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An abstract of
a thesis submitted to the Faculty of Emory College of Arts and Sciences
of Emory University in partial fulfillment
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Abstract

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The education of students in STEM subjects has been a growing problem in recent years, leading to an increase in research on how to foster knowledge and interest in STEM, especially in school-aged children when interest and skills can be initially developed. Informal learning is a significant way that children learn and is typically informed by parental involvement. Specifically, shared book reading with a parent is a common way that children participate in informal learning, yet little is known about how parent-driven, child-driven, or hybrid (similar amounts of parent and child contributions) interactions while reading STEM materials together under informal learning settings impacts children's performance on different learning outcomes. The present study examined how parent-driven, child-driven, or hybrid interaction styles during shared book reading of online museum exhibits impact children's performance on three different learning outcomes. The stimuli were developed from actual exhibits from the Carlos Museum at Emory University and sessions were administered online from the participants' homes to best recreate an informal learning environment. We summarize findings on how parent-child interaction styles impacted performance on the learning outcomes.

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Introduction

The education of students in STEM subjects (science, technology, engineering, and mathematics) is important for our society. There has been a growing problem with numbers of individuals pursuing the STEM field not meeting the demand (Xue et al., 2015), and so it is important to answer questions about what and how learning experiences can foster knowledge of STEM and build a groundwork for children's future STEM educational and career pursuits (Palmquist & Crowley, 2007). This is important for the academic success of children and, since this will lead to more STEM jobs, the success of our economy (Langdon et al, 2011). One important way that children learn is through informal experiences, or self-directed learning experiences that occur outside of the formal, structured setting of a classroom. Informal learning is self-motivated and not externally goal directed, and it is important, because it can enhance both knowledge and interest in STEM topics (Callanan & Oakes, 1992). One important characteristic of informal learning is that it is often social and involves other more experienced figures, such as parents, to help guide learning through conversation and other interactions. In addition, shared reading (when the parent and child read together) is a major way that children acquire knowledge under informal learning environments. However, there is little research on how parent-child interactions during shared reading under informal learning conditions influence children's acquisition of STEM knowledge. In the present study, we tested how different types of parent-child interactions during shared reading under informal, self-directed conditions influence learning outcomes.

Informal learning is self-motivated and not externally goal directed and comes in many forms, including watching a documentary, visiting a museum or aquarium, or reading a book.

The majority of individuals' learning experiences actually take place outside of formal classroom settings and in informal learning environments. Research on informal learning shows that learning happens not just in schools and not just in school-aged children (National Research Council, 2009). Indeed, children learn a great deal at home and in their communities before they even enter school and outside of school in everyday settings (Callanan et al., 2011).

Long before they enter school, children learn about topics in everyday situations such as casual conversations with parents and others, visits to museums, television programs, and everyday observation (Scribner & Cole, 1973; National Research Council, 2007; Callanan & Jipson, 2001). In these every day, informal settings, children's questions are an entry point for discussion and learning. Even from a very young age many children ask complex "why" questions about the environments around them (Callanan & Oakes, 1992; Demirtas et al., 2018), and research has shown that these questions often are meant to seek out causal explanation (Frazier et al., 2009). Children's early learning about topics is influenced by both their own observations and the information that is communicated to them (Haden et al., 2010; Harris & Koenig, 2006). It is clear that children rely on sources in their environment to facilitate informal learning, whether that be television shows, learning materials such as books, or receiving information from other individuals around them.

