Investigating Children's Naturalistic Explorations in a Living History Museum

by

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Author's Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Statement of Contributions

I am either the majority contributor or sole contributor to all of the work presented in this thesis. This includes Chapter 4 of my thesis which is a publication co-authored with my supervisor Dr. Stephanie Denison, and collaborator Dr. Shaylene Nancekivell. Citation and information regarding this publication can be found in the relevant chapter.

Abstract

Researchers have taken the approach of examining children's learning in more naturalistic settings such as museums, science centers, and zoos (e.g., Sobel & Jipson, 2015), as in-lab experiments do not resemble the situations that children most often find themselves learning in. This work has primarily focused on how children acquire science concepts from highly structured indoor exhibits, and lacks ecological validity to everyday life. A living history village, on the other hand, offers a middle ground between children's everyday lives and other informal learning environments, as the context of the space is more similar to a child's life. This dissertation explores the learning opportunities in a living history village at the Ken Seiling Waterloo Region Museum (WRM), and whether the content of parents and children's conversations in these spaces resembles what one might expect given previous in-lab findings.

Chapter Two examines 4- to 8-year-old children's (N= 40, M_{age}=5.98 years) spontaneous interactions with parents and museum staff while exploring artifacts. The nature of discussions about artifacts evolved with child age, as the proportion of children's talk related to simple identification of artifacts decreases with age. Parents and staff provided unique learning opportunities by discussing different aspects of artifacts at different rates, and used a variety of strategies to teach their children about different artifact properties. Children also responded to different pedagogical strategies differently; they were most engaged and produced more information in response to critical thinking questions.

Using the same dataset as Chapter Two, Chapter Three examines whether there are opportunities for informal science learning for 4- to 8-year-old children in unexpected places, such as a living history village. I specifically examined the nature of science talk children were exposed to (i.e., biology, physics, or engineering; guided by the Ontario and Michigan Science Curriculums) and how these topics were discussed. Children of all ages are drawn to discussing

biology, whereas children discuss more science concepts related to engineering and physics with age. Parents and staff provide different science learning opportunities for children and discuss these science concepts differently.

Chapter Four explores whether it was possible to intervene on children's (*N*=61; 4-to 8-years-old) exploration and learning to direct their attention to a specific feature of an artifact, namely the causal mechanisms of its operation. Prior to entering the exhibit, children were randomly assigned to receive a "component" prompt that focused their attention on the machine's internal mechanisms or a "history" prompt as a control. Children generally discussed most aspects of the machine, including the whole machine, its parts, and to a lesser extent, its mechanisms. In the test phase, older children recalled more information than younger children about all aspects of the machine, and appeared more knowledgeable to adult coders. Children who received the component prompt were rated as more knowledgeable about the machine in the test phase, suggesting that this prompt influenced what they learned.

Taken together, the results suggest that children are engaging in the living history exhibit in a meaningful way, although they require the support of both parents and staff to fully take advantage of the learning opportunities present. It also provides evidence that the laboratory findings regarding children's artifact, science, and causal knowledge are evident in their spontaneous conversations. These findings are also a concrete step towards quantifying the educational value of visitor experiences at the WRM.

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Mom and Dad, thank you for giving me unconditional love my entire life and for always being there for me whenever I need you. I love you both so much. Catherine, thank you for being my best friend, giving me tough love, and always making me laugh. You'll always be my little baby. Taylor, thank you for believing in me even when I didn't believe in myself.

Dedication

This dissertation is dedicated to my grandmother, Maria Farace. Nonna, I hope I made you proud.

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Chapter 1: General Introduction

Many cognitive developmentalists aim to understand how children reason and learn about the world. Most research in our field occurs in controlled laboratory settings where we examine children's understanding of a phenomenon by testing their reactions to various manipulations in well-controlled experiments. For example, a typical researcher who is interested in preschoolers' causal reasoning might sit down with each individual child in an experiment and set out a single machine and a few objects, then show the child a pre-defined sequence of events: when you set a cube and a sphere on the machine together, it lights up. Then when you set just the sphere on the machine, it does not light up. Next, they will ask the child if the cube causes the machine to activate. Preschoolers make reasonable inferences in this case; they tend to determine that cubes are playing a causal role in activating the machine. We have gained a massive amount of insight into how children think and learn using these in-lab experimental techniques – from how children learn language, to how they think about natural kind and artifact concepts, to biology, causality, numbers, and so on (see Carey, 2009; Gopnik & Schulz, 2007; Goswami, 2019; Siegler et al., 2016). And while all of this work has provided incredibly valuable information about the power and limits of children's minds, it is certainly true that these in-lab experiments do not resemble the situations that children most often find themselves in. Therefore, this type of work often fails to capture some elements of *how* and perhaps even *what* children think about, talk about, and ultimately learn about in their everyday lives.

For instance, a visit to the park provides the (messy and noisy) opportunity for parents and their children to talk about different aspects of the jungle gym, such as the materials it is made out of, how it was built, and how to use it. It also provides opportunities for learning about living things, including animals and even other people. These are the kinds of learning opportunities one might study if they were committed to understanding learning in children's everyday lives. However, examining children's learning in naturalistic settings is challenging; it is very difficult to capture these experiences and throughout much of the history of our field, this has been a major limiting factor. Only in recent years has it become relatively easy to record children's experiences in their natural environments, such as the home, as major improvements in technology have begun to allow for smaller devices with longer battery lives (e.g., the LENA™). But even with such equipment, researchers are still mostly limited to capturing auditory experiences, as sending children home with video recording equipment is both intrusive and, for many researchers, prohibitively expensive. To combat these kinds of challenges, researchers have most often taken the approach of examining children's more naturalistic learning in informal learning environments such as museums, science centers, and zoos (e.g., Sobel & Jipson, 2015). In these settings, video and audio-recording devices can be installed to capture children's exploration and interactions.

These spaces are less constrained than laboratory settings, as children and their parents can move on to a different activity whenever they wish, which is similar to everyday life. Thus, this space allows researchers to gain insights into how learning may occur in everyday settings. Examining learning in these settings also allows researchers to determine how children's naturalistic learning aligns with in-lab effects. For example, while decades of work have revealed children's understanding of causal reasoning in laboratory settings, this has only recently been examined in informal learning environments (e.g., Callanan et al., 2020). Through examining children's learning in these spaces, researchers can gain a better understanding of the factors that affect children's learning in real-life settings where there are more degrees of freedom in terms of what children might focus on and discover. However, in many museums that children visit with their families, there may be clear objectives for parents and children to discover and discuss together in these settings. Some museums also have ample signage provided to parents to direct their children, or staff members present to provide support and scaffolding. So, while these spaces have gone a long way towards understanding how children learn in more naturalistic contexts, much of this work has primarily focused on how children acquire scientific concepts from highly structured indoor exhibits particularly at science museums (e.g., Sobel & Jipson, 2015), and therefore still lacks ecological validity to everyday life. That is, the spaces most commonly examined so far are specifically tailored for children's learning.

Due to the many challenges that come with examining children's learning in their everyday lives, a living history village offers the perfect middle ground between children's everyday life and other informal learning settings, such as science museums[1]. That is, the context of a living history village is much more similar to a child's everyday life than a science museum. These museums are set up as small historic towns and they contain exhibits such as a post office, a butcher shop, and a grocery store. They also tend to contain typical family homes from the historical period, which are similar to many children's current homes, with kitchens, bedrooms, and living rooms. There are also differences that allow for unique learning opportunities; the buildings contain objects that are historical versions of those that would be found in the child's own home and local stores. Therefore, these sites have both a familiarity for children, but also a unique context that requires further exploration and explanation. Living history museums also do not explicitly encourage children's learning and exploration like some children's science museums, as they do not contain signage to guide the visit and the space is created to be suitable for people of all ages.

[1] If you are familiar with the Ken Seiling Waterloo Region Museum, continue reading. If not, it may be beneficial to skip to page 12 and read that section before returning.

This dissertation explores learning opportunities in a living history village by examining children's conversations with their parents and museum staff. Specifically, I examine not only how children's learning opportunities are influenced by their own verbal exploration and engagement, but how parents and museum staff also impact their experiences through their spontaneous use of pedagogical techniques. To do this, I recorded children's conversations with their parent and any present staff members as they explored exhibits at the Ken Seiling Waterloo Region Museum (WRM). I focus on children's conversations about artifacts (Chapter Two), science (Chapter Three), and causality (Chapter Four), in this truly unstructured setting. Children's artifact discussions and learning was chosen not only because it is an area that has a rich history of being heavily studied in labs (e.g., Bloom & Markson, 1998; Casler et al., 2009; German & Johnson, 2002; Kelemen, 1999; Matan &Carey, 2001), but because there are hundreds of novel artifacts for children to encounter and explore at the museum. Understanding how to support children's science learning is currently a priority topic not only for cognitive developmentalists (e.g., Crowley et al., 2001; Haden et al., 2015; Pagano et al., 2020), but also for museum educators (e.g., Anderson et al., 2006; Kisel, 2014; Watermeyer, 2015). Children's understanding of causality has also been heavily studied in laboratory settings (e.g., Sobel & Kirkham, 2006; Sobel et al., 2004; Sobel et al., 2007) and more recently in science museums (e.g., Callanan et al., 2020, Willard et al., 2019). Thus, it is interesting to see how this unfolds in a living history museum, which is more similar to how children encounter these topics in their everyday lives. In this chapter, I will first briefly discuss children's learning as it relates to their understanding of artifacts, science, and causality. Next, I will review research on children's learning in informal learning environments. Finally, I will discuss the Ken Seiling Waterloo Region Museum, the space in which I collected data for my dissertation.

Children's Learning

Cognitive developmental psychologists tend to consider two sides of the learning coin: children's active exploration (a la Piaget) and children's learning from others (a la Vygotsky). Beginning with the child as an active learner, much theory and research suggests that children actively and spontaneously explore the world around them like little scientists (e.g., Piaget, 1930). Under this view, children are motivated to acquire concepts and construct theories about their world (Gopnik et al., 1999; Gopnik & Wellman, 1994). Sociocultural theorists on the other hand, posit that learning is not a solitary process for children, and that children mainly learn through social interactions with others, particularly parents and other parents (Rogoff, 1990; Vygotsky, 1978). In my dissertation, I capture both of these features by examining children's exploration and the role that their parents and experts play in their experiences. But first I discuss children's learning as it relates to their understanding of artifacts, science concepts, and causality. With both artifact understanding and causality, there is a great deal of research from laboratory experiments, which allows for predictions about children might discuss in a naturalistic setting. For science learning, I used elementary school science curricula to make predictions about what we might expect children to discuss.

Children's Artifact Understanding

In all chapters of this dissertation, I either directly or indirectly examine children's naturalistic discussions about artifacts. Much research has examined how and what children learn about artifacts in laboratory studies, as artifacts are ubiquitous, as discussed in further detail in Chapter Two. For example, laboratory studies have shown that children believe that natural kinds, such as animals, have an inner causal essence that gives an item its identity, whereas man-made artifacts do not contain such an essence (Brandone & Gelman, 2009; Gelman, 2003; Keil, 1989). Due to this lack of internal causal essence, children view artifact category boundaries as not as rigid as that of natural kinds (Gelman, 2013; Keil, 1989; Labov, 1973). For example, a large mug can serve a similar purpose as a small bowl, but you would not make a similar inference between a cat and a tiger. Children also believe that artifacts are created with a specific purpose (Diesendruck et al., 2003; Kelemen, 1999), and will actively protest others' atypical use of familiar artifacts (e.g., Casler et al., 2009; Weatherhead & Nancekivell, 2018).

However, there is limited research examining how children discuss artifacts in naturalistic environments, which I discuss in more detail later in this chapter and in Chapter Two. In Chapter Two, I examine how children talk about artifacts in an unstructured museum setting. Specifically, I investigate what features of artifacts children are drawn to discussing with age, using findings from the literature to inform my coding scheme, and how parents and staff influence children's discussions. In Chapter Three, artifact concepts come up again in the context of the science concepts I explore, such as engineering (i.e., discussing an artifact's purpose and operation). In Chapter Four, I examine what children discuss and learn about a coffee grinder, a specific artifact located at the living history village.

Children's Understanding of Science Concepts

Perhaps surprisingly, there is ample opportunity to discuss science at the living history village, which I explore in this dissertation. In Chapter Three, I examine the opportunities children have to learn about science in the space and how these relate to school curricula, specifically concepts related to biology, engineering, and basic physics and chemistry. In terms of biology, children in early elementary school are required to learn about how to categorize various forms of biological life, including humans, and that all animals have basic needs such as air, food, water, and shelter (Michigan Department of Education, 2015; Ontario Ministry of

Education, 2007). Children must also learn that the goal of engineering is to understand the problem at hand and how to solve to it. Engineering concepts also require children to learn about various simple machines and forces, such as levers, pulleys, and gears (Michigan Department of Education, 2015; Ontario Ministry of Education, 2007). Finally related to engineering, children learn that different materials afford an object's purpose (Michigan Department of Education, 2015; Ontario Ministry of Education, 2007). Engineering concepts are also discussed in Chapters Two and Four, although less explicitly, as they relate to different features of artifacts that children can discuss with parents and museum staff. For basic physics and chemistry, children are required to learn about different states of matter: solids, liquids and gasses, and different types of energy, such as electrical, and physical (Michigan Department of Education, 2015; Ontario Ministry of Education, 2007). Children's understanding of these science concepts has typically been examined in educational settings such as classrooms (e.g., Barak et al., 2007; Kruger et al., 1992; Nakhleh & Samarapungavan, 1998), and therefore less is known about how and when children discuss these concepts in their everyday lives.

Children's Understanding of Causality

A common theme throughout this dissertation is children's causal reasoning. Decades of research in laboratory settings has provided an understanding of what infants and children know about causality (see Sobel & Legare, 2014 for a recent review). Classic research has shown that children have an understanding of physical causality as early as infancy. For example, infants expect a ball to immediately roll after being hit by another object, and find it surprising when the ball instead moves after a temporal delay or without a collision (Leslie & Keeble, 1987). Infants also have intuitive theories of support, in that they know that objects need to be physically supported and cannot suspend in mid-air (Needham & Baillargeon, 1993). This also extends to psychological causality, with infants and toddlers expecting a person to act in accordance with their goals and desires (Wellman, 1992; Woodward, 1998). For example, if an infant sees a person consistently reach for a teddy bear, they anticipate the person to continue to reach for that teddy bear, rather than another toy, even if another toy switches locations with the bear (Woodward, 1998). Children are also able to use causal information to make predictions (Gopnik et al., 2001). In a seminal study by Gopnik et al., (2001), researchers introduced a blicket detector to children, that lit up and played music when certain objects, blickets, were placed on it, as described in the opening example to this chapter. Children are able to reason about which objects are blickets (i.e., causal items that activate a machine) based on particular patterns of evidence revealing which items activate and do not activate the machine. Researchers have continued to use this blicket detector paradigm to provide further evidence of children's causal reasoning abilities (e.g., Sobel & Kirkham, 2006; Sobel et al., 2007; Sobel et al., 2004), showing that they understand a variety of complex ideas that relate to formal causal reasoning.

While this research has provided evidence that children are skilled causal learners, there are some shortcomings: Much of this research uses similar designs, and are performed in highly constrained scenarios that isolate one variable at a time. For example, with the blicket detector, from these very specific observations children make their causal inferences. Therefore, these experiments are removed from how children may encounter causal mechanisms in the real world. This concern has led researchers to begin to examine children's causal reasoning in informal learning environments like science centers and museums (e.g., Callanan et al., 2020).

The current dissertation investigates the opportunities children have to learn about causality in the living history village. Causal reasoning comes up in Chapter Two, where I examine children's conversations about the mechanisms that enable different artifacts to function. For example, children discuss the internal mechanisms of many artifacts found in the space, such as the pump organ. In Chapter Three, I also examine causality as it relates to different science concepts that children are exposed to at the living history village. For example, children can discuss how plants and animals grow (biology), how various machines in the store operate (engineering), and how kerosene works as a light source (basic physics and chemistry). In Chapter Four, causality is examined as it relates to a specific artifact, the coffee grinder located in the general store. There I investigate how and what children learn about the internal causal mechanisms of the coffee grinder.

Children's Learning in Informal Learning Environments

Most of the previous work in this area has examined the factors that affect how children acquire science knowledge in science centers and museums (e.g., Sobel & Jipson, 2015). Some of the factors that influence children's learning in these spaces are as expected; for example, the more time children spend actively engaging with a museum exhibit the more children learn about the exhibit (Krakowski, 2012). Therefore, keeping children engaged is of high priority to many museum educators, as it keeps children in the exhibit space longer. To do this, some museum educators build interactive exhibits that promote children's exploration, which makes the experience more memorable for children (Anderson et al., 2002). Museum educators also recognize the important role that parents play in their children's learning in these spaces, and thus some museums build exhibits that encourage meaningful parent-child conversations (Callanan & Jipson, 2001; Callanan et al., 2017; Leinhardt et al., 2003). Signage is also included in many exhibits to help guide parents' interactions with their children, and museum staff are often present to help facilitate parents' and children's engagement in the exhibit. My dissertation work examines interactions that involve children, their parents, and museum staff, therefore I will briefly review the literature on how parents and staff influence children's learning in informal learning environments.

Parental Influence in Informal Learning Environments

Parents' interactions with their children in informal learning environments directly influence what children learn and remember about an exhibit (e.g., Benjamin et al., 2010; Callanan et al., 2020; Haden et al., 2014; Legare et al., 2017). For instance, parents can connect what children are exposed to in a museum exhibit to their own lives, allowing children to better recall information discussed at the exhibit (Anderson et al., 2002). Parents also ask children questions, offer them explanations about the exhibit, and bring various aspects of the exhibit to their child's attention (e.g., Benjamin et al., 2010; Fender & Crowley, 2007; Haden, 2010). For the purposes of the dissertation, we will focus on how parents influence children's conversations about artifacts and science concepts.

As detailed in Chapter Two, parents influence what children learn about artifacts in museum settings. For example, when children explore a zoetrope, a novel artifact that produces the illusion of movement, with their parents, they develop a deeper conceptual understanding of the artifact than if they explore the zoetrope on their own or with peers (Crowley et al., 2001; Fender & Crowley, 2007). Parents and children also have more in-depth conversations about an object when they establish joint attention around the object (Povis & Crowley, 2015). Parents' use of different pedagogical techniques influences how children discuss and learn about science concepts, as discussed more thoroughly in Chapters Three and Four. Specifically, parents' use of critical thinking questions leads to more on topic science related utterances in children (Callanan et al., 2017) and parents' use of explanations results in children engaging in higher levels of explanatory reasoning about an exhibit (Tare et al., 2011).

However, parents also have varying beliefs about the purpose of museums and how to interact with their children in them (Swartz & Crowley, 2004). That is, some parents believe that museum exhibits are a chance to let their child explore what they wish, letting their child take the lead, whereas others focus on explaining everything they see to help their children make connections between the museum and their own lives (Swartz & Crowley, 2004).

As such, many researchers have focused on supporting parents in this space, by providing prompts to influence their behaviour, which I discuss in greater detail in Chapter Four. For example, parents who were trained on elaborative conversational strategies, such as question asking, focusing on the child's interests, linking the exhibit to past experiences, and providing positive feedback, used these strategies more often than those that were not trained (Eberbach & Crowley, 2017). The increased use of these strategies also led to an increase in the amount of on-topic discussions parents had with their child in the exhibit and predicted what children learned from their visit (Eberbach & Crowley, 2017). In my dissertation, I examine whether parents spontaneously use pedagogical strategies when discussing artifacts in Chapter Two, and how they discuss various science concepts in Chapter Three.

Staff's Influence on Children's Learning in Informal Learning Environments

Given the specialized nature of the information museums and science centers contain, parents may not be familiar enough with the material to properly explain these concepts to their children. Parents then may rely on signage provided by the museum, or on interacting with museum staff. Museum staff can prompt parents to interact with museum exhibits in meaningful ways. For example, museum staff can explain scientific principles to families (Jant et al., 2014; Marcus et al., 2018), and scaffold parents' and children's scientific inquiry (Gutwill & Allen, 2010). Museum staff can also prompt parents to ask their children more questions (Haden et al., 2014), and prompt parents to encourage children's exploration and explanations (Willard et al., 2019). Indeed, children explore more of an exhibit with staff present than with just their parents (Letourneau et al., 2021). On the other hand though, the presence of staff has been shown to limit parents' engagement in parent-child interactions in some cases (Letourneau et al., 2021; Pattison & Dierking, 2012; Pattison et al., 2018). Due to their expertise, museum staff may be using different strategies at key moments compared to parents to help support children's learning in these spaces. This question is explored in Chapters Two and Three.

Ken Seiling Waterloo Region Museum

The informal learning environment that I examine in my work is the Ken Seiling Waterloo Region Museum (WRM). The vision of the museum is to be "a center of discovery and learning" that helps visitors to understand "their collective place in the world - past, present and future" (Waterloo Regional Museum's Mission Statement, 2018). As the largest community museum in Ontario, Canada, over 111,000 patrons visit the museum per year. The museum is located within city limits, and is within walking distance of public transportation. Admission is $11 CAD for adults, and $5 CAD for children 5- to 12-years-old, with free parking. Passes to visit the museum for free are also made available through local city libraries. Providing high quality learning opportunities for visitors of all ages is central to their mandate.

The museum site includes two museum galleries. The main indoor gallery tells the history of the Waterloo Region, going back over 12,000 years. This exhibit discusses the history of Indigenous peoples in the region, the community settlement of the Waterloo region, all the way up to the tech sector boom of the 21st century. The second indoor gallery is a rotating exhibit, that features exhibits from all around the world. For example, they have had exhibits on birds of prey, trailblazing women, and aquatic animals and oceans.

