tapping opportunities less often when the cues were extended. Missing a hotspot was not recommended, as all the hotspots had to be tapped in order to resume reading. When the mothers were asked to give their opinion on constant cues, they seemed to agree that this would not be distractive to them, nor to their children. The final decision was to keep the hotspots' cues blinking during the time they were inactive.

***Facilitating image-map of the hotspots and the drag-drop***

In the early stages of programming the hotspots, the clickable area was in the center of the image. After piloting and realizing that children may have difficulties pressing on the center of the object, the image-map was expanded by the programmer. Expanding the clickable area on the image meant that any part of the image can be tapped to activate the hotspot.

The drag-drop was programmed so that the object can be *dragged* by holding it from any point; the *drop* was programmed so that the object would drop into place a half

inch before reaching its final destination. The flexibility of not having to drag an object to the exact point was a critical implication of increased clarity and accessibility of using the eBook.

All hotspots were built to engage children through a surprise effect that comes along with their activation. Even when some hotspots became predictable - such as those that share the same results once pressed - children in the pilot studies repeatedly expressed excitement and engagement, which would, in turn, lead to activation.

Engaging children in the eBook was also accomplished through their self-exploration of the drag-and-drop options that were not always predictable (such as where to drag the fish). Dragging the fish and dropping it in the basket, or dropping the chair back in to the water are examples of self-exploration within the hotspot functions.

Embedded audios were also a source of engaging children in the story, such as the audio of the sneezing fish, the mewing cat, or the giggling bears. Some discussant even suggested adding more audios to increase child engagement. One of the early childhood educators commented: “You could put the sound of the river, a running water, I guess you had it before in the previous scene…or ssshhh like a stream.” The discussants agreed that the embedded sounds are important to set the story mood and to increase the child’s engagement with the narrative. One of the graduate students commented: “It was a kind of cool how you have the door open, and the sound at the beginning of each one. This gives a good mood to the story. You can add more of these.”

Revisions based on focus group input included: programming the hotspots’ cues to blink as long as they remained inactivated; and adding more audios to the final version of the eBook.

# Appendix C. Information Materials

## Letter to caregiver

Dear Caregiver,

This research is being conducted for the purpose of the principal investigator's doctorate dissertation. The main purpose of this study is to learn how children (between the ages of 36 – 48 months) benefit from the experience of shared reading of an electronic storybook with one of their caregivers. This is an important issue, in light of the prevalent use of electronic storybooks in children's homes.

**Method**. If you consent to your child's participation as well as your own participation in the research, you will be asked to take part in one reading session with your child, where you read and talk about an electronic storybook. The reading session will take approximately 15 minutes to complete. The session will be videotaped. As part of the procedure, you will be asked to fill out a short questionnaire to provide basic information about your child's development. The questionnaire will also ask questions about your child's prior exposure to storybooks and electronic storybooks. At the end of each session, you will be asked to complete a short questionnaire that asks about your feelings about the electronic storybook and how your child enjoyed reading it with you. In addition, your child will be asked to participate in a very short vocabulary-based activity after the reading session. If you and your child participate in the study, you will be videotaped while reading the electronic storybooks. Your verbal and non-verbal interactions will be transcribed and analysed to document how your child's participation.

**Confidentiality**. You and your child are participating in this study confidentially. Any contact information you provide will be stored separately from your child's data and from your questionnaire data. The principal researcher will know your child's name, but your child's name will not appear on any of electronic data or the published data. All data collected (video recordings, data from the questionnaires and the children's drawings) will be reported in an aggregate form on the principal researcher's password-protected computers. Video-recordings and questionnaires will be kept until the end of the study to

ensure that our transcriptions are accurate, and then the recordings will be destroyed. Your individual privacy will be maintained in all published data.

**Risks and Benefits**. There are no risks involved in this study, and there are no immediate direct benefits to you or your child after participating in this study.

**Withdrawal**. Participation in the study is completely voluntary, and you may refuse to participate or withdraw from the study at any time without consequence. If at any time, you or your child wish to be withdrawn from the study, please contact Soaad Abdelhadi, the principal researcher, at her phone number 778-[...] or email: [...] @sfu.ca.

**Contact information about this study**. If you have any questions or would like further information about the research or you to access the findings of the study in the future you may direct them to the principal investigator, Soaad Abdelhadi, the principal researcher, at her phone number 778-[...] or email: [...]@sfu.ca.

**Contact for complaints**. If you have any concerns about your rights or your child's rights as a research participant and/or your experiences while participating in this study, please contact the Office of Research Ethics [...] @sfu.ca or 778 – [...].

**Reimbursement**. At the end of the activity, your child will be offered a gift as a thank-you for participating.

**Organizational Permission**. Permission for conducting this research has been obtained from the SFU childcare society administration.

If you sign the form below to indicate that you and your child are able to participate in the study, the principal researcher of the researcher assistant will contact you to arrange a meeting. We hope you will join us in our research!