Attention to learning in informal settings highlights the importance of considering learning as not just an individual process, but also as a social process (Nasir et al., 2006; Guiterrez & Rogoff, 2003). Since children often learn under the guidance of a more experienced figure, parental involvement and parent-child interactions play a large role in how children learn in informal settings. Parental involvement is crucial to helping children acquire knowledge in informal settings, since children have poorer executive functioning and working memory skills, and thus it can be harder for them to focus on relevant information (Landry et al., 2006). Because of this, parent-child interactions such as conversations can direct children's attention in ways that enhance their understanding (Thompson, 2006). Research has shown that parent's exploration at children's museums lead to the child's increased exploration of the exhibit as well (Willard et al., 2019). Observational studies of family interactions in museums show that when children engaged in an exhibit with their caregivers, their exploration of evidence was longer and more focused on relevant material than children who engaged in the exhibits without their parent (Crowley et al., 2001; Gleason & Schauble, 1999). Moreover, studies have shown that parent-child conversations lead to children's better understanding and recall of personal events (Peterson et al., 2007; Salmon & Reese, 2015); parents who were more elaborative (asked question or made comments) had children who recalled more about a hospital event due to an injury that required hospital emergency room treatment. It is clear that parent involvement in informal learning is both a major part of how children learn in informal settings and also a ground for facilitating and improving children's understanding of information and knowledge acquisition.

One common and encouraged way that parents interact with children under informal learning environments is through shared book reading (when the parent and child read together), and thus offers a great way to study parental involvement and informal learning. Shared book reading is a common way for children to learn with their parent's support (Lonigan et al., 2008). In shared book reading, a parent will either read to the child, the child will read with assistance or support from the parent, or both the child and parent will read and split up how much each one reads. Shared book reading is a way to actively engage children in the reading material. For example, in narrative books, shared reading allows children to be involved in telling a story and discussing its characters. Adult readers often ask questions of the child and attend to the child's oral responses with feedback (Lonigan et al., 2008). Shared book reading between parents and children is an important activity for promoting oral language and emergent literacy skills and is associated with reading achievement and recreational reading (Towsen et al., 2017). Given the significance of shared book reading on learning and reading comprehension, and the fact that it is a common method used in informal learning, it is important to study how children learn through shared reading under informal learning settings.

The majority of research on shared book reading is done with pre-school aged children using fictional narratives, or books that communicate a story with characters, conflict, and settings. Research on narratives has mainly focused on the caregiver's extra-textual talk—conversations that extend the text such as asking questions or offering explanations—and how it enhances children's language and reading abilities (Bus et al., 1995; Roberston & Reese, 2017). Additional research has found that high quality extra-textual talk, such as open-ended questions and comments, predicted higher scores in reading comprehension (Hindman et al., 2008). Important as this work is, it does not tell us about STEM learning.

Although literacy and reading comprehension are important, STEM learning is particularly significant to address in our society. Research is showing an increasing disinterest of young people in science and technology (Newhouse, 2017). The decreasing interest, readiness, and motivation of students to pursue science, technology, engineering, and mathematics (STEM) creates problems with the growing demands for a trained workforce (Xue & Larson, 2015; National Science Board 2016). Furthermore, STEM learning has impacts beyond just facilitating economic growth. Education in science and technology also informs individual's personal decision-making and participation in civic and cultural affairs (National Academy of Sciences, 'Rising Above the Gathering Storm' Committee, 2010). In order to fill the need for skilled, knowledgeable STEM professionals, it is important to understand factors that influence student STEM learning, especially in school aged children when interest and skills can be initially developed. Between the ages of 4- and 7-years old, children start to act to uncover new information or fill in gaps in their knowledge (Sobel & Letourneau, 2017) and thus by the age of 8-years-old, children are in an age group that has the greater skill set and ability to expand their knowledge and skills in STEM. This age range is also a good time to start to develop interest in STEM. Identifying the underlying mechanisms of STEM learning outcomes in youth can provide guidance to communities and parents and contribute to how students learn STEM content. Shared reading, as previously mentioned, is common and encouraged under informal learning settings and thus can offer insight on what factors play a role in STEM learning under informal conditions.