My dissertation research took place in their 60-acre living history village, the Doon Heritage Village. Here, the museum aims to teach visitors about local social, economic, and technological history by transporting them to the year 1914. The village contains multiple exhibits that help transport visitors to the turn of the 20th century. There is a railway station, a weaver, harness shop, a tailor shop, blacksmith, meat market, and post office. My work focuses mainly on three locations within the Doon Heritage Village, specifically the Dry Goods and Grocery Story, the Seibert House, and the Sararas-Bricker Farm. The Dry Goods and Grocery Store is a typical 1914 general store. The store was a place for patrons to purchase canned goods, luxuries such as coffee, and other necessities such as school supplies. The Seibert House is a typical house that a wealthier individual in 1914 would have owned, such as a tradesman. This house contained more “modern conveniences” such as a telephone, sewing machine, and pump organ. The Sararas-Bricker Farm is what was referred to as a “mixed-use farm”, where they grew a variety of crops as well as raised livestock. The livestock included pigs, cows, goats, and sheep. With these features, the living history museum is an extremely immersive space that allows children to begin to understand what life was like during this time period.

However, this particular living history village was not designed for children’s learning, or even designed with solely children in mind. Additionally, all the exploration is visitor driven, there is no signage scaffolding parents on how to interact with or engage their children in the exhibit, in order to maintain the integrity of the space and give the illusion that visitors have been transported to 1914. Instead, museum staff members are stationed throughout the village, wearing traditional 1914 clothing, and are available to answer questions and provide helpful information to all visitors. These staff members are predominately White, between the ages of 18-24, and are undergraduate students with a specific interest in history. Although these staff members are highly knowledgeable about the contents of the museum, they are not experts at disseminating information specifically to children. Therefore, this space acts as a middle ground between a museum exhibit and the real world. It contains hundreds of novel artifacts, animals, and scientific concepts to discover and learn about. However, it also resembles how children can encounter information in their everyday lives. High quality learning opportunities are ubiquitous, but not necessarily immediately apparent.

Overview of Dissertation

This work aims to bridge this knowledge gap to further examine how artifact, science, and causal learning opportunities occur in this space, and whether the conversations that parents and children have in these spaces align with the findings from laboratory experiments about children's learning. To do this, I carried out naturalistic observations and an intervention on children 4- to 8-years-olds with their parents at the WRM over the summers of 2018 and 2019. Chapter Two explores 4- to 8-year-old children's spontaneous interactions with parents and museum staff while exploring artifacts. Previously, it has been found that children's artifact understanding changes with child age (e.g., German & Johnson, 2002), however very little work has examined what children are learning about artifacts in naturalistic settings, who they are learning this information from, and how they respond to being provided information.

Using the same dataset, Chapter Three examines whether there are opportunities for informal science learning for 4- to 8-year-old children in unexpected places, such as a living history village. Finally, while Chapters Two and Three highlight the abundance of STEM learning opportunities that this living history exhibit contains for young children, this raises the question of whether it is possible to intervene on children's exploration and learning to direct their attention to a specific feature of an artifact, namely the mechanisms of its operation, which is explored in Chapter Four. Chapter Four is also the only chapter in the dissertation that directly examines children's learning, in that children's knowledgeability about a particular artifact was measured in a test phase, following their explorations and conversations with their parents and the staff.

Chapter Two: "So, what is it?" Examining parent-child interactions with artifacts in a museum

Imagine you encounter a pasta-making machine for the first time. You would probably be eager to understand it, wondering what it's called, what it does, how it operates, and what it's made of. Upon discovering this information, your newly acquired knowledge would allow you to make fresh pasta of your own, teach others how to use it, and think about how this machine is similar to or different from other machines you know about. Young children often find themselves in this situation. They constantly encounter novel artifacts and they must quickly and efficiently acquire information about them, often through their interactions with others.

In the present study, I explore how children and their parents discuss artifacts in a local social history museum in the presence of experts. Specifically, I ask: what aspects of artifacts are children, parents, and staff drawn to discussing in an unstructured museum setting? What strategies do parents and staff use to introduce new features of artifacts to their children in a naturalistic setting? How do children respond to these strategies? Investigating these questions will inform researchers about whether the laboratory findings regarding children's artifact knowledge are evident in more freeform environments and how parents and experts interact when encountering artifacts that are new to children. It will also inform researchers and museum staff about how to best explain different features of artifacts to children, and how to increase children's engagement by examining how they react to some of the pedagogical techniques adults spontaneously use.

Artifact Understanding

There is a strong tradition of examining how children learn about artifacts in the lab, suggesting that children's reasoning about artifacts, including their identity, operation, and purpose, evolves substantially throughout early childhood (e.g., Casler & Kelemen, 2005; German & Johnson, 2002; Greif et al., 2006). Very early on, children are equipped to rapidly learn the identity and categories of novel artifacts via helpful reasoning biases such as the whole-object bias, shape-bias, basic-level bias, and the mutual exclusivity bias (e.g., Halberda, 2003; Landau et al., 1988; Landau et al., 1998; Markman, 1990; Markman et al., 2003), and to make inductive inferences and generalizations based on these biases (e.g., Xu & Tenenbaum, 2007). For example, if an adult points to a truck and labels it "a truck", young children are most likely to assume that the label applies to the entire truck as a kind, and not to something like the wheels or the windshield (i.e., the whole object bias; Markman, et al., 2003; Markman, 1990).

By the preschool years, these biases that help children identify objects have also shaped their conceptual development and learning in other ways. For example, mutual exclusivity guides children's belief that artifacts should only belong to a single category and the belief that artifacts typically hold a singular operation (e.g., German & Johnson, 2002). Children around this age also start to reason in sophisticated ways about the causal mechanisms underlying the operation of artifacts (Gopnik & Sobel, 2000). For example, young children are able to use their understanding of insides to reason about what causes (or prevents) an artifact's operation (e.g., Sobel et al., 2007). Their new understandings of artifacts eventually lead children to view artifact function normatively and to actively protest others' atypical use of familiar artifacts (e.g., Casler et al., 2009; Weatherhead & Nancekivell, 2018).

By the end of early childhood, children's increased knowledge about artifacts allows them to become better tool makers (e.g., Beck et al., 2011, Beck et al., 2014), and to appreciate the role of design, in deciding an artifact's identity (e.g., Bloom & Markson, 1998; Diesendruck et al, 2003). For example, at around 6-years-old children start to view the designer's intended purpose for an artifact as more central to its identity than other considerations like how someone else is currently using it (German & Johnson, 2002; Kelemen, 1999; Matan & Carey, 2001).

Thus, in the current investigation, I examine how children talk about artifacts in an unstructured museum setting to determine which of these aspects emerge as topics in their natural conversations with adults. Specifically, I am interested in children's discussions related to an artifact's composition, identity, operation, and purpose. Although laboratory studies have shown that by 4-years-old, children want to know about the identify of an artifact (Greif et al., 2006; Markman et al., 2003), how it operates (e.g., Greif et al., 2006), and what its purpose is (Casler & Kelemen, 2005; German & Johnson, 2002), it is unclear how these findings translate to more naturalistic settings such as museums, in unstructured interactions.

Children's Interactions in Museums

It is well known that parents play an important role in young children's learning. Research conducted in museums and science centers has been critical in establishing this empirically (Benjamin et al., 2010; Callanan et al., 2011; Callanan et al., 2020; Crowley et al., 2001; Fender & Crowley, 2007; Franse et al., 2020; Haden et al., 2014; Jant et al., 2014; Legare et al., 2017). Research in museums has explored the influence of parents on children's spatial and mathematical reasoning (e.g., Perez & McCrink, 2019; Polinsky et al., 2017; Vandermass-Peeler et al., 2016) and children's understanding of engineering concepts (e.g., Marcus et al., 2017).

Two studies have examined how children explored a novel artifact (a *zoetrope*) in informal spaces with their parents (Crowley et al., 2001; Fender & Crowley, 2007). In these studies, 4- to 8-year-old children were more engaged and discovered more properties of the zoetrope when they explored it with their parents as opposed to their peers or on their own.

These children also left the exhibit with a deeper understanding of zoetropes, including a deeper understanding of the underlying mechanisms that support its operation (Crowley et al., 2001; Fender & Crowley, 2007). In terms of parent talk, studies using interviews and structured tasks have revealed that parents often highlight teleological (function/purpose) information in their discussions about artifacts with children. However, these studies also reveal that parents are more likely to invoke causal than teleological explanations when children ask them an ambiguous question, suggesting that parents provide varied information to their children, which can change depending on circumstances (Gelman et al., 2015; Kelemen et al., 2005).

Specific parental behaviors also elicit different amounts and types of engagement from children (e.g., Benjamin et al., 2010; Callanan et al., 2017; Chandler-Campbell et al., 2020; Haden et al., 2014; Pagano et al., 2020). One such study about an evolution exhibit showed that the nature of parents' discussions can influence children's engagement levels. In that study, parents' use of explanations resulted in children engaging in higher levels of causal-explanatory reasoning about an exhibit (Tare et al., 2011). Another study showed that parents who encourage their children to *explain* in a gear exhibit can enrich their experience by influencing what they notice about the causal mechanisms of the gears, and how they experiment with them (Willard et al., 2019). Parents who prompted their child to *explore* led their children to spend more time interacting with the gears (Willard et al., 2019). Finally, children provided more scientific information in response to causal statements made by parents when the dyad was prompted to question and explain in a circuit board exhibit (Chandler-Campbell et al., 2020). Beyond the particular strategy parents employ, parent-child interaction style also influences how children learn about artifacts (Medina & Sobel, 2020): children whose parents directed their experience while interacting with a causal system (i.e., a light up toy) best learned how to make the toy light up, compared to children whose parents allowed them to lead the interaction and children whose parents jointly engaged in the exhibit with them (Medina & Sobel, 2020).

Due to the nature of museums and science centers, staff are often present to facilitate learning and provide expertise. While a large body of research has examined how instructions from museum staff to parents impact children's engagement (e.g., Haden et al., 2014), there has been an increasing interest in staff's interactions with families. A qualitative analysis revealed that staff and parents both actively facilitate children's learning in museum exhibits, and staff often introduce new learning goals to children (Pattison & Dierking, 2012), and increase engagement time (Pattison et al, 2018). However, parents can become less engaged if the museum staff member takes an over-active or strongly didactic role in the interaction (Letourneau et al., 2021; Pattison & Dierking, 2013; Pattison et al., 2018). This previous research suggests that parents and staff play different roles during an interaction with children in a museum setting.

Overall, these studies show that parents' and staff's explanations and guidance influence children's reasoning about artifacts, but they leave open many questions about how children interact with and discuss artifacts in these settings. For example, this work does not speak to the wider range of strategies, beyond explanations, that parents and staff might naturally employ when teaching their children about novel artifacts (e.g., analogies, or questions) nor how they might be strategically used. Specifically, are staff and parents using a variety of strategies, and in roughly equal amounts when discussing artifacts? Are they tailoring their strategies to specific aspects of artifacts? For instance, are they using more analogies when discussing the identity of an artifact, or more causal reasoning statements when discussing an artifact's operation? In the current investigation, I examined the pedagogical strategies parents and staff use when discussing different features of artifacts. Namely, I examined how they use questions, causal reasoning statements, analogies/comparisons, and simple procedural information (Callanan et al., 2017).

Finally, while research has shown that parents' explanations can increase causal understanding in children (e.g., Tare et al., 2011), less is known about how children respond to different pedagogical strategies in an unstructured, naturalistic setting. For instance, we know that children are more engaged when parents request explanations and ask critical thinking questions, rather than make explanatory statements (causal reasoning statements/ simple procedural information) when discussing scientific concepts at a science museum (Callanan et al., 2017). However, I examine whether these four pedagogical strategies elicit increased or decreased engagement, and whether they result in different amounts of information-seeking, or information-giving from children.

The Present Study

Building on both the artifact and parent-child interaction literature, the present investigation includes a series of analyses that offer insight into how children and parents interact with artifacts in an unstructured learning environment. It has the following goals:

1) To identify the artifact features (i.e., the composition, identity, operation, or purpose) that children, their parents, and museum staff target in their discussions about artifacts and explore how these discussions may evolve with children's age.
2) To explore the pedagogical strategies naturally employed by parents and staff in their unstructured discussions about artifacts with their children.
3) To examine how children's engagement and responses are affected by the pedagogical strategies used by parents and staff.

Method

Participants

Participants were 40 parent-child dyads, as well as museum staff. Children were between the ages of 4- and 8-years old (20 females, M_{age}=5.98 years, *SD*=1.06, R_{age}= 4.22- 8.01 years) and they participated with their parents. This age range was chosen because it coincides with notable development in artifact understanding (e.g., German & Johnson, 2002), and fully encapsulates early childhood. I use the term *parents* for shorthand, but three children participated in a child-grandparent dyad. These grandparents were reported to be highly involved, regular caregivers to the children. Seven additional dyads participated but were not included in the analyses; six because they were out of the interested age range (which was discovered after their participation), and one for lack of footage in one of the buildings. For demographics pertaining to the children and their families, see Appendix A. The participants were primarily White (*N*= 32) and Christian (*N*=20) or Atheist (*N*=13), university educated, and middle class. They are more diverse from a linguistic perspective, as 57% of the sample primarily speak English in the home. Most of the participants visit the museum once a year (*N*= 18), followed closely by those who had never visited previously (*N*= 13). The dyad completed the study without additional children (such as siblings or friends) present.

The parent-child dyads visited three locations at the museum, thus there was also the opportunity for each dyad to interact with any of the staff members at each location. Museum staff members were not held constant across children or locations, as to not disrupt typical museum functioning for the study. Staff members were asked to behave as they normally would with any other patrons. These staff members were generally not trained in research and blind to all study hypotheses.

All participants were recruited from Kitchener-Waterloo Region via social media advertisements or from a university database. Participants were tested between July and August 2018. The testing window was constrained by weather, as the village museum is only open in the summer months and closes frequently for inclement weather. The goal was to collect as many participants as possible during this time period, thus I did not base the sample size on a formal power analysis. Prior work employing similar open-ended investigations in museums suggests that the achieved sample size of 40 participants was adequate for investigating the present questions (e.g., Benjamin et al., 2010; Chandler-Campbell et al., 2020); however, it is possible that some of the analyses may be under-powered. Participants received a family pass to come back to the museum in appreciation.

Materials and Procedure

Over the course of two hours, participants visited three locations in a counterbalanced order: a general store, a typical 1914 house, and a farm. Recordings from the farm were not used in this paper, as very few artifacts were present there for the dyad to explore. The general store featured dry goods on one side and groceries on the other and encouraged children to learn about the commercial and social activities in the community through artifacts like the cash register, coffee grinder, and telephone. The 1914 house reflected the family lifestyle of a typical small business owner and featured artifacts like a pump organ, sewing machine, and phonograph (see Table 1 for list of artifacts in both locations).

Table 1

Examples of artifacts in the store and house

Artifacts at the store	Artifacts at the house
Cash Register	Pump Organ
Coffee Grinder	Sewing Machine
Cheese Cutter	Stereoscope
Wind-up toys	Laundry Rack
Scale (to weigh items)	Kaleidoscope
Spittoon	Oven
Gumball Machine	Gramophone
Fireplace	Phonograph

Interactions were recorded using a Zoom Q2n-4k camera fitted to the child's chest using a GoPro Junior Chesty. After fitting children with the camera, they were led to the exhibits. Before participating, parents were told to interact with their child as they normally would, and that the researcher would let them know when it was time to visit the next location. Children were given the minimal instruction to "learn as much as you can and to ask as many questions as you can." Notably, this prompt was given to only the children and not their parents. It also did not direct children to attend to certain artifact features or even to artifacts at all. As such, it gave children a general goal (to learn) and encouraged them to speak, but also did so without introducing significant structure to the interaction.

The dyad was also given a suggestion of where to begin in each location (e.g., "We suggest starting with the pump organ"), as piloting indicated that giving children and parents a starting point helped ease them into the study. However, they were told to explore the exhibit as they would on any other day. They did not have to start at that location if they did not want to.

Dyads were given a maximum of 8 minutes to explore each exhibit during the study. The time was selected based on pilot data and discussions with museum staff. At the 8-minute mark or when the dyad indicated they were done exploring, the research assistants would enter the exhibit and direct the dyad to the next location.

Transcription and Coding

Each visit was transcribed and then broken into utterances by a research assistant. An utterance was operationalized as a continuous unit of speech without pauses, interruptions, or changes in subject (e.g., typically an independent clause). Transcripts were originally created in Microsoft Word, and then transferred to a Microsoft Excel file, with each utterance on a single row. Each participant had their own Excel file, with all utterances from their visit in the single file. These transcripts were not time stamped. All transcripts were checked for errors by a second research assistant. If any errors were detected in the transcripts, they were discussed, and then checked again for accuracy by a third research assistant. This process resulted in the identification of 4,051 utterances spoken by children, 5,698 utterances by parents, and 5,747 utterances by staff for the two locations of interest.

Transcripts were then coded in Microsoft Excel. Each coded category was given a column in Excel, and if the utterance fell within the coded category, it was marked with a 1 in the appropriate column, if not, it was marked with a 0. As a first step, a research assistant identified utterances that were related to artifacts at the museum. An artifact was operationalized as any object at the museum that was made by a person or factory like toys, clothing, and simple machines that do not occur in nature. Through this process, 1904 child, 3137 parent, and 3447 staff utterances were identified as pertaining to artifacts. Therefore, 47% of child, 55% of parent, and 60% of museum staff utterances are related to artifacts.

Artifact-related utterances were then coded as they related to the aims of the investigation using three coding schemes. To prevent bias, age and gender of the child (and identity of the parent) were blinded before coding. The primary coder was a research assistant blind to the hypotheses of the study throughout the process. I acted as a secondary coder and reliability coded 30% of utterances. The coding schemes were as follows (see OSF supplement osf.io/8r5pm for the full coding scheme).

Artifact Discussions

The first scheme aimed to capture the topics of discussion among the child-parent-staff members (i.e., triad). To accomplish this goal, utterances were coded into four mutually exclusive categories: identification, operation, purpose, and composition (Evangelou et al., 2010). These categories reflect what a child would need to discover in order to fully understand an artifact, and they were based on the experimental psychology literature that has examined how children learn about artifacts in laboratory settings (e.g., Casler & Kelemen, 2005; German & Johnson, 2002; Greif et al., 2006; Markman et al., 2003). Reliability was excellent with a Kappa of .916 (Landis & Koch, 1977). The majority of the utterances, including, 1143 child, 1906 parent, and 2360 museum staff utterances, fell into one of these four categories.

In terms of children's own talk, at least three different potential patterns of results are possible: First, it is possible that children's discussions might be mainly focused on the composition and identity of artifacts. For example, children might have focused on commenting on the color or size of artifacts and/or naming things they are familiar with. This pattern of findings might occur if young children rely mainly on their sensory experiences to guide their discussions (e.g., Brandone et al., 2007; Landau et al., 1998). Alternatively, children's discussions about artifacts may have focused mainly on less obvious and more complex features of artifacts, such as their operation and purpose. This is in line with prior research suggesting that from a young age children view purpose and operation as important features to learn about artifacts (Greif et al., 2006; Kemler Nelson et al., 2004). A third possibility, and the one I hypothesized as most likely, is that age might influence the topics of children's conversations and we may see a shift in their discussions from more to less obvious features of artifacts.

When examining discussions about artifacts in naturalistic settings, much of the previous work provided parents with prompts to guide their conversations with their children (e.g., Willard et al., 2019). As such, I aimed to fill the gap in the literature as to what parents and staff would naturally discuss about artifacts with children.

Parent and Staff Pedagogical Strategies

The second scheme focused on understanding the strategies parents and staff used to teach children about the artifacts they encountered. Parent and staff utterances were coded into four mutually exclusive categories: questions, causal reasoning statements, analogies/comparisons, and simple procedural information (Callanan et al., 2017). Reliability was excellent with a Kappa of .849 (Landis & Koch, 1977).

This coding allowed me to capture and differentiate among the strategies parents could adopt when teaching their children about artifacts, of which there are a few possibilities. First, and what I hypothesized as most likely, parents and staff might have been selective with their use of pedagogical strategies. In this case, they would tailor the strategy they use to the features of the artifacts under discussion. For instance, they may have used more analogies/comparisons when trying to explain the identity or category membership of an artifact, but more causal statements when discussing the operation of an artifact. This possibility is supported by developmental work suggesting that certain strategies might be more effective for teaching children about certain topics (e.g., Callanan et al., 2017). A second possibility is that parents and staff might have relied on one or two strategies that they view as highly effective. For example, they may have primarily used question asking and causal statements regardless of the topic under discussion because they thought those are the best teaching strategies generally or for their specific child (e.g., Legare et al., 2017). A final possibility is that parents and staff would indiscriminately use all pedagogical strategies. In this case they would use strategies equally often regardless of the topic under discussion.

Given the conflicting research suggesting that museum staff can increase engagement in an exhibit (Pattison et al., 2018), but can also cause parents to become less engaged (e.g., Pattison & Dierking, 2013), it is important to examine if there are differences between the pedagogical strategies parents and museum staff employ. Because this particular museum is not specifically tailored to children, staff may not have tailored their pedagogical strategies in a similar manner to parents, or use these strategies at similar frequencies and proportions.

Children's Responses to Pedagogical Strategies

The third coding scheme examined how children respond to the pedagogical strategies provided by parents and staff. Here, I examined children's conversational turns that followed a pedagogical strategy provided by a parent or staff member. This was done in combination with the raw footage of each participant's visit. As a first step, I eliminated instances where a child had no opportunity to respond to a pedagogical technique, because an adult immediately interrupted or spoke, giving the child no space to respond (825 of the total 2345 techniques, leaving 1520 instances). I next coded whether children did or did not respond for the 1520 instances in which they had the opportunity. Children responded to 1128 pedagogical strategies either verbally or physically (by touching or manipulating the artifact in some way). Of these, 979 pedagogical strategies were responded to verbally. Physical responses could not be coded in any finer detail due to the angle of the camera footage (being on the child's chest versus an aerial view of the space), so those physical responses will not be discussed further.