Sincerely,
Soaad Abdelhadi (The principal researcher. SFU)

## Consent form

By signing this form you agree to take part in the aforementioned study which will include: reading an electronic storybook to your child and of being videotaped. Signing this consent will give permission to use information from the questionnaires, information from the videotapes and results of your child's performance in the vocabulary activity. Participation is completely voluntary. Even if you express agreement to participate with your child through signing this consent, it is your right to withdraw at any time through the experiment without penalty.

If you agree to participate, please sign and submit this form to the childcare educator of the centre your child is attending.

I consent my participation in this study

My name: _____ My signature: _____

I consent my child's participation in this study

My child's full name: _____ (girl / boy)

My child birth date (year and month): _____My Signature: _____

Please provide your contact information in order to set times for our two meetings. You may be contacted through or after the experiment if need arises for completing or clarifying information.

Your Phone number: _____ Email address: _____

If you have any questions or concerns you may direct them to the principal investigator, Soaad Abdelhadi, by email at [...] @sfu.ca or by phone at 778- […]

# Appendix D. Demographic and Home - Literacy Questionnaire

Please complete the following demographic questionnaire and return it to the researcher with the consent form.

**The caregiver.**

- Your Name: _____
- Occupation:_____
- Level of education:
  - □ Less than High school
  - □ High school
  - □ Bachelor's or equivalent degree
  - □ graduate degree

**The child.**

- Your child's name: _____ (girl / boy)
- You child birth date (month/day/year): _____
- Language/s spoken at home?

  _____
- Which language do you speak most often with your child at home? _____
- Does your child have any health issues that may influence how you read with your child?
  - □ Yes
  - □ No

**If yes, please clarify.**

_____

_____

**Reading and other activities at home.**

(1) How often do you engage in mathematics activities with your child?

- □ At least once a day
- □ A couple of times a week
- □ Once a week
- □ 1-3 times a month
- □ Once a month
- □ Less than once a month

(2) Do you read print **books** with your child?

- □ Yes
- □ No

**If <u>yes</u> please answer the following questions**

(4) How often do you read print storybooks with your child at home?

- □ At least once a day
- □ A couple of times a week
- □ Once a week
- □ 1-3 times a month
- □ Once a month
- □ Less than once a month

(5) How often does your child ask you to read to him/her?

- □ At least once a day
- □ A couple of times a week
- □ Once a week
- □ 1-3 times a month
- □ Once a month
- □ Less than once a month

(6) How often does your child look at books on his/her own?

- □ At least once a day
- □ 1-3 times a month
- □ A couple of times a week
- □ Once a month
- □ Once a week
- □ Less than once a month

(7) Do you read **electronic books** with your child?

- □ Yes
- □ No

**If <u>yes</u> please answer the following questions**

(9) How often do you read electronic books with your child at home?

- □ At least once a day
- □ 1-3 times a month
- □ A couple of times a week
- □ Once a month
- □ Once a week
- □ Less than once a month

(10) How often does your child look at electronic books on his/her own?

- □ At least once a day
- □ 1-3 times a month
- □ A couple of times a week
- □ Once a month
- □ Once a week
- □ Less than once a month

# Appendix E. Caregiver eBook Satisfaction Questionnaire

Please rate the following statements according to your experience with sharing the electronic storybooks (eBooks) with your child. Please use the rating scale to express your agreement with the given statement by writing the number in the scaling column to the left of the statement:

**Scaling Key**

**1:** Agree **2:** Somewhat Agree **3:** Somewhat Disagree **4:** Disagree

| Scaling | Statement |
|---|---|
| **1** | My child enjoyed reading this eBook with me. |
| **2** | The eBook helped my child improve his/her mathematics thinking. |
| **3** | The mathematical content was **clear** to my child. |
| **4** | The hotspots in this eBook were **distracting** to my child. |
| **5** | The hotspots in this eBook were **distracting** to me. |
| **6** | The hotspots were **important** to maintain my child's attention to the story. |
| **7** | The hotspots **highlighted the mathematics language very well**. |
| **8** | My child **had an active role** while reading this eBook. |
| **9** | I **had an active role** while reading this eBook. |
| **10** | Overall, I am **satisfied** that this is a good eBook for my child. |
| **11** | In future, I will **continue to read** eBooks with my child. |