While the majority of research with shared reading has focused on pre-school aged children, fictional narratives, and extra-textual talk, some research has given attention to the question of how shared reading practices and parent-child interactions influence STEM knowledge acquisition in school-aged (ages 6-12) children. One study showed that school-aged children learn STEM materials better in school settings when reading with the teacher rather than when the lecture is teacher dominated (Varelas & Pappas, 2006). Additionally, joint verbal exchanges between a parent and child predicted better memory of events (Jant et al., 2014; Hedrick et al., 2009). During museum visits, parent-child talk resulted in the highest performance on recall when the interactions were highly communicative between the parent and child (Haden et al., 2010). Although this research has been insightful, it does not shed light on parent-child interactions during shared book reading. Given that shared book reading is a major and facilitative way that children participate in informal learning, along with the importance of understanding how children best learn STEM information, it is important to investigate what factors are involved in learning during shared book reading not only in narrative books but also in STEM material.

There is still much to be addressed about how children learn STEM information with their parent or caregiver during shared reading in informal settings. Research on the amount that the parent versus the child reads the texts, ask questions, or makes comments during shared STEM reading has not been investigated. In other words, it is yet to be known how parent-driven, child-driven, or hybrid (similar amounts of parent and child contributions) interactions while reading STEM materials together under informal learning settings impacts children's performance on different learning outcomes.

To explore parent-child interactions in informal learning environments through shared reading, we chose to use online museum exhibits from the Carlos Museum on the Emory University campus. These online exhibits have no direct educational goal or purpose other than for the child to explore different information from the exhibits of the museum. Additionally, the online exhibits offer a context that encourages open-ended exploration and parent-child interaction and can be read for pleasure in the comfort of the parent and child's home. This allows for an ideal way to study informal learning. The exhibits are rich in text, and therefore offer a way to study shared reading of STEM materials.

Research showing that joint verbal interactions between parents and children predicted better memory and recall of those events (Jant et al., 2014) implies that parent-child interactions that are interactive on both the parent and child's side lead to the highest memory and recall. Additionally, parent-child talk that was highly communicative and interactive between the parent and child in museums lead to highest recall in children (Haden et al., 2010). Although this research was not done on shared book reading, it indicates that parent child interactions that are joint and collaborative lead to the highest recall of events. Thus, for the purpose of our study, we predicted that if children were in parent-child dyads that were hybrid during shared reading of the online exhibits, then they would perform higher across learning outcomes in both open-ended and forced-choice testing.

Since past studies looking at parental involvement in museum exhibits focused on school-aged children, we chose to focus on 8-year-olds in this study since it gives an ideal age to start building interest and knowledge in STEM material and skills. Children are becoming more independent learners and thinkers, yet at the same time still require guidance and support from parental or more experienced figures during informal learning.

To test children's learning of information from the online exhibits, we used three types of questions: direct factual, self-derivation, and inferential reasoning. Direct factual questions are a common way in the literature to test direct recall of material, self-derivation questions test a higher order learning by requiring the reader to integrate separate episodes of learning (Bauer et al., 2020), and inferential reasoning questions test a different type of learning and require the reader to make novel conclusions based on both the text and prior knowledge or experiences (Doerr et al., 2017). These different types of questions were used to test a range of various learning types and outcomes and to test different levels of learning (higher order such as self-derivation and inferential reasoning as well as more straightforward direct factual recall).