Next, verbal responses were coded into a binary scheme to determine whether children were engaged and on topic in their verbal responses or not. To be included as engaged and on topic, children had to be discussing an artifact or an artifact of a similar kind or category. Thus, responses were coded as not engaged if they included replies such as “yeah” or “mhm”, or were *one-word replies* such as “antique”[2], which are difficult to classify any further and appeared to reflect minimal engagement. 606 responses were coded as engaged verbal responses, whereas 310 responses were coded as not engaged verbal responses. 51 responses were coded as versions of “I don’t know”.[3]

Finally, the engaged verbal responses were further classified into one of three mutually exclusive categories. These categories were: information-seeking responses, information-giving responses, and responses that involved both seeking and giving. These categorizes were chosen to capture the responses these pedagogical strategies elicit from children in naturalistic settings, whereas previous research has mostly examined engagement as it relates to learning outcomes (e.g., Callanan et al., 2020).

I predicted that children would have the highest level of engagement and the most information-giving responses to questions (Callanan et al., 2017), but had no specific predictions for which types of strategies would elicit a higher proportion of information-seeking responses.

Results

Goal 1: Discussions About Artifacts and Their Features

Both the proportion of utterances and the frequency of utterances were analyzed. Frequency was analyzed because they reveal the sheer volume (i.e., pure exposure to) of

[2] As an example, this particular reply was in response to a parent telling their child that old artifacts are called antiques. Thus, it was a simple repetition of a (probably) novel word, reflecting minimal engagement.
[3] *I don’t know* is difficult to classify. This can be a meaningful statement reflecting introspection of one’s knowledge state or it can be used as a somewhat dismissive device.

different kinds of artifact talk and pedagogical strategies, which is of particular interest to the partner museum and those like it because it gauges overall engagement. Proportion of each speaker's type of talk was also analyzed, because I wished to understand how their artifact talk was distributed. This offers insights into what the triad was drawn to discussing. Also of note, analyzing proportion scores eliminates the confounds generated from the fact that some participant triads may talk more overall than others.

For proportion of artifact talk, Dirichlet regressions were conducted, with proportion of the speaker's artifact talk as the dependent variable, and child age in months as a predictor variable, with each speaker analyzed separately. Dirichlet regression is suitable when proportional data are distributed over more than two categories and the categories sum to one (e.g., the subtypes of artifact talk sum to one for each speaker, Douma & Weedon, 2019). Proportions of artifact talk were calculated using the raw frequency of type of artifact talk, by the total amount of categorizable artifact talk for each speaker.

For the frequency of artifact talk, a poisson-based Generalized Estimating Equations (GEEs) was run, which included the predictors child age in months (centered and entered as a covariate) and the within-subjects variable category of artifact talk (operation, purpose, identification, and composition). The dependent variable was the frequency of artifact talk. A poisson-based GEEs was used, as this is most appropriate for count data.

Children's Artifact Talk

The highest proportion and frequency of children's artifact talk related to identification, followed by operation, then purpose, and finally composition (see Table 2 for means). The Dirichlet regression examining proportions revealed a main effect of age for the proportion of talk identifying artifacts $z = -2.320$, $p = .020$, but not for the proportion of children's talk discussing an artifact's composition, operation, and purpose (*ps* > .428). This indicates that the proportion of children's talk related to identification *decreased* with children's age.

Table 2

Means and Standard Deviation for Proportion and Frequency of Artifact Talk

	Child		**Parent**		**Staff**	
	Proportion	Frequency	Proportion	Frequency	Proportion	Frequency
Composition	.070	2.075	.062	3.075	.050	3.200
	(.199)	(2.575)	(.054)	(3.181)	(.051)	(3.757)
Operation	.290	8.200	.346	15.975	.529	31.000
	(.173)	(6.223)	(.178)	(10.232)	(.127)	(16.824)
Identification	.490	13.475	.411	19.675	.191	11.450
	(.069)	(8.333)	(.157)	(12.646)	(.081)	(7.551)
Purpose	.150	4.825	.181	8.925	.230	13.350
	(.106)	(4.156)	(.080)	(7.290)	(.099)	(8.722)

The GEE examining frequencies revealed a main effect of age $WaldX^2$(df = 1) = 6.348, p = .012, with frequency of all types of talk increasing with child age, a main effect of category of artifact talk, $WaldX^2$(df = 3) = 110.828, p < .001, and no artifact talk by age interaction $WaldX^2$(df = 3) = 2.196, p = .533. Follow-up pairwise comparisons revealed that all talk types differed from one another (*p*s < .001)[4].

Parents' Artifact Talk

Like children, the highest proportion and frequency of parents' artifact utterances related to identification, followed by operation, then purpose, and finally composition (see Table 2 for means). The Dirichlet regression examining proportions revealed a main effect of age for identification z = -3.839, p < .001, but no other types of talk (*p*s > .093). This indicates that the proportion of parents' talk related to identification *decreased* with children's age.

[4] All follow-up comparisons were corrected for multiple tests.

The GEE examining frequencies revealed no main effect of age *WaldX*^{2}(df = 1) = .825, p = .349, a main effect of category of artifact talk *WaldX*^{2}(df = 3) = 203.597, $p < .001$, and an artifact talk by age interaction *WaldX*^{2}(df = 3) = 13.133, $p = .004$. Follow-up pairwise comparisons revealed that all types of talk differed from one another (*p*s < .03). Separate GEEs spilt by artifact talk category with age as a predictor were used to examine the interaction and no main effects of child age were found (*ps* > .064).

Staff's Artifact Talk

Unlike parents and children, the highest frequency and proportion of staff's artifact utterances related to operation, followed by purpose, then identification, and finally composition (*M* = .050, *SD* = .051; see Table 2 for means). The Dirichlet regression examining proportions revealed no main effect of age for any types of talk (*p*s> .143), indicating that staff did not change the proportion of their discussions about artifacts based on child age.

The GEE examining frequencies revealed no main effect of age *WaldX*^{2}(df = 1) = .095, p = .758, a main effect of category of artifact talk, *WaldX*^{2}(df = 3) = 297.223, $p < .001$, and no artifact talk by age interaction *WaldX*^{2}(df = 3) = 3.291, $p = .349$. Follow-up pairwise comparisons revealed that all types of talk differed from one another (*p*s < .001), except for identification and purpose ($p = .088$).

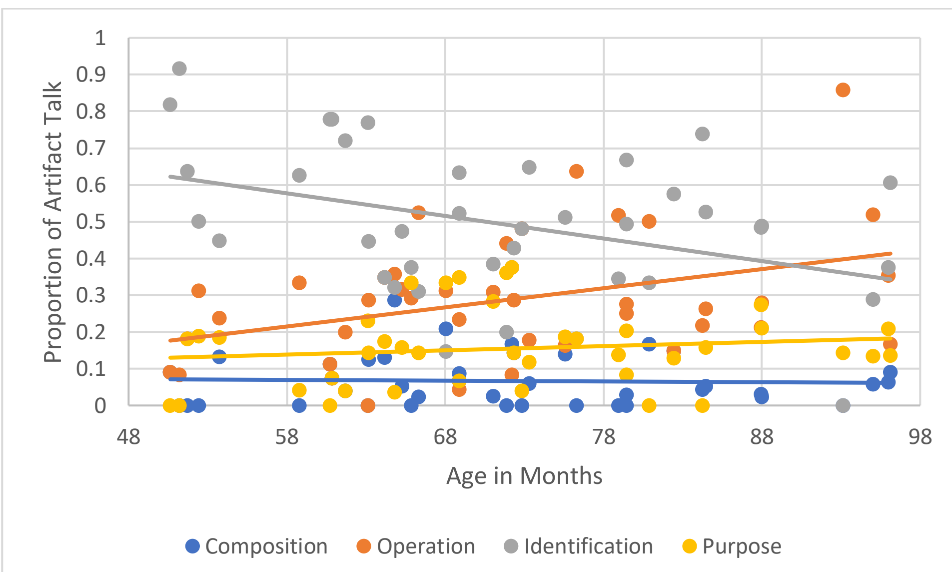
Summary

Members of the triads talked about the four aspects of artifacts in differing amounts. Interestingly, while parents and children talked most about identification, then operation, then purpose, then composition, staff talked most about operation, then purpose and identification, then composition. This suggests that different members of the triad bring unique information and interests to the interaction.

Additionally, the proportion of parents' and staff's discussions about artifact features did not differ based on child age, except for parents' identification talk decreasing with age. However, there were age-related differences for both the proportion and frequency of children's talk. Specifically, the proportion of children's talk related to identification decreased with age, suggesting that the proportion of talk relating to more sophisticated aspects of the machine (i.e., operation, purpose and composition) increased with age. Visual inspection of the data (see Figure 1) suggests that the proportional increase with age was mostly concentrated in operation, and to a lesser extent purpose. For example, children would ask what artifacts are for as made hypotheses about this: "*Well oh um I think that's for knitting and stuff.*".

Figure 1

Proportion of Children's Artifact Talk



Goal 2: Pedagogy

I explored the pedagogical strategies employed by parents and staff in their discussions of artifacts. To do this, Dirichlet regressions were again conducted, with proportion of the speaker's pedagogical strategy as the dependent variable, and child age in months as a predictor variable.

Proportions of pedagogical strategies were calculated using the raw frequency of the type of pedagogical strategy, by the total amount of pedagogical strategies for each speaker.

The frequency of each kind of pedagogical strategy was also examined and whether their use differed as a function of child age in months using a poisson-based GEE. These GEEs included the predictors of child age (centered and entered as a covariate), and the category of parental strategy (causal, comparisons, procedural, and question asking) entered as a within-subjects factor. The dependent variable was the frequency of the pedagogical strategies.

Parent Pedagogy

The highest proportion and frequency of parents' pedagogical strategies were question asking, then simple procedural information, followed by comparisons, and causal statements (see Table 3). The Dirichlet regression examining proportions revealed no main effect of age for any strategy (*p*s > .125), indicating that the proportion of parents' pedagogical strategies did not change with child age.

Table 3

Means and Standard Deviation for Proportion and Frequency of Pedagogical Strategies

	Parent		**Staff**	
	Proportion	Frequency	Proportion	Frequency
Critical Thinking Questions	.449 (.207)	13.275 (10.598)	.087 (.079)	2.750 (2.959)
Causal Reasoning	.090 (.085)	2.800 (3,204)	.258 (.146)	8.150 (5.758)
Comparisons or Analogies	.157 (.109)	4.750 (3.794)	.104 (.086)	3.000 (2.828)
Simple Procedural Information	.278 (.193)	7.075 (5.932)	.552 (.128)	17.025 (10.666)

The GEE examining frequencies revealed no main effect of age *Wald*X^2(df = 1) = .308, p = .579, a main effect of pedagogical strategy *Wald*X^2(df = 3) = 161.180, p < .001, and a category by age interaction $WaldX^2$(df = 3) = 11.596, p = .009. Follow-up pairwise comparisons revealed that all strategies were used at significantly different proportions from one another (ps < .02). Separate GEEs, spilt by parent strategy with age as a predictor were used to examine the interaction and no main effects of child age were found (ps > .1).

Staff Pedagogy

In contrast to the pattern from parents, the highest proportion and frequencies of staff's pedagogical strategies were procedural information, then causal explanations, followed by comparisons, and question asking (see Table 3). The Dirichlet regression examining proportions revealed no main effect of age for any strategy (ps > .229).

The GEE examining frequencies revealed a main effect of pedagogical strategy $WaldX^2$(df = 3) = 307.634, p < .001, no main effect of age $WaldX^2$(df = 1) = .098, p = .754, and no category by age interaction, $WaldX^2$(df = 3) = 3.520, p = .318. Follow-up pairwise comparisons revealed that all strategies were used at different proportions from one another (ps < .001), except for comparisons and question asking (p = .718).

Relation Between Artifact Discussions and Pedagogy

Finally, I sought to understand how parents' and staff's use of different strategies might be related to type of artifact talk. This was done using linear-based GEEs, with predictors of child age in months (centered, and entered as a covariate) and within-subjects variables of type of artifact talk (composition, identification, operation, and purpose). The dependent variables were the frequency of each pedagogical strategy by all pedagogical strategies involving that artifact talk category (e.g., questions involving function by all pedagogical strategies involving function), log plus .1 transformed to account for the zeros in the dataset. Dirichlet regression was not used here, as the proportional scores do not sum to one.

See OSF supplement osf.io/8r5pm for all statistical analyses, Table 4 for a summary, and Table 5 for means. Results indicated that parents and staff employed the four strategies in different proportions depending on the aspect of the artifact they were discussing (there was a main effect of category of artifact for all GEEs for all speakers; ps < .006). These proportions generally did not differ depending on children's age, except that parents were less likely to ask critical thinking questions as children got older ($p = .025$). However, both parents and staff used these strategies in sophisticated ways: The highest proportion of comparisons (*p*s < .035) and critical thinking questions (*p*s < .05) occurred when discussing the identity of artifacts. For example, in discussing the sewing machine a parent said: *"Doesn't that look like grandma's sewing machine ?"*. The highest proportion of causal reasoning statements occurred when discussing the purpose and operation (*p*s < .02) of artifacts. For example, when discussing the operation of the sewing machine, a parent said, "*That turns this belt, which turns a gear in there that pumps up the needle up and down*.". Parents and staff also used simple procedural information when discussing an artifact's operation (*p*s < .003). For example, when explaining how the pump organ operates, a staff member said, "*You pump your feet back and forth."*.

Table 4

Summary of the Proportion of Each Type of Artifact Talk for the Pedagogical Strategies

	Highest to lowest proportion
Parents	
Critical Thinking Questions	Identity > Purpose > Operation > Composition *critical thinking questions decreased with child age
Causal Reasoning	Purpose > Operation > Composition & Identity
Comparisons	Identity > Composition & Operation & Purpose
Procedural Information	Operation > Purpose > Composition & Identity
Staff	
Critical Thinking Questions	Identity > Purpose > Composition & Operation *but purpose and operation did not differ
Causal Reasoning	Purpose & Operation > Composition & Identity
Comparisons	Identity > Composition & Purpose & Operation *but composition and operation differed
Procedural Information	Operation > Purpose > Composition & Identity

Note. > indicates a significant difference; & indicates a non-significant difference.

Table 5

Means and Standard Deviation for Parents' and Staff's Relation Between Artifact Discussions and Pedagogy

	Composition	**Identification**	**Operation**	**Purpose**
Parents				
Critical Thinking Questions	0	.691 (.284)	.165 (.202)	.406 (.335)
Causal Reasoning	.042 (.168)	.005 (.024)	.109 (.179)	.234 (.284)
Comparisons or Analogies	.229 (.405)	.254 (.245)	.104 (.119)	.079 (.132)
Simple Procedural Information	.005 (.032)	0	.587 (.291)	.132 (.270)
Staff				
Critical Thinking Questions	.058 (.225)	.227 (.316)	.047 (.065)	.108 (.234)
Causal Reasoning	.125 (.315)	.048 (.175)	.243 (.156)	.384 (.345)
Comparisons or Analogies	.202 (.378)	.476 (.421)	.027 (.049)	.072 (.184)
Simple Procedural Information	.040 (.169)	.024 (.073)	.684 (.167)	.312 (.305)

Goal 3: Children's Responses to Pedagogical Strategies

For each of these analyses, analyzed parent and staff pedagogical strategies were analyzed together to increase power.

Engaged Responses.

First, I examined if children's engagement differed between pedagogical strategies. To do this, a linear-based GEE was run, with the predictor child age in months (centered, and entered as a covariate) and the within-subjects variable, pedagogical strategy (critical thinking questions, causal reasoning, comparisons, and procedural information). Proportion of engagement was calculated using the raw frequency of engagement by the total amount of engagement for each pedagogical technique. The dependent variable was the log-transformed proportion of engaged responses to each of the pedagogical strategies plus .1.

This GEE revealed a main effect of type of pedagogical strategy $WaldX^2$(df = 3) =88.667, p < .001, no main effect of age $WaldX^2$(df = 1) = 2.430, p = .119, and no interaction $WaldX^2$(df =

3) = 3.788, $p = .285$. Children were most likely to be engaged when responding to questions, then comparisons and procedural information, and finally causal statements (see Table 6). Follow-up pairwise comparisons revealed that the proportion of engaged responses to all strategies were different from one another (*p*s < .015), except for procedural information versus comparisons ($p = .485$).

Table 6

Means and Standard Deviation for Children's Responses to Pedagogical Strategies

	Engaged	**Information-Seeking**	**Information-Giving**
Critical Thinking Questions	.827 (.197)	.122 (.194)	.811 (.222)
Causal Reasoning	.405 (.404)	.213 (.334)	.337 (.426)
Comparisons or Analogies	.609 (.374)	.154 (.285)	.633 (.422)
Simple Procedural Information	.501 (.313)	.290 (.383)	.489 (.439)

Information-Seeking and Information-Giving Responses

Next, I explored how children responded to different pedagogical strategies, and whether their responses differed as a function of child age in months using a linear-based GEE. This GEE included the predictor child age in months (centered and entered as a covariate) and the within-subjects variable, pedagogical strategy (critical thinking questions, causal reasoning, comparisons, and procedural information). The dependent variables were the proportion of information-seeking, and information-giving responses within each of the pedagogical strategies, log plus .1. Proportions of response type (information-seeking or information-giving) were calculated using the raw type of response within each pedagogical strategy, by the total amount of response type within each pedagogical strategy (i.e., information-seeking questions by all responses to questions). The proportion of "both" was not analyzed as it occurred infrequently ($M = .056$, $SD = .159$).

Information-Seeking Responses. This GEE revealed no main effect of type of pedagogical strategy $WaldX^2$(df = 3) = 3.756, p = .289, a main effect of age $WaldX^2$(df = 1) = 4.541, p = .033, and no interaction $WaldX^2$(df = 3) = .344, p = .952 (see Table 6 for means). These results indicate that children do not change the proportion of their information-seeking responses based on pedagogical strategy, but information-seeking responses increase with age.

Information-Giving Responses. This GEE revealed a main effect of type of pedagogical strategy $WaldX^2$(df = 3) = 68.944, p < .001, no main effect of age $WaldX^2$(df = 1) = 1.385, p = .239, and an interaction $WaldX^2$(df = 3) = 16.660, p = .001. The highest proportion of information-giving responses occurred in response to questions, then comparisons, procedural information, and causal information (see Table 6). Follow-up pairwise comparisons revealed that responses to all strategies differed from one another (*p*s < .001), except for procedural information and causal statements (p = .08) and procedural information and comparisons (p = .147).

To break down the interaction between pedagogical strategy and age, a linear GEE split by pedagogical strategy, with age as a predictor was run. There was no main effect of age for causal statements, comparisons or critical thinking questions (*p*s > .088). There was a main effect of age for procedural information $WaldX^2$(df = 1) = 7.695, p = .006.

Summary

The specific pedagogical strategies parents and staff used appeared to influence children's engagement, with children being most engaged when responding to a question, and least engaged when responding to a causal reasoning statement. Parents and staff tended to ask children about the identity "*Have you seen a toy like this?*", and the purpose of artifacts "*Do you know what this is for?".*

The pedagogical strategies parents and staff used also appeared to influence *how* children responded to parents and staff. While the proportion of children's information-seeking responses did not change based on pedagogical strategy, children's proportion of information-giving responses did, with children providing information more when asked a critical thinking question and least when given causal reasoning information. Additionally, there were age-related differences in children's information-giving responses, with the proportion of responses increasing with age for procedural information.

Discussion

I examined how children, parents, and staff talk about artifacts in an unstructured museum setting, the pedagogical strategies that parents and staff used in their discussions, and children's responses to these pedagogical strategies. Below I discuss the implications of key findings in turn.

Artifact Understanding

Discussions in the museum touched on the purpose, operation and identity of artifacts, but less often on their composition. For example, children would discuss how to operate the pump organ *"I think you have to have them [the stops] pulled out"* and showed interest in how the artifacts operated *"I wanna see how this works."*. Parents would discuss the identity of artifacts by pointing them out to their children *"Did you see their sewing machine?"* as well as the purpose of artifacts *"Maybe it could measure how much something weighs"*. There were a few notable patterns in children's discussions.

First, I found that children did not talk exclusively about obvious visible features of artifacts such as their composition. Children could have easily mostly discussed visible features of the artifact, and indeed some children provided "composition" statements like: *"Hmm, why is that sharp?"* and *"Ohh look it's red"*, and the physical size of artifacts *"Look it's the bigger* *one"*. It has been argued that young children often use salient perceptual information to organize and navigate their world when learning words (e.g., Brandone et al., 2007; Landau et al., 1998) and when forming categories and concepts (Sloutsky, 2010). Interestingly, I instead found that children of all ages spent significant time discussing non-obvious features of artifacts. For example, even young children discussed the purpose and operation of artifacts at reasonable rates (despite an age-related increase). For example, a 4-year-old child said "*What do you do with it?*", "*It's for making wool into string*." and "*Oh to put water in it and wash stuff in there*.". This suggests that even the youngest children were drawn to discussing these "deeper" features of artifacts.

I also found age-related changes, as the proportion of children's talk about identification decreased with age, with increases appearing for operation and to a lesser degree purpose talk. Frequency data confirms that with age children engaged with these topics in differing amounts, however with the current analyses I cannot determine the cause of these changes, but there are a few possibilities. First, changes may be driven by gains in children's understanding of artifacts, as children are active learners who seek out information that is relevant to their goals (see Bonawitz et al., 2014; Gelman, 2009; Piaget, 1929). Under this account, documented changes in children's understanding of the importance of purpose in determining artifact identity might have led older children to discuss information about these topics at greater rates (German & Johnson, 2002; Kelemen, 1999; Matan & Carey, 2001). It is also possible that parents and staff are driving this change as work on parent-child interactions suggests that parents commonly tailor their speech and interactions to their child's age (Clark, 2009; Rowe, 2012). Under this account, with age, parents and staff may have viewed children as more receptive to "complex" information about artifacts such as historical information related to its purpose and thus increased talk about these topics. Supporting this possibility, parents' talk related to identification also decreased with age. Future studies should investigate whether age-related changes are driven by the child, the parent, or both by examining individual differences in parents' beliefs and children's ability and motivation to discuss different topics.