# Appendix F. Sample Characteristics

| Language and literacy practices | Math % (of total) | Emotion-Action % (of total) | *df* | $\chi^2$ | *p* |
|---|---|---|---|---|---|
| | *n* =16 | *n* =16 | | | |
| **Language most often spoken by caregivers when communicating with the child at home** | | | 9 | 7.07 | 0.37 |
| English | 43.8% (7) | 50% (8) | | | |
| Indonesian | 6.3% (1) | 6.3% (1) | | | |
| Arabic | 12.5% (2) | 18.8% (3) | | | |
| Persian | 6.3% (1) | 6.3% (1) | | | |
| Kurdish | - | 6.3% (1) | | | |
| Mandarin | - | 12.5% (2) | | | |
| Filipino | 6.3% (1) | - | | | |
| German | 6.3% (1) | - | | | |
| Malayalam | 6.3% (1) | - | | | |
| Telugu | 6.3% (1) | - | | | |
| Cantonese | 6.3% (1) | - | | | |
| **Number of occasions that the child engages in mathematics activities** | | | 4 | 6.52 | 0.16 |
| At least once a day | 56.3% (9) | 37.5% (6) | | | |
| A couple of times a week | 25% (4) | 56.3% (9) | | | |
| Once a week | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| One-three times a month | 12.5% (2) | - | | | |
| Less than once a month | 6.3% (1) | 6.3% (1) | | | |
| | - | - | | | |
| **Number of occasions that print books are read with the child** | | | 3 | 1.07 | 0.79 |
| | 43.8% (7) | 43.8% (7) | | | |
| At least once a day | 43.8% (7) | 50.0% (8) | | | |
| A couple of times a week | - | - | | | |
| Once a week | 6.3% (1) | 6.3% (1) | | | |
| One-three times a month | 6.3% (1) | - | | | |
| **Number of occasions that the child asks to have a book read to him/her.** | | | 4 | 4.25 | 0.37 |
| At least once a day | 43.8% (7) | 56.3% (9) | | | |
| A couple of times a week | 37.5% (6) | 18.8% (3) | | | |
| Once a week | 12.5% (2) | 12.5% (2) | | | |
| One-three times a month | 0 % (0) | 12.5% (2) | | | |
| Less than once a month | 6.3% (1) | 0 % (0) | | | |
| **Number of occasions that the child looks at books on her/his own** | | | 2 | 2.04 | 0.36 |
| At least once a day | 43.8% (7) | 68.8% (11) | | | |
| A couple of times a week | 43.8% (7) | 25.0% (4) | | | |
| Once a week | 12.5% (2) | 06.3% (1) | | | |
| One-three times a month | - | - | | | |
| Less than once a month | - | - | | | |

| | | | | | |
|---|---|---|---|---|---|
| **Are eBooks read at home?** | | | 1 | 0.14 | 0.71 |
| Yes | | | | | |
| No | 37.5% (6) | 31.3% (5) | | | |
| | 62.5% (10) | 68.8%(11) | | | |
| **Number of occasions that the child reads eBooks with a caregiver** | | | 5 | 6.38 | 0.27 |
| At least once a day | 6.3% (1) | 6.3% (1) | | | |
| A couple of times a week | 12.5% (2) | - | | | |
| Once a week | 12.5% (2) | - | | | |
| One-three times a month | 6.3% (1) | 12.5% (2) | | | |
| Less than once a month | - | 12.5% (2) | | | |
| Never | 62.4% (10) | 68.7% (11) | | | |
| | | | 5 | 2.25 | 0.81 |
| **Frequency of the child looking at eBooks on her/his own** | 6.3% (1) | 6.3% (1) | | | |
| At least once a day | 18.8% (3) | 12.5% (2) | | | |
| A couple of times a week | 6.3% (1) | 0 % (0) | | | |
| Once a week | 6.3% (1) | 6.3% (1) | | | |
| One-three times a month | 0 % (0) | 6.3% (1) | | | |
| Less than once a month | 62.4% (10) | 68.7% (11) | | | |
| Never | | | | | |

# Appendix G. eBook Satisfaction Questionnaire: Results

*Mean Ratings by Caregivers in The Math and Emotion-Action Conditions Regarding Their Satisfaction with The eBooks.*

| | Math | | Emotion-Action | | *U* | *p* |
|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | | |
| **1. My child enjoyed reading this eBook with me.** | 1 | 0 | 1 | 0 | - | - |
| **2. The eBook helped my child improve his/her mathematics thinking.** | 1.75 | 1 | 2.06 | 1.18 | 0.22 | .642 |
| **3. The mathematical content was clear to my child.** | 1.38 | 0.62 | 1.81 | 1.05 | 1.24 | .266 |
| **4. The hotspots in this eBook were distracting to my child.** | 3.81 | 0.40 | 2.94 | 1.25 | 7.107 | .008 |
| **5. The hotspots in this eBook were distracting to me.** | 3.62 | 1.02 | 2.63 | 1.09 | 8.805 | .003 |
| **6. The hotspots were important to maintain my child's attention to the story.** | 1.56 | 0.89 | 2.31 | 1.25 | 6.608 | .010 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **7. The hotspots highlighted the mathematics language very well.** | 1.25 | 0.34 | 2.13 | 1.31 | 4.399 | .036 |
| **8. My child had an active role while reading this eBook** | 1 | 0 | 1.63 | 0.81 | 8.552 | .003 |
| **9. I had an active role while reading this eBook** | 1.13 | 0.62 | 1.37 | 0.72 | 0.996 | .318 |
| **10. Overall, I am satisfied that this is a good eBook for my child.** | 1.19 | 0.54 | 1.44 | 0.81 | 0.889 | .346 |
| **11. In future, I will continue to read eBook with my child.** | 1.38 | 0.62 | 1.94 | 0.93 | 3.593 | .058 |