Methods

Participants

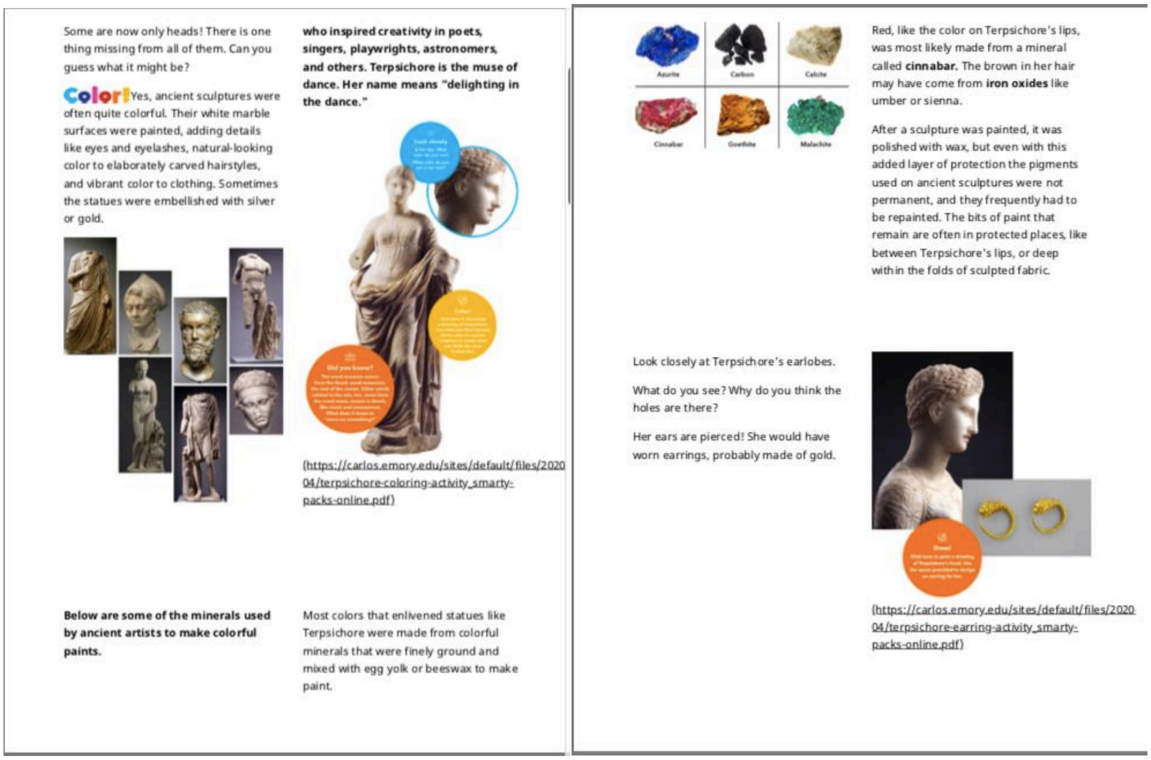
Participants were thirty-two 8-year-old children (M age = 8.58, *SD* age = .24; 12 females, 20 males) and one of their parents. Participants were recruited through a volunteer pool consisting of families who expressed interest in participating in child development research. Based on parental self-report, the sample was African American or Black (25%), Asian (6.3%), White or Caucasian (50%), American Indian or Alaskan Native (3.1%) and mixed race (9.4%); 12.5% identified as Hispanic or Latinx. One participant chose to not identify race or ethnicity. Written parental consent and children's verbal assent were obtained before the start of the study. Parents were compensated with a $20 gift card to a local merchant at the end of the session. All steps of this research were conducted in accordance with the university's Institutional Review Board.

Materials

Stimuli. The study used two full-color online exhibits from the Michael C. Carlos Museum ranging from 6-7 pages long. These online texts were developed from artifacts in the exhibits at the Michael C. Carlos Museum at Emory University. The two webpages were titled "Puzzling Pigments," and "Check out Those Kicks!". The average word count across the webpages was 940 ("Puzzling Pigments" = 729; "Check out Those Kicks!" = 1151), and the average number of pictures was 10.5 ("Puzzling Pigments" = 11, and "Check out Those Kicks!" = 10). Figure 1 shows sample pages from "Puzzling Pigments" as an example of what the webpages look like and illustrates the richness of information embedded in them.

Figure 1.

Sample pages from "Puzzling Pigments."