The findings here highlight the utility of looking at both proportion and frequency of utterances. I found that children provided a higher volume of purpose and operation talk with age, despite not finding a (significant) proportional increase. These two measures likely provide different insights about children's engagement. It seems very likely that both the quality (what we speak about at all) and quantity (how much we speak about certain topics) of information in an interaction will impact learning. Proportions are important for understanding what children thought was most valuable to talk about whereas frequencies, despite sometimes being "noisy", reveal what the triad was drawn to discussing in large amounts. Understanding what children are drawn to discussing in terms of sheer volume of talk is especially important for our partner museum and those like it, as it will allow them to capitalize on children's natural conversational tendencies and increase the overall amount of engagement with their exhibits.

Pedagogy

It was possible that parents and staff would use all pedagogical strategies at equal levels (or rely on a select few strategies), but that did not occur. Instead, staff and parents tailored their strategy use to the topic at hand, demonstrating sophistication in how they discussed artifacts with children. Despite some differences, staff and parents used strategies in similar ways. Their strategy use was compatible with the literature on how children learn best about new concepts. First, parents and staff often provided analogies when discussing the identity of artifacts, which is compatible with laboratory work suggesting that providing analogies and comparisons can facilitate relational reasoning and promote informational transfer between targets by facilitating the rapid learning of key information about the artifact (e.g., Christie & Gentner, 2014; Walker et al., 2016; Walker et al., 2018). As an example from the study, parents and staff sometimes made comparisons between the stereoscope and virtual reality software. Such comparisons likely helped children to discover that a stereoscope and virtual reality software belong to the same category of entertainment (i.e., its identity) and by doing so helped them understand that they are similar in many other ways, such as how they function (i.e., they affect what you see; optical illusions) and operate (i.e., you place them in front of your eyes).

Second, the findings make connections to a large body of work on children's causal reasoning and explanations. This work shows that causal explanations are a particularly powerful tool for teaching children (see Legare et al., 2017), especially in informal learning settings (see Callanan et al., 2020; Haden, 2010). For example, prior work shows that children who heard causal explanations were more likely to understand the underlying mechanisms that allow an artifact to operate (Fender & Crowley, 2007). In the study, when teaching children the purpose of, for example, the scale, parents and staff used causal statements to discuss how the scale is used to measure the weight of a good, to determine how much the customer would owe.

Third and finally, the finding that parents frequently asked their children critical thinking questions is compatible with work on the importance of posing questions in early learning. Critical thinking questions are important for helping to draw children's attention to the important aspects of exhibits (Haden, 2010). *How* and *Why* questions can also help to trigger explanatory reasoning, which is known to promote inductive reasoning and broaden the scope of children's own question asking and aid in children's recall of information (Jant et al., 2014; Ruggeri et al., 2019; Walker et al., 2014). As an example from the investigation, parents and staff would most often ask their children what they thought an artifact was, followed by what the purpose of the artifact is, and finally how they thought a particular artifact would operate.

In sum, these findings are some of the first to capture these processes spontaneously unfolding in an unstructured setting, and showcase the importance of other pedagogical strategies parents and staff use beyond explanations. It should be noted that although I assume here that these pedagogical strategies led to increased discussions and impacted children's learning, it will be important for future work to more directly examine how these processes lead to specific learning outcomes. For example, one could examine how prompting parents and staff to use more or less of one pedagogical strategy may affect children's later ability to categorize related novel artifacts.

Children's Responses

The present study is the first to my knowledge to compare the impact of strategies of theoretically similar quality on children's (verbal) engagement (i.e., as discussed above, analogies and critical thinking questions appear to be useful teaching tools). Indeed, I found that different strategies appeared to influence the amount and type of engagement, at least verbally.

Children were the most engaged when responding to critical thinking questions and analogies from staff and parents. Prior work has demonstrated that critical thinking questions are an excellent tool for teaching in informal learning settings (e.g., Benjamin et al., 2010; Callanan et al., 2017; Chandler-Campbell et al., 2020). However, these findings are the first to show that spontaneous analogy use by parents and staff can lead to similarly high levels of child engagement outside the laboratory. For analogies specifically, children provided significant quantities of information to their conversational partners. I hypothesize that this is because, similar to questions, analogies scaffold children's learning by requiring them to think critically about the topic at hand and generate hypotheses (i.e., about the nature of the comparison drawn).

I also found that children had the lowest amount of verbal engagement when responding to causal statements. This might be surprising given the rich literature showing that causal information and explanations are vital to conceptual development and learning (e.g., Callanan et al., 2020; Legare et al., 2017; Haden, 2010). However, it is possible that children engaged less following causal statements because they were more difficult for children to respond to. That is, children were often responding with their own hypotheses about how artifacts worked and so when causal statements about the artifacts' operation were provided to children, it was difficult for them to engage because one of their main forms of verbal engagement was to generate these hypotheses for themselves. Moreover, these statements often provided a lot of novel mechanistic information that might have been difficult for children who were previously unfamiliar with the machine or artifact to engage with. Compatible with these proposals, causal statements were followed by the least amount of information-giving responses but the second greatest amount of information-seeking responses, whereas the reverse was true for analogies. Prior work has similarly shown that children's engagement is positively correlated with parents' critical thinking questions and explanatory requests, but *is negatively correlated with parents' explanatory statements* (Callanan et al., 2017). Unfortunately, I could not code children's physical exploration and so it is possible that causal statements might lead to more physical operation or physical testing of hypotheses. I believe this will be a fruitful area for future work.

Conclusion

The present findings call attention to the skill with which parents and staff teach children about artifacts in informal environments. They demonstrate how different kinds of techniques lead to different levels of (verbal) engagement. They suggest many fruitful directions for further work regarding how and when children learn about artifacts outside the laboratory.

These results also have implications for informal learning environments such as museums, but also more specifically to our partner museum the WRM. Due to the overlapping nature of many of these implications in the three empirical chapters, the more general implications will be discussed fully in Chapter Five. In terms of implications specific to this chapter, this space allows for museum staff and parents to provide different learning opportunities to children, as staff are likely playing a more central role in providing mechanistic and science-related information to children visiting the museum. Parents should also be empowered as educators in these spaces, as they often sensitively tailored their use of pedagogical strategies to their discussion of different features of artifacts. However, it seems that they were also limited in how much operation and purpose information they could provide to their children.

The limitations of the current investigation are also similar across the three empirical chapters of this dissertation, and will be discussed more fully in Chapter Five. Briefly, the results of the current investigation are also limited in terms of their generalizability as the sample of participants were mostly White (80%), with high household incomes, and post-secondary education/professional degrees (see Appendix A). Here, I also often equated verbal exposure with learning, which may not be the case.

Overall, this work highlights that children find the operation and purpose of artifacts as extremely important features to learn about, especially as children age. However, it also raises the question whether these discussions about artifacts relate to children's Grade 1 and 2 science curricula. For instance, do these discussions relate to the engineering concepts children are taught in elementary school, such as simple machines and forces. This also raises the question of what other science learning opportunities are present at the living history village. Chapter Three explores this question.

Chapter Three: Conversations about STEM in unexpected places: Science at a living history museum.

Where do children learn about science? Of course, when we ask ourselves this question, we immediately think about formal educational settings like schools. Along with schools, educators and parents probably also think about children's museums, science centers, and libraries as high-quality places for seeking out opportunities for science learning. Some of these spaces have either signage readily available to guide parents and children, they may have exhibits specifically created to engage children, or staff members trained to disseminate information about science in a child-friendly way. Because of these features, these kinds of spaces are also well structured for researchers to examine how informal learning processes influence children's learning about science (e.g., Crowley et al., 2001; Haden, 2010; Sobel & Jipson, 2015).

However, many other settings likely present opportunities for children to acquire new and rich scientific knowledge. One type of environment that has been generally underappreciated in the literature are social and living history museums. Such history museums are geared towards learning about human social and economic histories, but they often afford a number of overlooked unique opportunities for learning about science (Feinstein & Meshoulam, 2014; Kisel, 2014). They stand in contrast to more formalized learning opportunities like classrooms and science centers which are more tailor-made to teach children about science. In this way, children's learning in history museums are likely a middle ground between children's everyday worlds, which are difficult experiences for researchers to capture, and informal learning environments.

But, what about these spaces might facilitate learning? Social history museums are typically filled with hundreds of tools, objects, and machines that are novel to children because they are from a different historical period (i.e., the early 1900s). This allows for many opportunities for science learning relating to biology, engineering, and basic physics and chemistry, as these items generally solve problems or fulfil roles in ways that children are not immediately familiar with, because they are so different from 21st century artifacts due to changes in technology and ways of life. However, prior work has not documented the ways these spaces might facilitate learning about science.

In response to this knowledge gap, the current investigation aims to: 1) identify and characterize opportunities for learning about science in a living history museum, and 2) understand how, and the level at which, parents, children and staff members engage with these science opportunities.

This question is of theoretical and practical importance. Understanding whether and how science-related themes are discussed in the living history museum is particularly useful to our partner museum, the Waterloo Region Museum, and others like it. The staff at the WRM are dedicated to providing high quality learning opportunities to all visitors, so this investigation of spontaneous science learning in their space is valuable to them. Researchers examining other museums have pointed out that there is often a mismatch between teacher goals and museums programming. For example, one investigation noted that only 23% of teachers reported feeling like field trips met curriculum goals (Kisel, 2014). I hypothesize that one reason for this mismatch might indeed be that sometimes learning in such spaces is “hidden” and thereby the process of uncovering the ways these spaces meet curriculum expectations can be vitally important for bridging divides between educators (museum staff and teachers). Additionally, understanding the exact types of science learning that occur at the museum allows for different potential funding opportunities related to STEM learning for the museum.

The Present Investigation

Using the same dataset as Chapter Two, I explore what and how children learn about biology, engineering, as well as basic physics, and chemistry in the living history museum; specifically in the farm, general store, and house. These science learning opportunities are found in the Ontario and Michigan science curricula for children from Kindergarten to Grade 2. I used two curricula to ensure that these topics and subtopics are appropriate for children 4- to 8-years-old to actively reason about, and to ensure that the analysis is not only relevant to Ontario. This approach also helps address prior calls to action to bridge divides between informal education spaces and curricular goals (Anderson et al., 2006; Kisel, 2014; Watermeyer, 2015).

Identifying Learning Opportunities

Biology.

Opportunities for thinking about biological life are ubiquitous in a young child's daily experiences. There could be pets or plants in their home, or children could have a backyard or a nearby park where they play outdoors. Many children also learn about wildlife through television, videos, and picture books, and can gain direct exposure to animals at zoos and farms. In fact, children are so enamoured by concepts of biological life that researchers have posited a biophilia hypothesis, which states that there is a genetic predisposition to connect with nature and other living organisms (Kahn, 1997). Supporting this, children are happier in the presence of animals (Shepard, 1996). Due to this pull towards nature, researchers have examined what children understand, and wish to learn, about biological life. By 3-years-old, children have intuitions about the essence of living kinds and how this makes living kinds different from artifacts (Gelman, 2003). Young children also seek out different information about biological kinds than they do about artifacts (Greif et al., 2006). Specifically, children are more likely to ask where animals are typically found than where artifacts are typically found (i.e., their habitat), and are curious about what animals eat and how they reproduce (Greif et al., 2006). Conversely, children rarely ask, "What does it do?" about an animal, instead asking this question more about artifacts (Greif et al., 2006).

The living history village is a novel space to examine how children naturally learn and discuss biological life and to examine how these discussions align with the science curricula. For example, the Ontario science curricula for Grades 1 and 2 both have a unit on understanding biological life. In Grade 2 this relates to categorizing different animals, including humans, with the overall expectation that children will be able to understand the similarities and differences in the characteristics of different animals, and especially how they compare to humans (Ontario Ministry of Education, 2007). There is also the specific expectation that children will be able to describe a characteristic body part or behaviour that allows plants or animals to survive in their environment (Ontario Ministry of Education, 2007). In the living history museum, children have the opportunity to discuss these facts at the farm. The farm contains animals such as sheep, goats, cows, pigs, and ducks for parents and children to label and discuss. Parents and children could discuss how animals use their anatomy differently than humans do, such as how pigs dig with their snout instead of using their hands like humans would. Visitors could also acknowledge the familial relationships between the animals, such as how the cows were siblings, and relate this to the child's own life.

The curricula also include the physiology of animals, and how similar and different they are to humans. For example, the Ontario Grade 1 science curriculum has an overall expectation that children will understand the basic needs and characteristics of plants and animals, including humans, with the specific expectation that children will understand that humans and animals need air, food, water, and unique habitats to live (Ontario Ministry of Education, 2007). On the farm, children can discuss how the different animals all require unique diets, and how the farm house functions as the animals' home. Parents and children also have the opportunity to discuss how the animals were fed food that grew on the farm, and how the plants need water and sunlight to grow. With the addition of the 1914 house and general store, this context also allows for different discussions about how humans are also biological beings that require food and shelter, and opens the conversation for parents and staff to compare and contrast how humans acquire food and shelter today versus in 1914.

Finally, both the Ontario science curricula for Grades 1 and 2, and the Michigan Kindergarten curriculum places an emphasis on sustainability and stewardship (Michigan Department of Education, 2015; Ontario Ministry of Education, 2007). There is the overall expectation that children will assess the role of humans in maintaining a healthy environment, and the impact that humans have had on animals and their habitat (Ontario Ministry of Education, 2007). There is also the specific expectation that children will be able to describe how humans should protect animals and where they live, and to show care when handling animals (Ontario Ministry of Education, 2007). At the farm, discussions about this could include how farmers have to behave when caring for the animals. There is also the opportunity to discuss how the garden at the farm and at the house attract birds, bees, and butterflies. Additionally, families could have discussions about sustainable farming practices.

Engineering.

In general, the goal of engineering is to define a problem, develop potential solutions, test those solutions, and determine which is best. Advancing STEM (science, technology, engineering, mathematics) learning opportunities, especially engineering, has become a priority in North America (NRC, 2009, 2012). This emphasis is reflected in science curricula for children, as more traditional science content is now explicitly integrated with engineering information (Michigan Department of Education, 2015). Outside of school, museums are also important spaces for children to be exposed to STEM learning opportunities, as children who spend time in STEM-related exhibits show more interest and perform better in STEM classes in school (NRC 2009).

This has led to the recent push for cognitive developmentalists to evaluate how to best engage children in museum exhibits and programming to enhance children's STEM learning (e.g., Crowley et al., 2001; Haden et al., 2015; Pagano et al., 2020). Researchers have mainly focused on how children learn engineering concepts in children's museums. They find that providing children and parents with engineering information changes how families interact with the museum exhibit. For example, families that are instructed on how to build structures according to engineering principles build more stable structures than those not receiving the same instructions (Benjamin et al., 2010; Haden et al., 2014). Providing instructions on how to discuss engineering concepts (i.e., encouraging parents to ask *wh*- questions) led children to talk more about science and engineering when asked to describe what they learned at the exhibit (Benjamin et al., 2010; Haden et al., 2014). Children and parents who reflected about their experience building a structure at a museum exhibit demonstrated a higher level of transfer of the skills and principles they learned one week later than families that did not reflect about their experience (Marcus et al., 2021).

Given that this research has utilized highly structured, indoor children's science museum exhibits, it is unclear if children are being exposed to these concepts in less structured, non-obvious settings. For example, problem solving, a pillar of engineering, is introduced to children in Kindergarten, where children are asked to gather information about a situation to understand how a particular object functions to solve a problem (Michigan Department of Education, 2015). With all the novel artifacts present in the house and general store, there are many opportunities to do this at the living history museum. Children could ask what different novel artifacts were for, such as the washboard and ringer used for laundry in the house, or the scale in store used to measure the amount of different goods.

The curricula also includes simple machines and forces. For example, the Michigan Kindergarten curriculum has a unit focusing on understanding motion with pushes and pulls (Michigan Department of Education, 2015). The Grade 1 Ontario curriculum has an overall expectation that children understand that simple machines can help objects move, while the Grade 2 curriculum has the overall expectation that children can investigate the mechanisms that enable the movement, and how this has made life easier for humans (Ontario Ministry of Education, 2007). There is also the specific expectation that children will investigate the structure and function of simple machines, and identity the six basic types of simple machines; lever, plane, pulley, wheel and axle, gears, screw and wedge (Ontario Ministry of Education, 2007). Given that the artifacts in the living history museum are from 1914, they all operate using these simple machines, allowing for an abundance of opportunities to discuss this topic of engineering. Parents and staff could also invite children to discuss how the mechanisms of these artifacts differ from their 21st century counterparts.

A final engineering topic in the curricula, which children could discuss at the living history museum, is objects and their materials. For example, both the Ontario Grade 1 and Michigan Grade 2 curricula expect children to understand that the materials and structure of an object determine its purpose (Michigan Department of Education, 2015; Ontario Ministry of

Education, 2007). This includes classifying materials by their properties and testing materials for different purposes (Michigan Department of Education, 2015; Ontario Ministry of Education, 2007). At the living history museum, these discussions can occur while children are exploring artifacts in the house and store. For instance, they could compare what artifacts are made of in 1914 versus what their 21st century counterparts are made from and why that may be.

Basic Physics and Chemistry.

The final science category examined was basic physics and chemistry concepts, such as energy and states of matter. Very little research has examined what children are naturally exposed to with respect to physics and chemistry, although these topics, specifically energy, are often discussed in tandem with biology and engineering concepts (NRC, 2012). Instead, this research has mainly examined how children learn about these concepts in school (Barak et al., 2007; Kruger et al., 1992; Nakhleh & Samarapungavan, 1998).

For example, the Ontario Grade 1 and 2 curricula both have a unit on understanding matter and energy. In Grade 1, this concept relates more to how energy is used in children's everyday lives, and has an overall expectation that children will be able to assess the use of energy at home, school, and the community, and understand that the sun is the principal source of energy for earth (Ontario Ministry of Education, 2007). There is also the specific expectation that children should be able to describe how life would be different if electrical energy was no longer available (Ontario Ministry of Education, 2007). There are many opportunities for these topics to be discussed in the living history village. On the farm, children, parents, and staff could discuss how farming in 1914 was made more difficult by the lack of electricity to help farmers complete their tasks, and how cultivation practices have advanced by technology. They could also discuss how the sun provides energy for plants and animals to live and grow, which then allows humans to survive. In the house and store, this relates to how objects today use electricity, such as the sewing machine and coffee grinder, as well as lighting and heating. The Michigan Grade 1 science curriculum also includes a unit on light and sound waves, which is also a form of energy (Michigan Department of Education, 2015). Families have the opportunity to discuss this form of energy when exploring how the pump organ makes music at the house, or when discussing how the lights operate.

In Grade 2, children are taught about different states of matter, and has an overall expectation that children will understand that liquids and solids have different properties (Ontario Ministry of Education, 2015). In the museum, this could be used to discuss the properties of kerosene that allow it to burn. This investigation is a first step in quantifying children's discussions and exposure to these basic physics and chemistry concepts in a naturalistic setting.

How Discussions About Science Occur

While it is important to characterize the specific science learning opportunities children are exposed to, it is also important to examine *how* these topics are discussed. In addressing my aims, I examine the interactions among a triad composed of the child-parent-staff members, and each member of the triad may potentially be contributing towards different learning opportunities for the child. Based on the findings in Chapter Two, one may expect that parents will provide information about the observable features of the scientific concepts, whereas staff may provide more descriptive and causal information about the scientific concepts being discussed. Laboratory studies have shown that children are sensitive to expertise, as children choose to seek information from experts rather than non-experts (Aguiar et al., 2012; Lutz & Keil, 2002). There is also data from science museums showing that children appreciate who is an expert about animals, and are most influenced by the facts that those experts provide (Boseovski & Thurman, 2014; Marble et al., 2021). Additionally, the museum staff participate in field trips for children in this age range, so they are familiar with the curriculum, and thus one might expect staff to provide children with more curriculum relevant information than parents.

I specifically ask whether children, parents, and museum staff are using observational, descriptive, and/or causal utterances when talking about science (coding scheme inspired by Afosno et al., 2019). The simplest way to discuss scientific concepts is to acknowledge that they are occurring and draw children's attention to them and provide observational information. For children, this is useful because in order to learn about a concept, you have to recognize its presence. A potential example of this in the living history museum is a parent drawing their child's attention to a novel artifact, in this case the coffee grinder, by labeling it. Once the scientific concept has been acknowledged through observation, this can open the conversation to discuss deeper aspects of scientific concepts, with descriptive information that is not immediately observable. Continuing with the coffee grinder example, a parent could tell their child that the coffee grinder is used to grind coffee beans to make coffee, and how they might have one at home that is electric instead of manual. Finally, the conversation can also include causal information about the concept, explaining how things happen using cause and effect information. In the instance of the coffee grinder, parents or museum staff can explain that there are gears inside the machine that crush the beans when you turn the handle.

Previous research in science museums has shown that parents' explanations about scientific phenomena tend to be incomplete (Crowley & Galco, 2001); however, these explanations can still lead to children having a deeper conceptual understanding of the phenomena (Crowley et al., 2001). In the current investigation, it is unclear whether parents will provide their children with deep descriptive and causal information about scientific concepts, as they may not be as familiar with the concepts as the museum staff. There is also conflicting evidence in the literature on the effect of museum staff's explanations of scientific concepts to children. While extremely knowledgeable about the space and the information available, previous work shows that museum staff tend to disregard students' background knowledge and deliver information using inaccessible scientific jargon during school visits (Cox-Peterson et al., 2003; Tal & Morag, 2007). Conversely, other research suggests that museum staff adjust the content of their discussions to students' interests and knowledge states (Pattison & Dierking, 2012; Pattison & Dierking, 2013, Tran, 2007). Thus it is not clear whether we should expect staff at the living history museum to tailor their talk in accordance with children's age, given their involvement in field trips and knowledge of the curriculum. Specific to the current investigation, I examine whether museum staff adjust the amount of descriptive and causal information they provide with child age. Finally, the ways in which children engage in conversations around scientific concepts in this type of space is currently unknown. For example, will children discus only what they can immediately observe, or will they engaging in conversations that require deeper conceptual knowledge about these concepts, such as descriptive or causal information.

Summary of Present Goals

To summarize, this chapter asks:

1) What types of science learning opportunities are children exposed to at a historical museum?
2) How are these science learning opportunities discussed by children, parents, and staff at a historical museum?