Verbal comprehension. The Verbal Comprehension subtest of the Woodcock Johnson-IV (Test 1) served as a measure of children's verbal, semantic knowledge as well as a buffer task. The task used in this study was the picture vocabulary subtest (Test 1), which assesses verbal comprehension. Participants received one point for each correctly answered item, and the test was discontinued when three items were answered incorrectly. A total score was obtained by summing the points.

Open ended test questions. 12 open-ended questions were developed based on information from the "Check out Those Kicks!" webpage and 11 questions were developed about the "Puzzling Pigments" webpage. Three types of questions were included: direct factual recall, self-derivation, and inferential reasoning questions. An example of a direct factual recall question is "Who introduced seed beads to Native Americans?" and can be answered directly from the text. An example of a self-derivation question is "What color flower does the heart-berry plant have?" where the reader integrates two separate facts from the text in order to answer the question. An example of an inferential reasoning question would be “Why are some ancient statues in museums missing body parts like arms or heads?” where the answer is not directly in the text but requires the reader to integrate information from the text and prior knowledge in order to answer the question.

Forced choice questions. The forced choice testing consisted of the same questions from the open-ended testing but in a three-alternative forced choice format. Words that were discussed in the webpages were used as alternative options in order to avoid a familiarity bias.

Procedure

Participants were recruited from an online database for the Emory Child Study Center and asked to participate via email. After being contacted about the requirements for study, those who decided to participate were sent a link for an online video call. During this call, the parent was first given an informed consent form which they signed, and the child gave verbal assent to participate in the study before the session began.

Parent/child dyads were tested by one female experimenter (the author). The experimenter first provided the following instructions*, “I am going to show you two different online webpages. I will send you the link to the first one now. Please take as much time as you need to read through it together. Read through it as you normally would if you were just doing this for fun at home. When you’re finished, let me know and we will move on to the next one.*” Dyads had as much time as needed to read through the webpage. After finishing the first webpage, the experimenter returned to the video call and provided the following instruction to the child, *“Please tell me everything you remember from the webpage.”* The experimenter then recorded the child’s response. If the child did not respond at first, the experimenter prompted, *“Can you tell me one thing you remember?”*. After the child provided their complete response, the experimenter sent the link to the second webpage. Procedure for the second webpage was identical to the first. Analysis of children's open-ended responses is beyond the scope of this project and will not be included in analyses.

Once the parent and child has gone through both webpages, the experimenter asked the parent to leave the call. She then administered the Woodcock Johnson-IV Test 1 as a buffer activity to the child. After the Woodcock Johnson-IV Test 1, the experimenter provided the following instructions, "*I will now ask you some questions about what you learned from the "X" webpage. Please say your answer aloud. Even if you're not sure of the answer please try to make a best guess! If you do not have any guess at all you can just say that you don't know, and we can skip that question."* The experimenter then asked each of the open-ended questions aloud and recorded the child's answers. Each set of questions from a specific webpage were asked together, but the different types of questions were counterbalanced in order to avoid bias. After open-ended testing, the child was asked the same questions but in a three-alternative forced choice question format. The experimenter recorded the child's responses. The sessions lasted around an hour long.

Scoring, Data Reduction, and Analysis Plan

Sessions were transcribed and the numbers of words (parent utterances and child utterances) spoken were recorded. We then classified the dyads into one of three groups based on the types of parent-child interactions with the webpage: those that were majority parent driven, majority child driven, or a hybrid. Majority parent was defined as the parent having spoken more than 75% of the words, majority child was the child having spoken more than 75% of the words, and hybrid was defined as neither parent nor child having spoken more than 75% of the words.

This was determined by transcribing sessions into Word and using word count to find percentages of words spoken by parent versus child.

Recall of information was examined based on three types of questions: factual, integration, and inference. Children were given 1 point for each correctly answered item on the open-ended testing and 1 point for each correctly answered item on the forced choice testing. For the Verbal Comprehension subtest of the Woodcock Johnson-IV (Test 1) participants received one point for each correctly answered item, and the test was discontinued when three items were answered incorrectly; a total score was obtained by summing the points. A correlational research design was used to examine the influence of majority parent, majority child, and hybrid sessions on the 8-year-olds' recall of information from the online text, as well as more specifically examining the relations between type of interaction and performance on each type of question (factual versus higher order questions).