I had planned a third goal of investigating if children's gender influences the nature and type of science talk they are exposed to and participate in, however no notable differences were found.

Method

Participants

This investigation was completed using the same dataset and participants as Chapter Two: 40 parent-child dyads, with children between 4.00 and 8.01-years old, (20 females, M_{age}=5.98, *SD*=1.06). As the parent-child dyads visited three locations at the museum, there was an opportunity for each dyad to interact with at least three staff members, one per location.

Materials and Procedure

As a reminder, children were given the instruction "to learn as much as they can and to ask as many questions as they can.". The parent-child dyad was also given a suggestion of where to begin in each location, however, they were told to explore the exhibit as they naturally would. Dyads were given a maximum of eight minutes to explore each location, but could leave the location earlier. At the eight-minute mark, or when the dyad indicated they were done exploring, the research assistants would enter the location and direct the dyad to the next location.

Transcription and Coding

Transcription is fully described in Chapter Two. Recall that speech was broken into utterances, resulting in the identification of 6,349 utterances spoken by children, 8,427 utterances by parents, and 9,219 utterances by museum staff.

Transcripts were then coded for the present investigation. To prevent bias, age and gender of the child were blinded before coding. As a first step, the primary coder and the first author independently identified utterances that were related to science at the museum.

Disagreements on utterances were settled through discussion. Through this process, 1,671 child, 2,236 parents, and 4,146 staff utterances were identified as related to science.

Science-related utterances were then coded using two coding schemes. The primary coder, a research assistant, was naive to the hypotheses of the study throughout the process. I acted as the secondary coder and reliability coded 30% of utterances. Before this took place, the primary and secondary coders practice-coded five excluded participants. Disagreements on these practice participants were settled by discussion between the primary and secondary coder. The two coding schemes were as follows (see OSF supplement osf.io/8r5pm for the full coding scheme):

Science Learning.

The first scheme aimed to capture types of science learning opportunities among the triad (child-parent-staff member). To accomplish this goal, science learning was separated into three non-mutually exclusive topics: biology, engineering, and basic chemistry and physics (Ontario Ministry of Education, 2007; Michigan Department of Education, 2015).

Biology. Utterances related to biology were coded into three mutually exclusive categories: categorizing living things, physiology and survival, and stewardship (Ontario Ministry of Education, 2007; Michigan Department of Education, 2015). Reliability was excellent with a Kappa of .966. Utterances such as "*Oh is the sheep making the noise?*", "*Are they a boy and girl?*", and "*They use their noses to dig instead of using their hands.*" would fall into the category categorizing living things. Physiology and survival utterances would include *"What do they eat*" and "*What do you think they need the mud for?*". Finally, stewardship would include utterances such as "*Pigs are actually very smart.*" and "*She [a pig] likes getting scratched*.".

Engineering. Utterances related to engineering were coded into four mutually exclusive categories: labeling, problem solving, simple machines and forces, and object and materials (Ontario Ministry of Education, 2007; Michigan Department of Education, 2015). Reliability was excellent with a Kappa of .981. Labeling included utterances where children, parents, and staff simply identified an object or concept that they then discussed in one of the other categories. In the current investigation, topics related to problem solving arose through utterances like "*What are those for?*", and "*And then we have the icebox at the back, where the rest of the cheese would be kept to be the freshest."*. Utterances relating to simple machines and forces included children's utterances about figuring out how to operate the artifacts, such as "*And then I grind it like this $ and it goes down below*.". Finally, objects and materials included asking "*What is it made of?*" and *"Right here. It it's wooden. It's not plastic like yours*.".

Basic Physics and Chemistry. Utterances related to basic chemistry and physics were coded into three mutually exclusive categories: labeling, states of matter, and energy (Ontario Ministry of Education, 2007; Michigan Department of Education, 2015). Reliability was excellent with a Kappa of .976. Due to the infrequency of labeling (3 total instances), it is dropped from subsequent analyses. Once again, labeling included utterances where the speaker identified an object or concept that they then discussed in one of the other categories. Utterances categorized as relating to states of matter included statements like "*Yea we use lamp oil but they also would've used kerosene.*" and "*So all the smoke would go up and outside.*". Finally, energy included phrases such as "*So inside here there's big pipes and that's where it makes the sound.*" and "*So do you think it works with gas, electricity, or wood?*".

How Discussions About Science Occur.

The second scheme focused on understanding *how* children, parents, and museum staff talked about science. To do this, their utterances were further coded into three mutually exclusive categories: observational, descriptive, and causal (Afosno et al., 2019). Reliability was excellent with a Kappa of .928. Observational utterances refer to talk that exposes children to the names of scientific phenomena or draws their attention to opportunities to learn about science. This includes utterances such as "*They were sheep.*" and "*See how the one dollar popped up?*". Descriptive utterances describe the properties of scientific phenomena and focus on observable traits. Utterances such as "*What do they eat?*" and "*So it's supposed to make an image 3D so like it's popping out at you.*" are included, as they provide an additional level of information besides what children can immediately observe for themselves. Finally, causal statements include cause and effect information. For example, when discussing how to heat the general store, a staff member replied with "*They use to fireplace to light a fire and stay warm in the winter.*".

Results

Goal 1: Science Learning

Both the frequency of utterances and the proportion of utterances were analyzed as in Chapter Two, separated by domain of science (biology, engineering, basic physics and chemistry).

To examine the frequency of type of science-related talk, poisson-based GEEs were conducted, which included the predictors child age in months (centered and entered as a covariate) and the within-subjects variable category of science talk within each domain. The dependent variable was the frequency of science talk. Each speaker was analyzed separately.

To examine the proportion of type of science-related talk, Dirichlet regressions were conducted, with proportion of the speaker's type of science talk as the dependent variable, and child age in months as a predictor variable, with each speaker analyzed separately. Proportions of type of science talk were calculated using the raw frequency of type of science talk, by the total amount of categorizable science talk for each speaker within each domain. For all GEEs, only significant findings and follow-up analyses will be discussed. All follow up tests are statistically corrected for multiple tests.

Biology.

Children, parents, and museum staff discussed biological concepts often at the living history museum. On average, children had an average of 6.392 utterances related to biological talk (SD = 6.707); parents had 7.475 utterances (SD = 8.287), and staff had 15.800 (SD = 12.600). Below is an example conversation where the child, parent, and museum staff are discussing biological concepts related to pigs:

Parent: It's like she's eating, or he's eating the mud over there.

Child: What do they eat?

Museum Staff: Well, we feed them formulated grain pellets, kinda like breakfast cereal. And also Barley, which is a grain. But we can also feed them things like kitchen scraps, my potato peels, or apple peels or $ anything xxx.

Overall, children, parents, and staff discussed the different biological concepts at different frequencies ($ps < .001$, see Table 7). Follow-up pairwise comparisons revealed that children categorized living things (M = 10.150, SE = 1.037) and discussed their physiology (M = 8.299, SE = .998) at greater frequencies than stewardship (M = .725, SE = .174, ps <.001). Children did not categorize living things and discuss physiology at different frequencies (p = .088).

Table 7

Biology Frequency Tests, Means, and Standard Errors

	Statistical Test			Categorizing Mean (SE)	Physiology Mean (SE)	Stewardship Mean (SE)
		Wald X^2	***p***			
Children						
	Age	.020	.888	10.150	8.299,	.725
	Concepts	144.798	< .001***	(1.037)	(.998)	(.174)
	Concepts x Age	.026	.987			
Parents						
	Age	.546	.460	10.831	9.917	1.575
	Concepts	59.602	< .001***	(1.518)	(.998)	(.391)
	Concepts x Age	.668	.716			
Staff						
	Age	.071	.790	20.299	22.507	4.549
	Concepts	138.381	< .001***	(1.716)	(1.879)	(.698)
	Concepts x Age	1.129	.569			

Note. *** $p < .001$

Follow-up pairwise comparisons for parents revealed the same pattern as children, with parents categorizing living things (*M* = 10.831, *SE* = 1.518) and discussing their physiology (*M* = 9.917, *SE* = .998) at greater frequencies than stewardship (*M* = 1.575, *SE* = .391, *ps* < .001). Parents also did not categorize living things and discuss physiology at different frequencies (*p* = .524).

Staff members also had a similar pattern: they discussed physiology (*M* = 22.507, *SE* = 1.879) and categorized living things (*M* = 20.299, *SE* = 1.716) more frequently than stewardship (*M* = 4.549, *SE* = .698, *ps* < .001). Physiology and categorizing living things did not differ (*p* = .131). Below is an example of a child, their parent, and a staff member discussing the cows at the farm. These utterances would be classified as categorizing living things:

Child: Where's their mom?

Museum Staff: This is Fred and Felicity. Their mom is at their home farm.

Parent: So these are cows. What uhmm, I don't know this colour, what are they? They're not Jerseys…

Museum Staff: They are Black Angus, so they're a beef breed.

The Dirichlet regression examining proportions revealed no effects for all speakers (see Table 8). In sum, children, parents, and staff all discussed the different biological concepts at different frequencies. All speakers touched on all topics identified as important for children's biological learning. Age was not a factor in what was discussed.

Table 8

Proportional Tests for all Speakers and Categories

		Child		**Parent**		**Staff**	
		z	***p***	**z**	***p***	**z**	***p***
Biology							
	Categorizing	-.070	.944	.776	.438	.095	.924
	Physiology	.439	.660	1.272	.203	.879	.379
	Stewardship	.233	.816	.226	.821	1.233	.217
Engineering							
	Labeling	.866	.386	- 2.924	.003**	-.256	.798
	Problem Solving	.632	.527	-1.356	.175	-.687	.492
	Simple Machines	3.278	. 001***	.172	.863	-.233	.816
	Objects and Materials	.991	.321	-.489	.625	-8.23	.411
Physics							
	Energy	1.003	.316	1.835	.067	-.138	.667
	States of Matter	.832	.406	.880	.379	.891	.505

Note. ** $p < .01$, *** $p < .001$

Engineering.

On average, children had 4.375 utterances (SD = 4.315) related to engineering concepts; parents had 6.831 utterances (SD = 6.435), and staff had 12.375 utterances (SD = 11.550). Below is an example conversation where the parent points out an object and asks what problem it solves, and the museum staff categorizes the object and explains the simple machine and forces that allow its operation:

> *Museum Staff: That's the gramophone…. I think it's a little too humid for it now. But you turn on side and there's a little switch, and then it starts to spin. So it's fully wound right now but it just, doesn't go.*

Overall, children, parents, and staff discussed the different engineering concepts at different frequencies (*ps* = .001; see Table 9). Children also discussed more engineering concepts with age, $Wald X^2(\text{df} = 1) = 9.217$, $p = .002$.

Table 9

Engineering Frequency Tests, Means, and Standard Errors

		Statistical Test		Labeling Mean (SE)	Problem Solving Mean (SE)	Simple Machines Mean (SE)	Objects Mean (SE)
		Wald X²	***p***				
Children							
	Age	9.217	.002**	6.096	3.384	5.296	1.910
	Concepts	48.572	<.001***	(. 656)	(. 460)	(. 766)	(.361)
	Concepts x Age	4.575	.206				
Parents							
	Age	.503	.478	7.419	5.488	10.351	3.363
	Concepts	89.684	<.001***	(. 959)	(.697)	(.974)	(. 550)
	Concepts x Age	36.131	< .001***				
Staff							
	Age	.001	.970	8.374	9.913	25.650	5.533
	Concepts	212.372	< .001***	(.871)	(1.055)	(2.035)	(1.039)
	Concepts x Age	1.501	.682				

Note. ** $p < .01$, *** $p < .001$

Children labeled engineering concepts the most, ($M = 6.096$, $SE = .656$), followed by discussing simple machines and forces ($M = 5.296$, $SE = .766$), then problem solving ($M = 3.384$, $SE = .460$), and finally discussing objects and materials ($M = 1.910$, $SE = .361$). Follow-up pairwise comparisons revealed children talked about all engineering concepts at different rates (*ps* < .02) except labeling engineering concepts and simple machines and forces ($p = .353$).

Staff members discussed simple machines and forces the most ($M = 25.650$, $SE = 2.035$), followed by problem solving ($M = 9.913$, $SE = 1.055$), labeling ($M = 8.374$, $SE = .871$), and objects and materials ($M = 5.533$, $SE = 1.039$). Staff members discussed all these concepts at different frequencies (*p*s < .037).

Parents discussed simple machines and forces the most (*M* = 10.351, *SE* = .974), then labeling (*M* = 7.419, *SE* = .959), problem solving (*M* = 5.488, *SE* = .697), and finally objects and materials (*M* = 3.363, *SE* = .550). Parents discussed all the concepts at different frequencies from one another (*ps* < .005). Parents also had an engineering concept by age interaction, $WaldX^2$(df = 3) = 36.131, *p* < .001. To decompose this interaction, I split parent data by category of engineering talk and ran a poisson-based GEE with age as a predictor, with frequency of engineering talk as the dependent variable. There was only a main effect of age for simple machines and forces, $WaldX^2$(df = 1) = 6.962, *p* < .001, indicating that the amount parents discuss simple machines and forces with their children increases with child age. Here is an example of a parent discussing the simple machines and forces of the sewing machine: "*See the needle? The needle moves up and down. She has to move her foot fast to make it go."*. Here is another example of a parent discussing the simple machines and forces of a 1914 cash register "*So do you think this cash register does all the math for them?".*

The Dirichlet regression examining proportions revealed a main effect of age for the proportion of children's talk related to simple machines and forces, *z* = 3.278, *p* = .001, but not for labelling, objects and materials, or problem solving (*ps* > .322). This indicates that the proportion of children's talk related to simple machines and forces increases with child age.

For parents, the Dirichlet regression revealed a main effect of age for the proportion of parents' talk related to labelling, *z* = - 2.924, *p* = .003, but not for any of the other engineering categories (*ps* > .100). This indicates that the proportion of parents' talk related to labelling decreased with children's age. Finally, the Dirichlet regression for proportion of staff engineering talk revealed no main effects for any of the categories (*ps* > .410). Below is an example of a child, a parent, and a staff member discussing how the pump organ operates:

Museum Staff: So a pump organ—it looks a little bit like a piano but it's an organ. So you would use these pedals at the bottom to pump the air through it. And then you have to pull out these stops to make noise. So if you pull out more stops, you're gonna make more noise.

Child: Do you have to do it pretty fast to get it going?

Museum Staff: Yeah so you have to keep pedaling, which is a bit of a workout. Cause if you stop pedaling, like you can still hear music, but it will slowly fade away, after a while.

Parent: So it gets quieter until there's no more sound, once the air runs out.

Overall, children increased the frequency of their engineering talk with age, and labelled engineering concepts the most. In terms of the proportion of children's talk, children increased the proportion of their talk relating to simple machines and forces with age. Parents discussed simple machines and forces the most, and this also increased in frequency with child age. In terms of proportion of talk, parents decreased their proportion of talk related to labelling engineering concepts as children aged. Similarly to parents, staff also discussed simple machines and forces the most frequently.

Basic Physics and Chemistry.

On average, children had 2.200 utterances related to physics and chemistry (SD = 2.512); parents had 4.8375 utterances (SD = 5.375), and staff had 12.175 utterances (SD = 12.536). Parents would often point out to their child that there was no electricity in the home *"You can't flick a switch and turn the lights on. So you had candles and lamps like that to light it up.*".

Overall, children, parents, and staff discussed the different basic physics and chemistry concepts at different frequencies (*ps* = .001, see Table 10). Children also discussed more basic physics and chemistry concepts with age, *Wald*X^2(df = 1) = 6.812, p =.009. Follow-up pairwise comparisons revealed that children, parents, and staff all discussed energy at higher frequencies than states of matter (ps < .001). For example, a parent asked their child "*Do you think that's enough wood to make supper?*", and a museum staff member explained how the coffee grinder operated "*And they'd pour them [the coffee beans] in here. And then they would have to crank this really big wheel.*".

Table 10

Physics Frequency Tests, Means, and Standard Errors

		Statistical Test		Energy Mean (SE)	States of Matter Mean (SE)
		Wald X²	***p***		
Children					
	Age	6.812	.009**	3.039	1.099
	Concepts	19.433	< .001***	(.401)	(.239)
	Concepts x Age	.066	.798		
Parents					
	Age	.287	.592	7.819	1.773
	Concepts	43.721	< .001***	(.877)	(.416)
	Concepts x Age	2.940	.086		
Staff					
	Age	.007	.935	21.025	3.324
	Concepts	103.140	< .001***	(1.859)	(.61941)
	Concepts x Age	.022	.883		

Note. ** $p < .01$, *** $p < .001$

The Dirichlet regression examining proportions revealed no effects for all speakers (*ps* > .066). In sum, all speakers had more utterances relating to energy than to states of matter, and while the frequency of children's discussions about basic physics and chemistry concepts increased with age, the proportion of their discussions did not.

Goal 2: How Discussions About Science Occur

The second aim of the investigation was to understand how participants engaged with science concepts. To achieve this goal, both the frequency and proportion of utterances were analyzed. Frequency was examined using a poisson-based GEE with the predictors child age in months (centered and entered as a covariate) and the within-subjects variable category of type of engagement within each domain. The dependent variable was the frequency of type of engagement. To examine proportion of type of talk, Dirichlet regressions were used with proportion of the speaker's type of engagement as the dependent variable, and child age in months as a predictor variable, with each speaker analyzed separately. Proportions of type of engagement were calculated using the raw frequency of type of engagement, by the total amount of categorizable engagement for each speaker within each domain.

Children's Discussions.

Children made 14.35 science-related utterances on average (*SD* = 12.073) that could be classified as observational, descriptive, or causal. For the GEE examining the frequency of these utterances, children had a main effect of age, $WaldX^2$(df = 1) = 4.053, *p* = .044, and a main effect of engagement type, $WaldX^2$(df = 2) = 102.713, *p* < .001. There was no engagement type by age interaction, $WaldX^2$(df = 2) = 3.266, *p* = .195. Children mostly made descriptive utterances (*M* = 22.183, *SE* = 1.967), followed by observational utterances (*M* = 15.808, *SE* = 1.465), and finally causal utterances (*M* = 4.495, *SE* = .801). Follow-up pairwise comparisons revealed that children used all these engagement types at different frequencies from one another (*ps* > .002). Children used descriptive utterances when asking questions, such as "*Is this where you get your water?*" and when making statements like "*Well, the barn is made out of wood.*".

The Dirichlet regression examining proportions revealed a main effect of age for proportion of descriptive utterances, *z* = 2.121, *p* = .033, and causal utterances, *z* = 3.215, *p* =

.001, but not for observational utterances, $z = 1.226$, $p = .220$. This indicates that the proportion of children's descriptive and causal utterances increases with child age.

Parents' Discussions.

On average, parents made 16.642 science-related utterances ($SD = 14.079$) that could be classified as observational, descriptive, or causal. For the GEE examining the frequency of these utterances, parents had a main effect of engagement type, $WaldX^2(\text{df} = 1) = 226.075$, $p < .001$, indicating that they utilized these different strategies at different frequencies. There was no main effect of age, $WaldX^2(\text{df} = 1) = 1.253$, $p = .263$, however there was an engagement type by age interaction, $WaldX^2(\text{df} = 2) = 11.868$, $p = .003$.

Parents mostly made observational utterances ($M = 22.675$, $SE = 2.075$), followed by descriptive utterances ($M = 21.626$, $SE = 1.818$), and causal utterances ($M = 5.058$, $SE = .653$). Follow-up pairwise comparisons revealed that parents made causal utterances significantly less than observational and descriptive statements ($p < .001$), although the frequency of observational and descriptive utterances did not differ from one another ($p = .485$).

To decompose the engagement type by age interaction, I split the data by category of engagement and ran a poisson-based GEE with age as a predictor and the dependent variable frequency of engagement. There was a main effect of age for descriptive utterances, $WaldX^2(\text{df} = 1) = 4.101$, $p = .043$, indicating that parents make more descriptive utterances with increasing child age. Below is an example of a parent describing the lights that were present in the 1914 house to their child:

> *Parent: They didn't have lights like we do. But did they have switches? Would it still be a light a switch light or they had to light it? …. You'd have to light that. It's like a candle in the ceiling.*

The Dirichlet regression examining proportions revealed no main effect of age for any of the engagement types for parents (*ps* > .160), indicating that the proportion of parents' engagement type does not change with age.

Staff's Discussions.

On average, museum staff members made 31.775 science-related utterances (*SD* = 23.032) that could be classified in the engagement coding scheme. For the GEE examining the frequency of these utterances, staff members had a main effect of engagement type, $WaldX^2$(df = 1) = 912.294, *p* < .001. There was no main effect of child age, $WaldX^2$(df = 1) = .068, *p* = .794, and no engagement type by age interaction, $WaldX^2$(df = 1) = .145, *p* = .930.

Staff members mostly made descriptive utterances (*M* = 55.103, *SE* = 3.554), followed by observational utterances (*M* = 23.348, *SE* = 1.814), and finally causal utterances (*M* = 16.846, *SE* = 1.523). Follow-up pairwise comparisons reveal that staff members made all these utterances at significantly different frequencies from one another (*ps* < .001). Below is an example of a staff member explaining why pigs cover themselves in mud.

> *Museum Staff: So the reason that they're covered like that is because pigs like to jump in the mud here. And the reason for that being that uh they don't have sweat glands actually…. Uh these guys roll in the mud and that keeps them cool.*

The Dirichlet regression examining proportions revealed a main effect of age for proportion of causal utterances, *z* = -2.183, *p* = .029, but not for observational or descriptive utterances (*ps* > . 05). This indicates that staff made proportionally fewer causal utterances as child age increased.

Discussion

The results for the current investigation show that living history museums provide an abundance of rich science learning opportunities in biology, engineering, and basic chemistry and physics for children aged 4- to -8-years-old. The triads' discussions were not only about the surface level, observable features of these concepts, but also about non-observable descriptive and causal information, in line with science curricula (Michigan Department of Education, 2015; Ontario Ministry of Education, 2007). The living history museum also allowed for unique conversations that would not occur in other informal learning spaces, such as the comparisons to how humans operated then versus now.