Results

The primary aim of the experiment was to investigate the effects of the three different parent interactions types (parent driven, child driven, and hybrid) on open-ended and forced choice learning outcomes from online museum exhibits. Specifically, we tested the influence of parent-child interaction style on children's factual recall, inferential reasoning, and self-derivation through memory integration.

Sessions with the parent and child were transcribed and word count was determined using Word. Words spoken by parent versus child was used to determine whether the parent-child dyads were labeled parent-driven, child-driven, or hybrid. Parent-driven dyads were defined as dyads where parents read more than 75% of the words in the session. Child-driven dyads were defined as dyads where the child read more than 75% of the words in the session. Hybrid dyads were defined as neither the parent nor the child reading more than 75% of the words in the session. There were 13 parent-driven dyads, 7 child-driven dyads, and 12 hybrid dyads. The average number of words spoken in the parent-driven dyads was 2233 (*SD* = 172), 2110 (*SD* = 168) in the child-driven dyads, and 2340 (*SD* = 212) in the hybrid dyads. The average number of words spoken by the parent in parent-driven dyads was 1995 (*SD* = 102), 345 (*SD* = 52) in child-driven dyads, and 1450 (*SD* = 115) in the hybrid dyads.

In total, parent-child dyads spent an average of 22 minutes (*SD* = 6.4 minutes) going through both online exhibits. Parent-child dyads spent an average of 8 minutes (*SD* = 2.1 minutes) going through the “Puzzling Pigments” online exhibit and 14 minutes (*SD* = 5.2 minutes) reading through the “Check out those Those Kicks!” online exhibit. The longest time a dyad spent reading through both online exhibits was 41 minutes, while the shortest time spent going through both online exhibits was 10 ½ minutes.

Overall, each of the interaction types differed slightly in average time spent reading the online exhibits and the way that they approached the session. On average, parent-driven dyads spent 17 minutes (*SD* = 6.5 minutes) reading through both online exhibits. On average, child-driven dyads spent 23 minutes (*SD* = 10 minutes) going through both online exhibits. Three of these dyads consisted of the child reading through the text silently to themselves. Hybrid dyads took 24 minutes (*SD* = 4.5 minutes) on average to read through the online exhibits. All of the hybrid dyads except for one consisted of the child and parent taking turns reading paragraphs from the exhibits. The other dyad consisted of the child reading the first online exhibit and the parent reading the second online exhibit.

To assess the influence of parent child interaction style, we first examined overall task performance within interaction style. On average, across the three question types, children in the parent driven condition were successful 28% of the time (*SD* = .14) on the open-ended testing and 58% of the time (*SD* = .14) on the forced-choice testing. Children in the child driven condition were successful 31% of the time (*SD* = .14) on open-ended testing and 59% of the time (*SD* = .17) on forced-choice testing. Children in the hybrid condition, on average, were successful 36% of the time (*SD* = .18) on open-ended testing and 67% of the time (*SD* = .16) on forced-choice testing.

In order to investigate the effects of the three different parent interactions types (parent driven, child driven, and hybrid) on open-ended and forced choice learning outcomes, we conducted a one-way ANOVA. The data met all the assumptions necessary to conduct a one-way ANOVA. We found that there was no evidence of a statistically significant difference in overall performance based on interaction style for either open-ended testing, $F\ (2,29) = .710$, $p = .500$, or forced choice testing, $F(2,29) = 1.16$, $p = .329$.