Biology

The living history museum proved to be a space where children could participate in rich conversations about biological concepts. Children, parents, and museum staff discussed a variety of biological concepts irrespective of child age, which is unsurprising considering children's predisposition for biological life (Kahn, 1997). These findings are also in line with the current science curricula goals for biological life (Michigan Department of Education, 2015; Ontario Ministry of Education, 2007). Not only were the triads simply labelling the animals, but they were also having in-depth discussions about the animals' anatomy and habitats. For example, "*He's a bull why is his h- why is his horns not growing yet?*" would fall under categorizing living things. Here, the child is acknowledging the different characteristics that different animals have, in this case some cows having horns (Ontario Ministry of Education, 2007). These high-quality discussions were not only limited to animals on the farm, but also to how farmers would utilize the animals for food "*Now in 1914 though most farmers wanted what was considered dual purpose animal so something good for milk and for meat. So if you had something like a Black Angus you'd most often cross it with like a Jersey or a Guernsey or a milking breed uhm so that*

that way the offspring would be that half good for milk, half good for meat.". This conversation relates to the overall expectation that children should be able to recognize that humans are animals that require food for survival (Ontario Ministry of Education, 2007). Conversations like this also help to provide context to children as to how different life in 1914 was and how they acquired food from the farm, compared to the 21st century.

There were relatively fewer conversations among triads about stewardship and sustainability, as compared to other biological concepts. For example, while there was the opportunity for the triad to discuss sustainable farming practices, and treating animals with kindness and respect, these conversations happened very rarely for parents and children, and occurred much less frequently for museum staff compared to the other biological topics. Thus, museum staff can increase this type of discussion with visitors of the museum, as it is a unique aspect of the living history village that other informal learning environments cannot address as organically.

Engineering

Due to the large number of novel artifacts present, there were ample opportunities to discuss engineering concepts. As children aged, they talked at greater frequencies about engineering, which is in line with early science curricula (Michigan Department of Education, 2015; Ontario Ministry of Education, 2007). Additionally, the proportion of children's discussions related to simple machines and forces increased with age. For example, when examining a barrel and its pour spout, a child exclaimed "*What if you spin this and that would and that opened*?". While not explicitly using the term lever to describe the spout, this child is giving an example of how it would be used to pour the liquid in the barrel. Simple machine and forces are a key component of science curricula for children, as they act as building blocks for other engineering concepts that children will be introduced to as they progress through their education. For instance, understanding how to build a strong, stable structure, and the forces that act on these structures, all build off these simple concepts introduced at the living history museum (Ontario Ministry of Education, 2007). Given the nature of the dataset however, it is impossible to know what is driving this change in children's discussions. Children's own curiosity in simple machines and forces may be driving this increase, as they are actively seeking out this information from parents and museum staff (see Bonawitz et al., 2014; Gelman, 2009). Alternatively, parents and museum staff may be driving this change, as the frequency of parents' utterances relating to simple machines and forces increases with child age. Parents may view children as more receptive to more complex information about the internal mechanisms of machines as they age, and thus discuss this information more with older children than with younger children.

The triads also engaged in problem solving, regardless of child age. For example, children would commonly ask "*What is it for?*" and parents and museum staff would provide the solution as to how the object solved the problem. They would also pose questions to children about how certain problems would be solved in the early 20th century without the use of electricity, such as asking how they would see at night if there wasn't electricity to turn on a light. Problem solving is a cornerstone of engineering, and gaining practice asking questions, and gathering information about a problem to form potential solutions will aid children's understanding of the scientific method.

There are opportunities for an increase in discussions about objects and materials in the living history museum, as this type of engineering talk occurred the least often for all members of the triads. For example, "*And the cheese bacteria has absorbed into the wood so that's why you can still smell it.*" explains to children that a property of wood is the ability to absorb bacteria. To further expand upon this example, staff and parents could compare wood to metal, and describe how metal is not absorbent. Understanding why an object is built out a particular material, and the affordances that material provides is an application of children's problem-solving abilities.

Basic Physics and Chemistry

Prior to the current investigation, little was known about how children discuss and learn about these scientific concepts in an informal learning environment. Children discussed physics and chemistry concepts at higher frequencies with age, and all speakers made more utterances about energy than to states of matter, as energy can be brought up when discussion both biology and engineering concepts without being the main focus of the conversation or explicitly explained. For example, when a staff member instructs a child to make the pump organ play music by pumping the pedals, that not only contains information related to simple machines and forces, but also to energy, as one needs to exert energy to play music. This is an often-overlooked scientific concept but there are countless opportunities to bring this to children's attention in the living history museum. There were relatively few discussions about different states of matter at the living history museum by all speakers. While this topic may not come up as organically in this space due to there being less obvious opportunities to discuss these concepts, staff should continue to initiate these discussions with parents and children. One possible opportunity that relates to states of matter is for staff or parents to discuss how people kept food chilled in 1914 using ice boxes.

How Discussions About Science Occur

The second aim of the study was to examine *how* children, parents, and museum staff discuss science concepts, specifically if they were discussing observational, descriptive, or causal information. As children aged, they increased their proportion of descriptive and causal utterances. This again is in line with science curricula, as one would expect children to discuss these concepts in greater depth as they gain more experience with the concepts in school. It is also important to note that children of all ages made descriptive utterances most when talking about scientific concepts, rather than observational utterances. This suggests that children were not just discussing what they could immediately observe, but they were having more meaningful conversations about the scientific concepts found in the living history museum.

Previous work has focused primarily on how to best teach children engineering concepts in children's museums, teaching children about the structural integrity of buildings and bridges (e.g., Benjamin et al., 2010; Marcus et al., 2017; Pagano et al., 2020). For example, providing children and parents with building instructions and tips allowed them to build sturdier structures (Benjamin et al., 2010; Haden et al., 2014), and families who reflected on their experiences building structures after receiving instructions performed better on a transfer task than those that did not (Marcus et al., 2021). It then may be more useful for museum staff to provide more descriptive and causal information about scientific concepts to parents and children, and have parents reinforce this information in the exhibit. As an example from the current study, when teaching children how to use the pump organ, museum staff used many descriptive and causal utterances. Parents then reinforced what the staff said using descriptive utterances while the child was pumping the pedals and pressing on the keys.

Conclusions

Again, to their overlapping nature, the general implications of this work for informal learning environments will be discussed fully in Chapter Five. In terms of specific implications for this chapter, museum staff members play a more prominent role in providing curricular information to children, as opposed to parents. In all science categories, staff discussed these topics in greater depth by providing more descriptive information than observational information, whereas parents provided observational information the most. However, museum staff mostly did not tailor this information to children's age. Conversely, parents tailored how they discuss scientific concepts with their child's age, increasing the frequency of descriptive utterances and the frequency of utterances related to simple machines and forces with child age.

There are some limitations in the current investigation, as mentioned in Chapter Two. Most notably, the majority of the participants were White (80%), with high household incomes and post-secondary education. Thus, the generalizability of the results is limited. But overall, the living history museum proved to be a space where children and their parents can engage in meaningful conversations about science. These findings also highlight that parents may need to be scaffolded to fully take advantage of the learning opportunities presented to them, not only in museum spaces but also in their everyday lives. However, the current findings along with Chapter Two, raise the question of whether it is possible to intervene on children's behaviour to direct their attention to a specific scientific concept, namely children's engineering and causal understanding of a specific artifact. Chapter Four tackles this question.

Chapter Four: Components and mechanisms: How children talk about machines in museum exhibits

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When encountering a new artifact children have much to learn, including facts relevant to the whole artifact, such as its name and purpose, and facts about its components such as the role of specific parts in its operation. Mechanical machines provide a particularly unique learning challenge for young children, as they not only consist of external parts, but also internal parts and causal mechanisms that are unseen but critical to their functioning (e.g., Leuchtner & Naber, 2018; Reuter & Leuchter, 2020). Reflecting this fact, early childhood science curricula emphasize the importance of teaching young children about mechanical machines and forces during grade school (e.g., Ontario Ministry of Education, 2007; Michigan Department of Education, 2015). For developmental scientists, mechanical machines provide an opportunity to explore children's causal reasoning (e.g., Legare et al., 2010; Sobel et al., 2020). The present investigation seeks to understand how children learn about mechanical machines and their causal mechanisms during interactions with their parents in more informal, naturalistic contexts than those of schools or laboratories.

The main questions of this chapter are: what information do children discuss when learning about novel mechanical artifacts in museum exhibits; and how might short verbal instructions or prompts influence children's discussions and learning? To do this, I examined how children talk and learn about a novel artifact – a coffee grinder (circa 1914)—found in a local social history museum. Children were provided with one of two verbal prompts directing their attention to the internal mechanisms of the machine (experimental prompt) or a neutral control prompt. I focused on an informal learning environment because the minimal educational structure can reveal how learning about such artifacts unfolds when primarily driven by unstructured exploration (e.g., Sobel & Jipson, 2015). This unstructured exploration in a living history exhibit, which is not specifically geared towards learning about novel causal mechanisms, provided insight into how children acquire these concepts during their everyday lives. It also provided information for educators and designers in these spaces who hope to promote particularly rich and varied learning opportunities for children.

The first aim was to document how children talk about mechanical machines in museums when visiting with their families. When examining a novel machine, a child might choose to focus on: the whole machine (such as its name, what it is made out of, and its function and purpose), the machine's parts (both external and internal), and the causal mechanism of its operation. All of these aspects are important for understanding the machine's operation. Previous work has documented that children are particularly adept at learning about an artifact's function and purpose (Casler & Kelemen, 2005, 2007). From a young age, children view the function and purpose of an artifact as important features to learn (Greif et al., 2006; Kemler Nelson et al., 2004). Additionally, children as young as 3 years old in lab tasks acknowledge that the insides of an artifact are important to its function and identity (Gelman & Wellman, 1991).

A great deal of work in cognitive development has focused on children's reasoning about, and attention to, artifacts' internal causal mechanisms (e.g., Ahl et al., 2020; Ahl & Keil, 2017; Sobel et al., 2007). For example, 4-year-olds understand that an object's internal component can activate a machine and they expect other objects with the same internal component to work in similar ways (Sobel et al., 2007, see also Walker et al., 2014). Children are also able to reason about the diversity of a machine's functions, and how this relates to the complexity of a machine's insides (Ahl & Keil, 2017, see also Erb et al., 2013 for related findings). Further to this, children understand that complex objects require expert knowledge to be used or fixed (Kominsky et al., 2018). Some research has also focused on children's understanding of the internal mechanisms of machines in museum settings. This work shows that parents play a vital role in directing children's attention to important features of machines (e.g., Callanan et al., 2020; Medina & Sobel, 2020; Pagano et al., 2020). For example, children will discover more properties, and gain a deeper understanding of the underlying causal mechanisms and internal components of a machine when they explore with their parent, rather than on their own or with a peer (Crowley et al., 2001; Fender & Crowley, 2007).

Together, this work highlights the importance of examining children's understanding of machines and their components, as they relate to causal reasoning and STEM education. Because the machines at the museum in the present paper are from the early 20th century, they are novel and involve only manual parts and mechanisms, allowing children to identify the problem these machines solve, and hypothesize about how their parts and internal components aid in its operation, all of which children have been shown to have an appreciation for in laboratory settings (e.g., Ahl & Keil, 2017; Casler & Kelmen, 2005). This practice provides foundational knowledge for understanding the more complex machines and technology found in the 21st century.

The second aim was to understand how providing a minimal verbal prompt to children might affect their discussions with their parents about a machine in a museum exhibit. Prior work has established that children are more engaged when adults provide explanations (Frazier et al., 2009), and produce more on-topic utterances when their parent asks them causal questions (Benjamin et al., 2010; Chandler-Campbell et al., 2020; Rowe et al., 2017). As such, prior work has focused on how providing parents and children with supplementary materials and prompts can enhance their learning in exhibits (e.g., Benjamin et al., 2010; Callanan et al., 2017; Chandler-Campbell et al., 2020; Haden et al., 2014; Pagano et al., 2020). Most of this work employs conversational cue cards to parents to encourage them to interact with and explain information to their child. For example, in an African history exhibit, giving families materials suggesting what to look for in the exhibit (i.e., written prompts), and prompts related to the exhibit, influenced the amount of time spent at the exhibit (Tenenbaum et al., 2010). Similarly, a prompt on a cue card encouraging parents to promote explanations in their children leads children to spend more time testing the causal mechanisms of the gears in a gear exhibit, whereas a prompt to encourage exploration leads children to spend more time building complex gear machines (Willard et al., 2019). This suggests that prompting explanations leads to a greater causal understanding of how a machine operates, whereas a prompt to explore leads to increased engagement in the exhibit. Moreover, the presence of physical objects that parent-child dyads are able to manipulate also impacts how they engage with exhibits in a natural history museum (Jant et al., 2014; also see findings about "conversation cards").

These studies show that directing interventions at both parents and children influences how children engage in exhibits. At the same time, minimal verbal prompts directed specifically at children in laboratory settings have successfully guided their learning towards causal properties of artifacts. For example, asking a child to explain why a block did not activate a machine, rather than recall if the block activated the machine led children to privilege causal properties over perceptual similarity when making novel inferences (Walker et al., 2014).

Therefore, I aimed to connect these findings from laboratory settings to informal learning environments by examining whether prompts directed only at children in informal settings will also influence their learning.

The Present Study

Building on this work, I examined children's learning about a novel artifact in a living history museum. Children explored the exhibit with parents present, because this is how children would typically engage in this museum, and because previous literature suggests that the presence of parents is beneficial to children's learning in museums (Crowley et al., 2001; Fender & Crowley, 2007). The study began with a Prompt phase, where only children were provided with one of two minimal verbal prompts (experimental or control). While previous studies have provided prompts to parents and children (e.g., Benjamin et al., 2010; Haden et al., 2014), I was interested in examining whether providing a prompt directly and exclusively to the children would influence their talk and learning for two reasons: First, this ensures that any effect of the prompt is driven by children, deconfounding this from contributions that might come from the parent. Second, this also benefits the partner museum, as children visit the museum with varying degrees of adult support, sometimes attending with their families or friends and sometimes on school trips. Following the Prompt phase, children explored the artifact (Learning Phase) with their parents and with museum staff present, with audio recorded. Finally, in a test phase, children were asked two open-ended questions: one that probed all information they gained about the artifact and another that probed an explanation of how the artifact worked.

Methods

Participants

All participants were recruited from Southwestern Ontario via onsite recruitment, social media advertisements, and from a university database. All experiments were conducted with written informed consent obtained from a parent or guardian for each child before any assessment or data collection. All procedures involving human subjects in this study were approved by a University of Waterloo Research Ethics Board. Participants were 61 parent-child dyads. Children were between the ages of 4- and 8-years-old, randomly assigned to two conditions: a component prompt and a control prompt. Demographic information was completed on behalf of children by their accompanying parent or guardian (see Appendix B). In the final sample, 44 participants identified as White, 33 participants reported an annual household income of over $100,000 CND, and 39 participants reported that the primary parent attended a 4-year university or held an advanced/professional designation.

Participants were tested between June and August 2019, as this encompasses a single season in the museum, which only operates in summer months. Thus, I aimed to test as many children as possible over this period, with the expectation of testing at least 30 children per condition. Prior work employing similar open-ended investigations in museums suggests that this sample size was adequate for investigating the present questions (e.g., Benjamin et al., 2010; Chandler-Campbell et al., 2020). As a thank you for participating, participants were given a family pass to come back to the museum, valued at $25 CAD. Fifteen additional dyads were tested but not included in the analyses for the following reasons: parental reported developmental disorder (8); parents answering test questions for their child (3); and child noncompliance (4; e.g., indicating they did not wish to participate anymore). Some participants had siblings present when they arrived to complete the study, if this was the case, siblings stayed away from the exhibit.

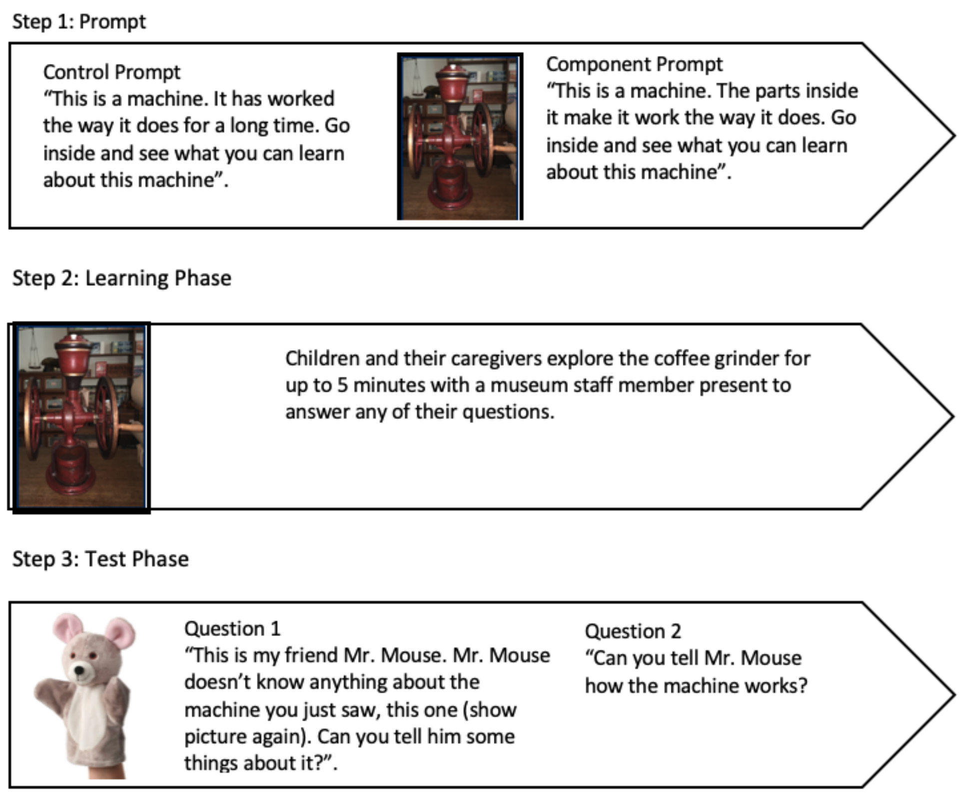
Materials and Procedure

Participants were greeted by the experimenter upon entering the museum, where written informed consent was acquired. Therefore, participants did not enter the exhibit that day before the experiment took place.

Participants were led to the general store, where the machine (i.e., coffee grinder) was located. All interactions were audio recorded using a Zoom Q2n-4k camera fitted to the child's chest using a GoPro Junior Chesty with the camera lens blocked. The experiment was broken into three phases, the prompt phase, the learning phase, and the test phase (see Figure 2 for a schematic of the procedure).

Figure 2

Visual Schematic of the Procedure



The Machine

The machine was a coffee grinder in use in 1914 (see Figure 3). This machine was made of cast iron with two large wheels on either side. The top of the machine contained a tin with a lid, where one puts the coffee beans into the machine. The beans would then fall deeper in the machine to the grinders. One would need to turn the two large wheels on the side to activate the machine, and grind the coffee beans. The grinds would the fall out of the machine and collect in a bin.

Figure 3

Coffee Grinder used in this Investigation

Prompt Phase

Prior to the learning phase, outside of the general store where the coffee grinder was located, children were briefly separated from their parent and given one of two prompts. Thirty children (12 males, M_{age}= 6.634 years, SD=1.463)[5] received the experimental component prompt

[5] An independent samples t-test was conducted to ensure that age was not significantly different between conditions, t(52.7)= 1.659, p= .103.

“This is a machine. The parts inside of it make it work the way it does. Go inside and see what you can learn about this machine”. This prompt was designed to focus children on the machine’s mechanisms, while avoiding the jargon “mechanism”, which young children may not know. Previous experimental paradigms reveal that both adults and children as young as 5-years-old rated characters who provide mechanistic explanations about mechanical machines as more knowledgeable than those that provide non-mechanistic explanations (Lockhart et al., 2019), and believe this mechanistic knowledge should be generalizable to related machines (Chuey et al., 2020). This suggests that children privilege mechanistic explanations, therefore prompting children to focus on mechanisms may increase their talk about mechanisms and lead to them recalling more mechanistic information at test.

Thirty-one dyads (13 males, M_{age}= 6.089 years, *SD*=1.058) received a control prompt “This is a machine. It has worked the way it does for a long time. Go inside and see what you can learn about this machine.” This neutral control prompt was designed to be as equivalent as possible to the component prompt. That is, it still references a machine “working” but is otherwise neutral against the historical backdrop of the immersive museum experience and does not reference the critical “parts inside” (i.e., the mechanisms).

Learning Phase

After children received the prompt, parents and children entered the store to explore the machine. While I only measured and reported the verbal discussions of children and their parents, they were free to explore the machine in any way they wanted, which included touching the coffee grinder and moving it physically, although this was not captured due to recording audio only. Parents were told “You and your children will explore the coffee grinder at the Dry Goods and Grocery Store. You can talk about any aspect of the coffee grinder, feel free to interact with your child as you normally would. You can talk about the coffee grinder as long as you would like, I'll come get you when time is up.". The experimenter was on the opposite side of the store, turned away from the participants and appeared to be sorting through paperwork. Museum staff were present to answer questions from the parents or children and preserve the typical experience for visitors. Thus, child talk was directed at parents and/or staff.

Beforehand, museum staff were instructed to interact with participants as they normally would: to provide information when requested, and to otherwise let them discuss the machine themselves. Dyads were given a maximum of 5 minutes to discuss the machine. At the 5-minute mark or when the dyad indicated they were done investigating, the experimenter would begin the test phase.

Test Phase

After the learning phase, experimenters took the child either to the other side of the store, or outside the store, depending on weather and the number of visitors in the space to complete the test phase. In the test phase children were asked two test questions to assess how much and what they had learned. Parents were nearby, and were instructed by the experimenter to not assist their child in answering the questions. To ensure that children's beliefs about the experimenter's prior knowledge did not influence the findings, the questions were asked on behalf of "Mr. Mouse" (a puppet), a naive learner. The first question was included to assess what children had learned about the machine and to extract as much information from each child as possible: "This is my friend Mr. Mouse. Mr. Mouse doesn't know anything about the machine you just saw, this one (show picture of the coffee grinder). Can you tell him some things about it?". The experimenter continued to prompt the child, using the interview probing technique, "Can you tell him something else?" until the child indicated they had nothing more to say.