Participants' performance based on parent-child interaction type across the different question types is shown in Table 1. We conducted a 2-way mixed ANOVA to examine effects between the parent-child interaction type (between subjects: 3 levels) and performance across the three different question types (within subjects: 3 levels). The data met all the assumptions necessary to conduct a two-way ANOVA. There was a main effect of question type on performance in open ended testing ($F\ (2,87) = 8.327$, $p < .001$) and forced choice ($F\ (2,87) = 8.797$, $p < .001$) testing. A Tukey post hoc test revealed that in open-ended testing, performance on the factual questions approached being significantly higher than performance on inference questions ($p = .052$); performance on factual questions was significantly higher than performance on integration questions ($p < .001$); performance on integration questions versus inference questions did not differ significantly ($p = .145$). A post hoc test for forced choice testing revealed that performance on both factual and inference questions was significantly higher than on integration questions ($p < .001$; p = .001, respectively); performance on factual and inference questions did not differ significantly ($p = .920$). We found no evidence of a statistically significant interaction between parent-child interaction type and performance across question type for either open-ending testing (F (4, 87) = .576, $p = .681$) or forced choice testing (F (4, 87) = .218, $p = .928$).

Table 1. Performance on learning outcomes by question type within each interaction style (child driven, hybrid, and parent driven).

Learning outcomes by Question Type	**Factual Recall**	**Inferential Reasoning**	**Self-derivation through memory integration**	**Overall**
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*
Open-ended				
Child driven	.41 (.18)	.31 (.21)	.21 (.20)	.31 (.10)
Hybrid	.45 (.23)	.31 (.19)	.30 (.25)	.36 (.10)
Parent driven	.40 (.18)	.30 (.21)	.12 (.13)	.28(.14)
Overall	.42 (.19)	.31 (.20)	.21 (.15)	.32 (.11)
Forced choice				
Child driven	.62 (.18)	.64 (.20)	.48 (.23)	.59 (.10)
Hybrid	.72 (.19)	.72 (.15)	.55 (.21)	.67 (.10)
Parent driven	.67 (.22)	.61 (.17)	.44 (.16)	.58 (.12)
Overall	.67 (.21)	.66 (.16)	.49 (.17)	.61 (.11)

In addition, the Verbal Comprehension subtest of the Woodcock Johnson-IV was used as a measure of children's verbal, semantic knowledge and assessed verbal comprehension. Overall performance as well as performance by parent-child interaction type is shown in Table 2. Verbal comprehension scores did not differ across parent-interaction style types. A one-way ANOVA revealed that there was no significant difference between the verbal comprehension scores across the three parent-child interaction types, F (2,29) = .803, p = .458. A Pearson correlation coefficient was computed to assess the relationship between Verbal Comprehension performance and performance on learning outcomes (open-ended testing scores and forced-choice testing scores). There was a correlation between Verbal Comprehension performance and open-ended testing performance (r = .490, n = 32, p = .004). There was also a correlation between Verbal Comprehension performance and forced-choice testing performance (r = .492, n = 32, p = .004).

Table 2. Performance on Verbal Comprehension Test based on parent-child interaction type.

Verbal Comprehension Test Scores by Interaction Type	***M (SD)***
Parent driven	9.9 (3.0)
Child driven	11 (1.0)
Hybrid	10 (1.3)
Total	**10 (1.3)**

Discussion

In the present research we tested major questions that have yet to be addressed in the literature. The current work offers original insights into how children learn online STEM information with their parents in informal settings. We examined how parent and child interactions while reading through online museum exhibits impacted children's learning outcomes of STEM materials. We coded parent-child interaction types based on the number of words spoken by the parent and child and collected individual measures of children's performance on three different learning outcomes: direct factual, self-derivation through memory integration, and inferential reasoning.