The second question was designed to more directly target children's ability to explain how the machine worked in a succinct explanation, and thus targeted what children believed was *causally important* for the machine's operation (as opposed to the quantity of what they knew as in question 1): "Can you tell Mr. Mouse how the machine works?". For this question, children were not repeatedly prompted as in question 1.

Transcription and Coding

Each participant's audio recording was transcribed and then broken into utterances by a research assistant. This coding process occurred as explained in Chapter Two. This process resulted in the identification of 1627 utterances spoken by children.

To prevent bias, age, gender and condition of the child and identity of the parent were removed from transcripts before coding. The primary coder, a research assistant, was unaware of the hypotheses of the study, whereas I was the secondary coder. Prior to coding, the primary and secondary coder coded five of the excluded participants for training purposes. The test phase was also coded separately from the learning phase (i.e., on a different day), at which time the coder could not see any data from the learning phase. The secondary coder reliability coded 30% of the participants. See OSF supplement osf.io/8r5pm for the full coding scheme.

Learning Phase Coding

The following coding was done for child speakers.

Total Talk. As a first step, a research assistant identified utterances that were related to the coffee grinder. This was done to filter out talk not directly related to the artifact of interest (e.g., talk about the store, other artifacts present). Through this process, 1233 child utterances were identified as pertaining to the machine. Reliability was excellent with a Kappa of .987 (Landis & Koch, 1977). A subset of this talk (507 utterances) consisted of content-free responses to adults, such as "yes" or "mhmm". Though this was technically related to the artifact due to the context provided by the parent or staff person, these were not coded into the schemes that follow. Therefore, a total of 726 utterances are used in the following analyzes.

Talk About the Whole Machine versus Talk About its Parts/Components. Utterances referring to the whole object included what a coffee grinder is, its name, history, its appearance and/or what it was made of ("*It's way older", "It's made of metal and steel")*. Utterances referring to parts or components of the coffee grinder included its handle, gears, and wheels (*"You spin this handle here", "The stuff goes in the top here")*. Reliability was excellent with a Kappa of .962 (Landis & Koch, 1977).

Mechanistic Talk. The third scheme aimed to capture talk about the components or mechanisms that underlie the operation of the coffee grinder. For an utterance to be defined as mechanistic, it must identify a component of the coffee grinder, and explain how or why that particular component operates the way it does (*"So you turn, what you see when I'm turning right here. Then it grinds the coffee, the gears inside of it",* Lockhart et al., 2019). From this, speakers were given a score of 0 (indicating there were no mechanistic utterances), or 1 (indicating there was at least 1 mechanistic utterance). I used this binary coding because very few speakers made mechanistic utterances (18 participants), and those that did, tended to make multiple such utterances. To prevent a small number of participants from skewing the data, I used binary coding rather than counts. Reliability was excellent with a Kappa of 1 (Landis & Koch, 1977).

Learning Phase Hypotheses

This coding allowed me to explore which aspects of the machine children were most drawn to discussing; how children's discussions evolve with age; and how the prompts influenced them. In terms of the prompts, I predicted that children who received the components prompt would have their attention drawn to the mechanisms of the coffee grinder. This might also result in them producing more utterances about the parts of the machine than children who received the history (control) prompt. The whole talk variable was included to examine how much children this age talk about the whole artifact, with no specific predictions about how the prompts might affect this talk, given that neither prompt was specifically designed to influence whole talk. Thus, this variable was included to examine whether the components or history prompt might have inadvertently influenced another variable (that is, it is important to ensure that the experimental prompt did not inflate all types of relevant talk or that the control prompt did not somehow inflate whole object talk, pulling focus away from the mechanisms and internal part talk). Additionally, I anticipated effects of age, with older children having more discussions about the parts of the machine, and more mechanistic utterances, as this is in line with previously documented gains in education research (Reuter & Leuchtner, 2020)

Test Phase Coding

Children's answers to the two test questions were coded on different days by the primary coder to prevent one set of codes from influencing another.

Question 1 of the test phase, which asked children to recall facts about the machine ("Can you tell him [Mr. Mouse] some things about it?"), was coded similarly to the learning phase, with some notable exceptions: Total talk was not included, as all child utterances should be related to the coffee grinder. Reliability was excellent with a Kappa of .965 for whole and part talk, and excellent with a Kappa of .948 for mechanistic talk (Landis & Koch, 1977).

Question 2 of the test phase, which asked children to explain how the machine worked ("Can you tell Mr. Mouse how the machine works?"), was coded using the same coding as question 1, as well as a global knowledgeability rating of the produced explanation. This knowledgeability rating aimed to capture the quality of children's explanations by having two coders, naïve to study hypotheses, rate on a 0 – 5 scale how knowledgeable the child was about the workings of the machine. As it was a judgement rating, the primary coder, and another coder who was also unaware of the hypotheses of the study coded 100% of the participants. Both coders were given explanations as to how the coffee grinder operated (see OSF supplement osf.io/8r5pm). Coders gave the child a score from 0 to 5, with 0 indicating that the child did not answer the question, 1 indicating that the child did not know much about the coffee grinder, and 5 indicating that the child knew almost everything (see OSF supplement osf.io/8r5pm for examples). As the coders ratings were highly correlated ($r = .870$, $p < .001$), an average of the two scores was used for subsequent analyses.

Test Phase Hypotheses

This coding scheme allowed us to test which facts about the machine children learned; how their learning evolves with age; and how their learning was influenced by the prompts. I predicted that children who heard the component prompt would recall more facts about the parts and mechanisms of the machine in both questions compared to children who heard the control prompt. I also predicted that these children would be rated as more knowledgeable in question 2 than those that received the control prompt. Coders did not rate knowledgeability for question 1, because the key aim of the knowledgeability rating was to determine whether children became more knowledgeable specifically about the workings of the machine, and question 1 prompted children to divulge all aspects of the information they gained. I predicted that children who received the component prompt would be rated as more knowledgeable because prior work shows that explanations that reference the internal mechanisms and parts of a machine tend to appear more knowledgeable than those that provide non-mechanistic explanations (Chuey et al., 2020; Lockhart et al., 2019). Again, there was also a predicted effect of age, with older children recalling more about the machine's parts and mechanisms (Reuter & Leuchtner, 2020).

Results

Learning Phase

When learning about the machine, children discussed most aspects of the machine, producing 11.902 relevant utterances (*SD*= 8.833) on average. In terms of talk about the whole machine, children discussed what it was made of, where it was made, and how old it is (*M*= 4.246 utterances, *SD*= 3.585). When learning about its parts children discussed the opening where you add coffee beans, the bin where you collect the grinds, and its wheel (*M*= 4.738, *SD*= 4.423). Mechanistic utterances included identified a component of the coffee grinder, and explained how or why that particular component operates the way it does (*M*= 0.295, *SD*= 0.459).

I ran a series of Generalized Linear Models (GLMs) to test the hypotheses[6]. For all analyses, frequency of target talk (i.e., total, part, whole, mechanistic) was the dependent variable, condition (component vs control prompt) was entered as a between subjects factor, and age in months entered as a mean-centered covariate, to control for any effects of age on the other variables of interest. Here and in the test phase, the total amounts of talk, amounts of whole object talk, and amounts of talk about object components were analyzed using a quasi-poisson-based model. I planned to use a poisson-based model, but there was significant over-dispersion for all of these dependent variables (they violated the poisson model's assumption of

[6] I did not examine the proportion of utterances as there was less variability in terms of the overall amount of talk for children, parents, and staff than in the previous chapters.

mean=variance), making quasi-poisson-based models a better and more conservative choice. Children's mechanistic scores (coded as 0/1) were analyzed using a Binary Logistic model.

For the GLMs for each dependent variable, there were no main effects of condition, no main effects of age, and no interactions for any of the dependent variables, except for a main effect of age for total talk[7], t= 2.862, p= .006, and whole talk, t= 2.900, p= .005 (see Table 11 for all statistical tests).

Table 11

Learning Phase Statistical Tests and Means

	Statistical Test	*t*	*p*	Control Prompt Mean (SD) (Range)	Component Prompt Mean (SD) (Range)	Total Mean (SD)
Total						
	Age	2.862	.006**	10.548	13.3	11.902
	Condition	-.448	.656	(6.908)	(10.396)	(8.833)
	Condition x Age	-.307	.760	(0-27)	(1-45)	
Whole						
	Age	2.900	.005**	4.226	4.267	4.246
	Condition	.901	.371	(3.253)	(3.956)	(3.585)
	Condition x Age	.764	.448	(0-15)	(0-17)	
Part						
	Age	1.732	.089	3.903	5.600	4.738
	Condition	-1.08	.285	(3.986)	(4.746)	(4.423)
	Condition x Age	.311	.757	(0-14)	(0-22)	
Mechanistic						
	Age	.353	.553	0.258	0.333	0.295
	Condition	.202	.653	(0.445)	(0.479)	(0.459)
	Condition x Age	.168	.682			

Note. Mechanistic data is binary and is analyzed using a Binary Logistic model GLM. Therefore, it is reported with a *WaldX*^{2}. ** $p < .01$.

[7] This was also examined using all child utterances that were on topic, (including utterances such as "yeah" and "mhm". I found no significant main effect of age (t = 1.707, p = .093), condition (t = .798, p = .428), or condition by age interaction (t = .157, p = .876). This amount of children's total talk was also significantly correlated with parent/staff total talk (r= .462, p< .001).

There is a potential concern that the control prompt may have focused children's attention to historical information about the machine, or about the setting more broadly, taking focus away from mechanisms in that condition. Thus, historical utterances were coded for both children and parents/staff in the learning phase (see OSF supplement osf.io/8r5pm for parental analyses and additional supplemental analyses). The coder was instructed to code any references to how old the machine was, using phrases such as "a long time ago", "back in the olden days", "1914", or comparisons between old versus new, then versus now. For children, (*M*= 0.361, *SD*= 1.081) when analyzed using a quasi-poisson GLM, there was no main effect of age (*t* =.497, *p* = .621), condition (*t* = .503, *p* = .617) or condition by age interaction (*t* = 1.001, *p* = .321). Therefore, the control prompt did not lead children to discuss the more historical aspects of the machine at higher rates.

Learning Phase Correlations

Next, I examined how parent and museum staff engagement was related to children's engagement. Parent and staff utterances were coded using the same coding scheme as with children. The amount children discussed the machine in general (*r*= .304, *p*< .001), the whole machine (*r*= .546, *p*< .001) and its components (*r*= .460, *p*< .001) was correlated with parent and museum staff discussions of each respective type of talk. Children's mechanistic score was not related to parent and museum staff's mechanistic score (*r*= .153, *p*= .239).

Test Phase

The second aim of the investigation was to determine whether the verbal prompts differentially influenced children's learning about machines.

For test question 1, all types of talk increased with age (see Table 12). When children recalled facts about the whole machine they recalled what it was called, and how old it was ("*It's* *a hundred and five years old", M*= 1.213, *SD*= 1.462). When recalling facts about the machine's parts, they recalled the handles and wheels of the machine (*"It grinds more coffee every time you roll the wheels", M*= 2.819, *SD*= 2.306). Mechanistic utterances included discussions about mechanisms (*"You spin the wheel and it grinds the beans",* 22 participants, *M*= 0.361, *SD*= 0.484). There was no main effect of condition and no interaction (see Table 12).

For test question 2, both part (*M*= 1.984, *SD*= 1.512) and mechanistic (16 participants, *M*= 0.262, *SD*= 0.443) talk increased with age (see Table 12). There were no whole talk utterances for any participant for this question. This is unsurprising, as children were directed to explain how the machine operated.

Table 12

Test Phase Statistical Tests and Means

	Statistical Test	*t*	*p*	Control Prompt Mean (SD) (Range)	Component Prompt Mean (SD) (Range)	Total Mean (SD)
Question 1 Whole						
	Age	2.726	.008**	1.193	1.233	1.213
	Condition	.295	.769	(1.492)	(1.455)	(1.462)
	Condition x Age	.810	.421	(0-6)	(0-5)	
Question 1 Part						
	Age	2.403	.019*	2.548	3.100	2.819
	Condition	-.700	.486	(2.488)	(2.107)	(2.306)
	Condition x Age	1.620	.111	(0-8)	(0-7)	
Question 1 Mechanistic						
	Age	4.588	.032*	0.355	0.367	0.361
	Condition	.143	.706	(0.486)	(0.490)	(.484)
	Condition x Age	.351	.554			
Question 2 Part						
	Age	4.532	<.001***	1.710	2.267	1.984
	Condition	-.547	.587	(1.553)	(1.437)	(1.512)
	Condition x Age	.676	.502	(0-6)	(0-5)	
Question 2 Mechanistic						
	Age	7.678	.006**	.194	.333	.262
	Condition	.297	.586	(.402)	(.479)	(.443)
	Condition x Age	.207	.649			
Knowledge						
	Age	24.935	<.001***	2.129	2.967	2.541
	Condition	4.902	.027*	(.991)	(1.332)	(1.236)
	Condition x Age	.043	.836	(0-3.5)	(0-5)	

Note. Mechanistic data is binary and was analyzed using a Binary Logistic model GLM, while knowledge ratings was analyzed using a Linear model GLM. Therefore, both are reported with a $WaldX^2$. *p < .05, ** p < .01, *** p < .001.

Knowledge ratings were analyzed using a linear model with the average ratings (0 to 5) as the dependent variable. There was a main effect of age $Wald X^2$(df = 1) = 24.935, p < .001, and a main effect of condition: children who received the component prompt (M= 2.967, SD= 1.332) were rated as more knowledgeable than children who received the control prompt (M= 2.129, SD= .991) $Wald X^2$(df = 1) = 4.902, p = .027. There was no condition by age interaction $Wald X^2$(df = 1) = .043, p = .836.

Next, I examined how children's talk in test question 1 related to their knowledge rating in test question 2. Whole talk was not significantly correlated with children's knowledge rating (p= .080). However, both part talk (r= .383, p= .002) and mechanistic scores (r= .267, p= .037) were significantly correlated with children's knowledge ratings. Children who recalled more facts about parts and mechanisms when asked about the machine more globally are likely to produce an explanation in the next phase that seems to convey high knowledgeability. Additionally, I examined how children's talk in test question 2 related to their knowledge rating in question 2. Both part talk (r= .665, p< .001) and mechanistic scores (r= .649, p< .001) were significantly correlated with children's knowledge ratings.

Discussion

The first aim of this study was to understand how children talk and learn about machines in museums when visiting with their families. Children generally talked about all aspects of the machine in the learning phase. While they increased their discussions about the whole machine with age, at all ages children were discussing the machine's parts, such as its wheels, gears, and handles, and to a lesser extent its mechanisms. This finding supports the idea that from a young age, children are interested in and motivated to learn not only facts about an entire artifact, but also its less obvious parts and mechanisms (Chuey et al., 2020; Lockhart et al., 2019; Sobel et al., 2007)

However, in the test phase, interesting age effects emerged as older children had greater recall of facts about the whole machine, its parts, and mechanisms, and appeared more knowledgeable. This could be due to a combination of factors: First, children from 4 to 8 years make notable gains in understanding how machines work (Leuchtner & Naber, 2018; Reuter & Leuchter, 2020), and thus they would likely know more about all these factors at baseline. Second, older children have better developed memory and other executive functions than younger children (Gathercole, 1998; Ghetti & Angelini, 2008), which may aid in their better recall for all aspects of the machine than younger children. Third, parents and museum staff may have directed children's learning to these topics more with older children, given that adults likely assume that older children can handle a larger quantity of information and perhaps greater complexity. This possibility is supported by the fact that children's total, whole, and part talk in the learning phase were related to parent and staff discussions of these respective types of talk, This also supports that some scaffolding may be necessary to draw younger children's attention to these features and take advantage of the learning opportunities presented to them (Crowley et al., 2001; Fender & Crowley, 2007; Ferrara et al., 2011; Treagust & Duit, 2008; Weisberg et al., 2016). As the current analyses cannot disentangle these possibilities, future work could investigate which aspects of these age-related changes in children's recall are driven by children or parents and museum staff.

The second aim was to see whether providing a verbal prompt directed to children about mechanisms might affect children's talk and learning. In general, many children talked about and recalled facts about the internal parts of the machine, although talk about the machine's mechanisms occurred less frequently. I found that children that received the component prompt did not discuss parts of the machine or its mechanisms more than participants who received the control prompt during the learning phase, or in the test phase. I had hypothesized that focusing children's attention on the parts of the machine would lead them to discuss its mechanisms more. Future work might explore this relation further by examining how to encourage children to focus on how the components of a machine relate to its internal mechanisms. Because it seems that the minimal verbal prompt did not affect children's talk, it may have been helpful to scaffold the parents as well so that they could better support their children's learning. This could have been in the form of a verbal prompt, or through the use of cue cards. This museum contains artifacts that may be unfamiliar to 21st century parents and so they may have needed additional information or suggestions about the questions to ask staff, or the kinds of things they could say to their children to draw their attention to important features.

However, I did find that children who received the component prompt were rated as more knowledgeable than those who received the control prompt by naïve coders. Further, children's knowledge rating in question 2 was positively correlated with their part and mechanistic utterances in question 1 and question 2. These correlations provide further support for lab work showing that discussing internal components and mechanisms in explanations makes one appear more knowledgeable (Lockhart et al., 2019), and that prompting children to explain increases their causal understanding (e.g., Walker et al., 2014).

So why do the subjective knowledge ratings of the children's explanations differ by condition when the number of part utterances and the number of children generating mechanistic utterances in those explanations did not? I suspect that while the overall number of children making mechanistic utterances about these topics did not differ statistically by condition, the *quality* of their part and mechanistic utterances might. As is the case with much of our perception and cognition, examining the sum of children's explanations may have revealed something more interesting than examining their parts. Based on these findings, children who received a prompt directing their attention to parts and mechanisms may have produced more coherent and logical explanations about those aspects, even if they did not mention them at higher rates.

In general, the effects of the prompts were minimal. What might explain this? First, prior work (e.g., Gelman & Wellman, 1991) suggests that young children understand that the insides of an artifact are important to an artifact's function and identity. Thus, children in the component prompt condition may not have been as influenced as I had hoped to focus on insides, because they may already be well-aware of their importance. However, given that so few children referenced mechanisms in the present dataset, this interpretation is perhaps unlikely. A second possibility is that the prompt was simply too short or subtle, or that the control prompt was too well-matched to the experimental prompt to reveal differences. That is, both prompts contained the sentence, "go inside and see what you can learn about this machine," and both prompts referenced the machine "working", which could have masked differences across conditions. The neutral control prompt was designed to be as equivalent as possible to the component prompt, and to direct children's learning to the machine rather than the store itself. This allowed us to highlight the "inside parts of the machine" specifically in just one prompt to see if that would increase their discussions about mechanisms. On the other side, a separate potential concern about the prompts was that the control prompt may have directed children's attention to the historical aspects of the setting. I ruled out this possibility by showing that children in the control prompt condition did not discuss the historical aspect of the setting more than children in the component prompt condition. Future research could investigate whether there are differences in children's discussions between a component prompt condition versus a baseline "no prompt" condition. However, pilot data from a previous study conducted by my supervisor's lab in the same setting suggests that a baseline "no prompt" condition may not be a viable option. In that work we discovered that some small instruction to learn, talk or ask questions was necessary to get the youngest children to engage in the visit meaningfully. Another option could be to provide a more heavy-handed component prompt, or perhaps a prompt directed at both parents and children, as these findings, compared to previous findings, hint towards the possibility that providing the prompt to both parents and children might be critical to influencing engagement in these settings.

This study had a number of limitations, here I discuss a few: First, there was a non-significant age difference between the two conditions, where the component prompt condition contained more older children than in the control prompt condition. This occurred due to random assignment to conditions. When parents inquired about participating, we only asked whether the child fell in the age range of the study, and we alternated condition assignment. In the future, a pseudo-random approach, where children are signed to alternating conditions based on their age in years would reduce age imbalances. However, age was statistically controlled for throughout analyses by entering age in months as a covariate, which alleviates some of this concern. Second, there is a limitation on the generalizability of the current findings given the narrow demographics of the sample (mostly White, highly educated and high income). Finally, the analyses were also limited to participants' speech and to assessments of their recall of information, which will be discussed in more detail in Chapter Five.

These findings have implications for visitor experience and exhibit design in historical museums, which will be more fully discussed in Chapter Five. Briefly, they confirmed for this specific museum that their exhibits are supporting young children's learning, including learning about machines and mechanisms, which is well aligned with the local science curricular expectations for grades K-2.

These findings also show how a simple verbal prompt accompanying an exhibit can influence children's learning, as it resulted in children producing higher quality explanations of how the machine worked. This finding was particularly valuable for the museum staff as their exhibits are embedded in an outdoor historical village, which cannot take advantage of "traditional exhibit features" that are typically used to enhance learning (e.g., plaques or interactive electronic features). When museum staff embark on an explanation about a machine's functioning in the exhibits, they can begin by drawing children's attention explicitly to the inside of machines. Afterwards, staff could ask children to explain to them how the artifact operates to draw their attention to the mechanistic information about the artifact. This approach could be taken in similar museums, with the use of age-appropriate pamphlets or prompt cards for the parents to use with their children.

Chapter Five: General Discussion

Summary of Findings

This dissertation provides evidence of the rich learning opportunities that children are presented with in the living history village at the WRM. Chapter Two examined 4- to 8-year-old children's conversations about artifacts with their parents and museum staff. This revealed that the triad discussed features of artifacts in differing amounts, suggesting that all members of the triad bring unique information to the conversation. Parents' and children's artifact talk differed based on child age, with the proportion of parents' and children's identification talk decreasing with age. Parents and staff also used different pedagogical strategies when interacting with children, with parents using question-asking techniques the most, when identifying artifacts and staff providing simple procedural information when explaining an artifact's operation. Children were the most engaged when responding to questions and were inclined to give more information in response to procedural information with age.