Throughout the sessions, parents and children interacted in various ways. Sessions with the parent and child were transcribed and word count was determined using Word. We grouped the styles into three interaction styles based on words spoken by parent versus child (if the parent spoke more than 75% of the words it was categorized as parent driven; if the child spoke more than 75% of the words, it was categorized as child driven; if neither the parent nor child spoke more than 75% of the words it was categorized as hybrid). There were 13 parent-driven dyads, 7 child-driven dyads, and 12 hybrid dyads. Before we analyzed any differences between interaction styles and learning outcomes, we examined whether there was evidence that the children learned from the online exhibits. Overall, children were successful 31.6% of the time on open ended testing and 61.4% of the time on forced choice testing; it is reasonable to conclude that the sessions constituted a learning experience for the children.

In our first analysis, we examined how the various interaction styles impacted overall performance across all three learning outcomes. Our hypothesis that the hybrid group would score highest on the learning outcomes was not supported, as we found no significant difference in overall performance between the groups. We then analyzed whether there were any differences in performance on question type (direct factual, self-derivation through memory integration, and inferential reasoning) based on parent-child interaction style. We also found no evidence of a significant difference in performance on the different question types based on parent-child interaction style.

Although past studies have not looked into reading of STEM materials, recent research on parent child interactions has explored the idea of whether children learn best when exploring on their own or when adults give direct instruction. The notion that a mixture of the two through an interactive hybrid style (or when adults watch child-directed activities while making comments or asking questions) is the most successful for learning has gained interest and support (Weisberg et al., 2016). Although past research was not focused on STEM learning during shared book reading, the body of research implies that children learn better through interactive exchanges with their parent. However, our data do not support this conclusion since we found no difference in performance across the parent-driven, child-driven, and hybrid groups. It is worthy to note that the children in these previous studies were of ages 4-8 years old which could be a potential explanation for the difference in findings since our study focused solely on 8-year-olds. This age group was of focus in this study, since they are at an ideal age to learn more about STEM materials but also still spend much of their experiences during informal learning with a parental figure or older, more experienced adult (Mermelshtine, 2017).

There are various other potential explanations for why our data did not support previous research that showed joint-interactive parent-child interaction styles led to better learning of STEM material. This study focused on the number of words spoken by the parent versus the child to determine differences in parent child interactions during shared reading. However, extra-textual talk such as comments, questions, or explanations could be a stronger indicator of child versus parent involvement and have a greater impact on children's learning than words spoken alone. Future research designs may benefit from examining extra-textual talk in addition to how much the parent versus child reads the text or talks. Another explanation could be that since this study consisted of a small number of participants, significant differences might become visible with larger sample sizes. Lastly, children's or parent's lack of interest in the topic or lack of motivation to examine the material could be another factor that interfered with how parents and children engaged with the online exhibits and thus could explain why we found no differences between the groups.

Our data have the potential to inform research on parent-child learning when reading through STEM materials in informal, everyday settings. Although this study did not find significant effects, it implies that words spoken or read may not be the significant indicator of how parent-child interaction can improve learning. However, there are opportunities for further analysis and investigation of parent-child interaction and informal STEM learning during shared book reading. Parent-child extra textual talk and content or format of the text materials' impact on children's learning of online museum exhibits are both potential avenues to explore. Additionally, future studies may look into younger school-aged children or a wider age range as this may offer more insight on how parental involvement impacts learning during shared book reading in informal settings across development.

In conclusion, adult involvement in children's reading is an important part of how children learn and serves as a great avenue to learn more not just about how to implement strategies to aid STEM learning in shared book reading, but to examine how children learn in informal, everyday settings in general. In fact, children spend around 53% of their time in informal learning—in comparison, only a mere 14% of their time is spent in school (Stevens et al., 2005). From birth to high school graduation, parents oversee most of kids learning time, and whether or not they are aware of it, parents are continuously engaged in their children's learning out of school (Knutson & Crowley, 2005). Thus, it becomes apparent that parents' skills and involvement is tied to children's informal learning, providing an important avenue for studying how children learn in informal settings. Research in this field has the opportunity to inform not only knowledge on informal learning over development, but also to explore ways to facilitate and improve children’s learning in these settings.

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