Using the same dataset as Chapter Two, Chapter Three explored the science learning opportunities present in the unexpected location of a living history village. Children, parents, and staff all discussed the different biological concepts, regardless of children's age. Children increased the frequency of their engineering related talk with age and increased in the proportion of their talk related to simple machines and forces with age. Correspondingly, parents increased the frequency of their discussions about simple machines and forces with child age as well. Children's discussions about basic physics and chemistry also increased with their age. Notably, children discussed science concepts by using observational statements the most, although their proportion of descriptive and causal utterances increased with age. Parents also mostly made observational utterances, although the frequency of their descriptive utterances increased with child age. Staff mostly made descriptive utterances.

Chapter Four examined whether it was possible to direct children's attention to the causal mechanisms of an artifact's operation with a minimal prompt. Regardless of prompt, older children had more utterances related to the whole machine, its parts, and its mechanisms, and appeared more knowledgeable to adult coders. However, children who received the component prompt appeared more knowledgeable than those that received the historical (control) prompt, and this was correlated to their use of part and mechanistic utterances.

These results provide evidence that the living history village is a space where children can have meaningful conversations about artifact, science, and causal reasoning, with support of their parents and museum staff. This space should continue to be considered when examining children's learning in naturalistic settings and should not be seen as limited to only providing children with historical information.

Limitations of this work and Future Directions

There are a couple of notable limitations of the current dissertation. First, the sample of participants were mostly White (80% in Chapter Two and Three, 72% in Chapter Four), from high household incomes, and whose parents possessed post-secondary education/professional degrees. This limits the generalizability of the current findings. For example, in Chapter Two, examining different populations may allow us to discover pedagogical tools that parents in this sample did not use. Cultures with stronger oral traditions (see Gardner-Neblett et al., 2012) may engage in the museum exhibits differently. Also in Chapter Two, while I found that children did not differ in their information-seeking based on pedagogical strategy, cultures with stronger oral traditions might exhibit interesting differences. Different cultures and communities may also emphasize different science concepts than what was found in Chapter Three. For instance, a different population may have had more utterances for all speakers related to stewardship and sustainability, as they may place more importance on respect for animals and the environment.

Second, throughout Chapters Two and Three, I often talked about children's exposure to these different concepts through conversations as learning opportunities and sometimes assumed that they led to learning. In Chapter Two when describing parents' pedagogical strategies, I often assumed that this was directly related to how children were learning about artifacts. Future studies could include a post-testing phase that examines whether the increased use of certain pedagogical strategies impacts what children recall about artifacts. Further studies could even include prompts to increase or decrease particular strategies, before measuring learning. In Chapter Three, we do not know whether children learned the descriptive or causal science information they were exposed to, as again post-tests were not included. Future research should then examine if these informal, naturalistic conversations relating to science translate to children's learning.

All analyses in all three empirical chapters were also limited to participants' speech (Chapters Two-Four) and children's ability to recall information (Chapter Four). These analyses do not take into account if there were differences in the amount of time children spent exploring the machine manually, looking at it, or otherwise interacting with it. Future studies could examine children's active exploration in this space (e.g., Callanan et al., 2020, Willard et al., 2019). This decision was partly made due to preferences of the museum staff, who did not want any overhead cameras in place (to maintain the historical aesthetic) and to the ethical guidelines at the University (who ultimately concluded that having a camera overlooking the space was intrusive to staff and other visitors). But eye tracking could be a possibility for future experiments, and such data could measure what artifacts captured children's attention and how long children spent exploring the artifact and the specific parts. Parents and museum staff might also have been scaffolding children's learning through gestures and showing children how different artifacts physically operate. These additional factors could not be examined using speech alone.

Finally, my approach in Chapter Four for the test phase did not allow for any other measures that might have shown a greater understanding of mechanisms than the ones used here, such as asking children simple forced-choice questions about what they learned.

Implications for Cognitive Development

This dissertation and its findings demonstrate that the rich and varied interactions that occur in museum settings are rife for bidirectional research collaboration. For cognitive developmentalists, living history museums present a unique opportunity to see how learning unfolds in everyday settings and how this aligns with in-lab effects. The museum contains hundreds of artifacts, that are analogous to those that children encounter in their everyday lives, while still being novel. For instance, a 1914 cash register resembles a 2021 cash register, in that it serves the same purpose, and appears as though it belongs to the same category, but its composition and mechanisms are quite different.

In Chapter Two, there were age-related effects in children's discussions, as the proportion of their talk related to simple identification decreased with age, while operation and to a lesser extent purpose talk appeared to increase. These results align with in-lab findings that children appreciate the operation and purpose of artifacts more with age, which may have led to older children discussing these topics more (e.g., German & Johnson, 2002; Kelemen, 1999; Matan & Carey, 2001). In Chapter Three, children discussed more engineering and basic physics/chemistry concepts with age, corresponding to the science curricula (Michigan Department of Education, 2015; Ontario Ministry of Education, 2007). Children's proportion of talk related to descriptive and causal information also increased with age, indicating that children discussed deeper aspects of science concepts with age, which is again in line with the science curricula. In Chapter Four, while older children did recall more information about the whole machine, its parts and mechanisms, I did not find as much (spontaneous) mechanistic talk as I had expected. This finding is in contrast to prior experimental work in the lab that suggests that by early preschool children know that internal mechanisms are important to a machine's operation (e.g., Ahl et al., 2020; Ahl & Keil, 2017; Sobel et al., 2007). Both these similarities, and differences, demonstrate the value of examining children's behavior in real-world learning settings. In the latter example, it is perhaps the case that while children show an understanding of these concepts in lab settings, they are not central to children's spontaneous thoughts about machines so early in development, or that they do not yet know how to put these thoughts into words without significant support.

Implications for Informal Learning Environments

This dissertation also helps the partner museum, and museums like it, better understand how families navigate their space and the conversations that occur between visitors and museum staff. Understanding verbal engagement was of particular importance for this museum, and history museums like it, which include many artifacts that are out of reach for children to physically manipulate. This allows museums of this nature to further their understanding on how to best engage children in their exhibits and implement these findings in their staff training and exhibit designs. As Chapter Four demonstrates, a simple prompt from museum staff could influence children's learning. The findings of Chapter Three and Four also confirm that living history museums present opportunities for children's science learning in ways that are compatible with the science curricula. Fostering this type of science learning can lead to potential funding opportunities for these museum, as it is currently a priority area in the funding landscape.

Living history museums are regular sites for school field trips during which the museum staff are the main educators. Thus, the findings in this dissertation contribute to the limited literature on the role of staff in children's engagement and discussions in museum settings. Indeed, many of the findings suggest that museum staff and parents provide valuable and different learning opportunities for young children in the exhibits. Namely, staff are likely playing a more central role in providing mechanistic and science-related curricular information to children visiting the museum. In Chapter Two, their increased use of operation talk suggests that they are providing more detailed information regarding how simple machines (e.g., levers and cranks) operate. For example, a museum staff member talked about the operation of the cheese keeper in the following way: "*...you could measure out how much somebody wanted using this crank. And then they would lift up the lever, cut it down, and they would cut the perfect size of cheese...*". This was supported in Chapter Three where staff had the most engineering utterances related to simple machines and forces. Additionally, staff also discussed these topics in greater depth as they provided descriptive information the most, while parents provided observational information the most. For example, a staff member provided descriptive information about the cash register found in the general store *"Alright inside, my favourite part about it is, I'm not sure if you guys are tall enough to see, but there's actually a calculator in there that's running a total."*. These findings are unsurprising, given museum staff's experience providing curricula-relevant information to children during field trips, and their familiarity with the purpose and operation of the novel artifacts found in museum. This suggests that in this particular setting, museum staff do not limit parent engagement, but instead provide new learning opportunities to children (Pattison & Dierking, 2012). Laboratory studies have shown that young children are sensitive to expertise, as they expect experts to be more accurate at labeling items that pertain to their domain of knowledge than non-experts (Koenig & Jaswal, 2011), and are sophisticated in whom they wish to seek information from (Aguiar et al., 2012; Lutz & Keil, 2002). Future studies should examine whether children are sensitive to expertise in an unstructured setting by seeing whether children prefer to learn some types of information from museum staff (as opposed to their parents).

While museum staff were providing this high-quality information to children, they did so without tailoring this information to children's age. In Chapter Two, the museum staff spoke about all features of the artifacts, regardless of child age. In Chapter Three, museum staff spoke about all science concepts to children, again regardless of the child's age. While this provides a more uniform experience for visitors, this may not be the best way to disseminate information to children. By uniformly providing information, museum staff members may be providing information that is beyond the child's comprehension and abilities at that age (Letourneau et al., 2021; Pattison & Dierking, 2012; Pattison & Dierking, 2013, Tran, 2007).

Parents however tailor how they discuss different learning opportunities concepts with their child's age. In Chapter Two, the proportion of their discussions related to identification decreased with child age, and parents were less likely to ask critical thinking questions as children got older. In Chapter Three, they increased the frequency of their descriptive utterances and the frequency of utterances related to simple machines and forces with child age. These findings highlight the importance of empowering parents as educators in this space, as it seems that they were limited in how much operation and purpose information they could provide their children (Chapter Two), and in-depth curricula relevant information about science concepts they encounter in this space (Chapter Three). Therefore, museum staff and parents should work together, supporting one another when interacting with children. Improving parents' baseline knowledge of exhibits may help to promote children's learning in these settings. Future work should examine the impact of developing supporting materials such as informational pamphlets and signs that are specifically targeted to parents visiting with their children in these types of spaces. On a similar note, our findings suggest that museum staff might benefit from explicit training about how to support parents in this environment (see Spruijt et al., 2020), ensuring that they are acting in collaboration with one another and in a complementary manner (Pattison & Dierking, 2012). Finally, parents have been found to give lower ratings of learning opportunities in museum spaces than staff (Song et al., 2017). Therefore, this museum, and other museums similar to it, should market themselves to parents and other visitors as a space where science learning occurs, in addition to the previous suggestions to increase parental awareness of the large and varied amount of learning opportunities at the living history museum.

Applied Outputs from this Partnership

This has been a successful partnership between the University of Waterloo and the WRM, which started with a successful Social Sciences and Humanities Research Council (SSHRC) Partnership Engage Grant for $25,000 CAD. This partnership was created with the goal of examining how children learn in the living history village, which filled a large knowledge gap in cognitive development concerning how children learn in non-scientific museum spaces. This was beneficial to the museum, as they articulated to our lab in discussing a potential partnership that it is difficult for museum staff to identify the learning opportunities their space offers, and the efficacy of their programming. An extensive (and resource intensive) research investigation helps to illuminate how, when, and what children can learn during a visit. Additionally, the learning opportunities afforded to children are likely the result of a combination of complex factors, including the museum's unique living history environment, the age of the children, the availability and informativeness of museum staff, and parents' input. This knowledge gap is becoming an increasing concern for the WRM who wish to expand their program offerings and address urgent local needs for early learning programs. Thus, the partnership grant was truly mutually beneficial to our lab and the museum, which is a top priority of this funding opportunity (that the work be highly beneficial to both organizations).

To fulfil the aims of the partnership, technical reports based on Chapters Two and Four have been created for the WRM to help begin to identify the learning opportunities for children in their living history exhibit (see Appendix C and D). In these reports, the results of the chapters are presented in a clear, easy to read manner, free of jargon. They also specifically highlight the educational opportunities these conversations (Chapters Two, Three, and Four) and interventions (Chapter Four) provide children, and implications specific to their space. For example, Chapter Four demonstrated how a simple verbal prompt given to children before engaging with an exhibit can positively influence children's knowledgeability rating. As there is no signage in the village to keep the integrity of the exhibit intact, museum staff can create guidebooks with prompts for children to focus on specific aspects of the village, or artifacts to ensure visitors are hitting different curriculum goals. For example, one guidebook could focus on biology concepts, another engineering concepts, and finally one on social history concepts.

Before the COVID-19 pandemic, this partnership also helped create a living lab space between the Developmental Learning Lab at the University of Waterloo and the WRM. A living lab engages visitors by immersing them in developmental science. In a living lab educational model, scientists conduct studies within "an exhibit" at their local museum. This exhibit format can range from a more typical exhibit one might expect to see in a museum to a table in an open space staffed by research assistants. At the WRM, this lab was a booth in their indoor gallery space. Museum visitors benefited from learning about and observing developmental science to increase their scientific literacy skills. The Developmental Learning Lab members also benefited by gaining access to new participants for their studies and experience discussing scientific results with the community.

The key to successful partnerships like this one is to clearly communicate the goals and expectations of both parties for the partnership. As such, this partnership has also produced applied outputs made specifically for the WRM. At their request, we evaluated their "Day-in-the-Life" programming during the summer of 2018 (see Appendix E). After exploring the three locations, the parent-child dyads would participate in a museum staff led activity. These activities changed on a rotating basis and consisted of typical activities individuals would do in 1914, such as barn chores, cream separating, paper dolls, and creating s-hooks. Here, we qualitatively evaluated each activity for how the staff members delivered information, the learning potential, the perceived level of enjoyment, and the capacity. For instance, barn chores were highly rated for both learning potential and enjoyment level, whereas making paper dolls was given a lower rating for learning potential, but a higher rating for enjoyment level. Included in the report is testimony from participants about their experience participating in the activity. For activities that received lower rating for either learning potential, enjoyment level, or both, we provided suggestions on how museum staff could increase the ratings. For example, for paper dolls, we suggested that staff can mention the historical relevance of the activity by teaching children about historical attire worn in 1914 and discussing why making paper dolls was a popular activity for children in the past.

The WRM also asked if we could evaluate their training materials for the "Day-in-the-Life" programming to help staff disseminate information to children, as the activities are meant for visitors of various ages. For each activity, we created an output that could be added to the existing training materials that contained information specific to educating children (see OSF supplement osf.io/8r5pm). In the output for each activity, we listed learning objectives for each domain (e.g., history, biology, engineering, basic physics/chemistry) and alternative vocabulary to use with young children (e.g., instead of contraption say machine, instead of dampened say wet). These outputs also included "dos and don'ts" when interacting with young children such as, do ask children *wh*- questions, and do not ask mostly yes/no questions, as well as tips for interacting with older children. For each domain listed in the learning objectives, we created some sample questions staff can ask children to help promote children's thinking of each domain, and their understanding of each learning objective. Finally, the WRM was also provided funding from the SSHRC Partnership Engage Grant to purchase materials that would benefit their museum space and programming, such as new artifacts for their living history village.

Partnerships with spaces like the Ken Seiling Waterloo Region Museum should continue to not only advance our knowledge about children's cognitive development, but also to continue to build upon the learning opportunities provided to children outside of classroom settings. Other museums will gain the opportunity to get exhibit-specific insights from cognitive developmentalists, and potentially reveal overlooked learning opportunities their exhibit spaces and programming provide. They will also get the opportunity to improve staff training, and therefore the overall visitor experience in their space.

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Appendix A

Participant Demographics (Chapters Two and Three)

Table 1

Demographics of Child and Parent Identity

Characteristic	Frequencies	Percentage (%)
Gender		
Male	20	50
Female	20	50
Age (in years)		
4	6	15
5	15	37.5
6	11	27.5
7	6	15
8	2	5
Racial Identity		
White/Caucasian	32	80
Multiracial	8	20
No Response		
English as Dominant Language at Home		
Yes	23	57.5
No	15	37.5
No Response	2	5
Languages Other than English Spoken		
French	8	20
Mandarin	1	2.5
Spanish	1	2.5
Norwegian	1	2.5
More than 2 Languages	4	10
No Response	25	62.5
Frequency of Prior Visits to Museum		
First Time	13	32.5
Bi-Monthly	1	2.5
Monthly	1	2.5
Once a Year	18	45
A Few Times a Year	7	17.5
Parent Identity		
Mother	29	72.5
Father	7	17.5
Stepparent	1	2.5
Grandmother	2	5
Grandfather	1	2.5

Note: Additional options were available for most categories but only categories selected by at least one participant are reported.

Table 2

Demographics of Family Household Information

Characteristic	Frequencies	Percentage (%)
Religion		
Atheist	13	32.5
Agnostic	3	7.5
Christian	20	50
Jewish	0	0
Muslim	0	0
Sikh	1	2.5
Other	2	5
No Response	1	2.5
Household Income		
Less than 10,000	0	0
25,000-49,999	2	5
50,000-74,999	3	7.5
75,000-99,999	3	7.5
Over 100,000	30	75
No Response	2	5
Education Level of Parent One		
Less than high school diploma	0	0
High School/GED	2	5
2-Year College	7	17.5
4-Year University	9	22.5
Some University/College	5	12.5
Advanced/Professional Degree	17	42.5
No Response	0	0
Education Level of Parent Two		
Less than high school diploma	1	2.5
High School/GED	2	5
2-Year College	6	15
4-Year University	11	27.5
Some University/College	4	10
Advanced/Professional Degree	13	32.5
No Response	3	7.5

Appendix B

Participant Demographics (Chapter Four)

Table 1

Demographics of Child and Parent Identity

Characteristic	Frequencies	Percentage (%)
Gender		
Male	24	39.3
Female	37	60.6
Age (in years)		
4	9	14.75
5	16	26.3
6	20	32.8
7	7	11.5
8	9	14.75
Racial Identity		
Aboriginal	1	1.6
Black or African American	1	1.6
Latin American	1	1.6
South Asian/West Asian/ Arab	4	6.6
White/Caucasian	44	72.1
Multiracial	7	11.5
No Response	3	4.9
English as Dominant Language at Home		
Yes	41	67.2
No	19	31.1
No Response	1	1.6
Languages Other than English Spoken		
Arabic	2	3.3
French	7	11.5
Polish	1	1.6
Spanish	1	1.6
Twi	1	1.7
More than 2 Languages	7	11.5
No Response	1	1.6

Note: Additional options were available for most categories but only categories selected by at least one participant are reported.

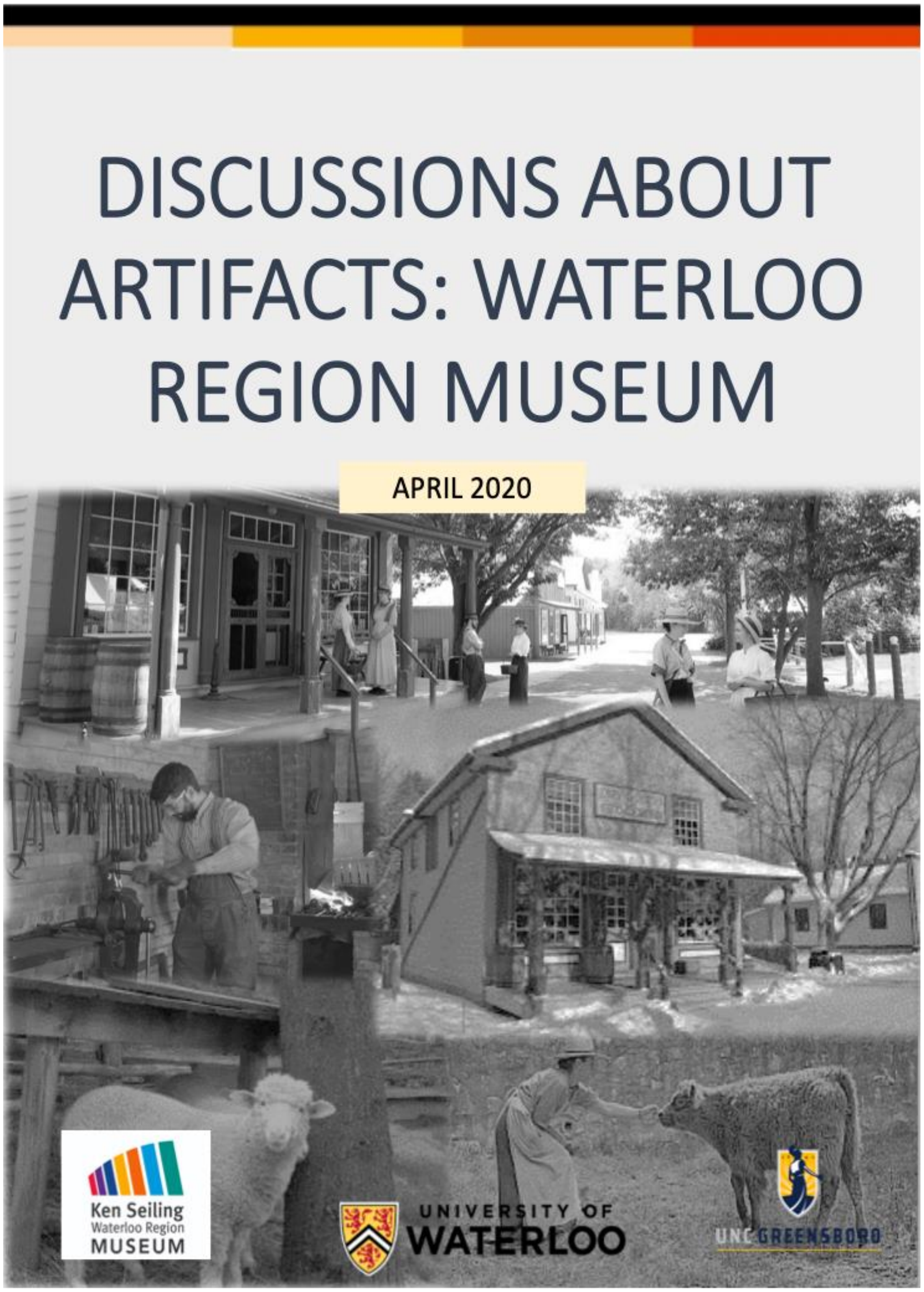
Table 2

Demographics of Family Household Information

Characteristic	Frequencies	Percentage (%)
Religion		
Atheist	8	13.1
Agnostic	5	8.2
Christian	32	52.5
Hindu	1	1.6
Jewish	2	3.3
Muslim	2	3.3
Other	6	9.8
No Response	5	8.2
Household Income		
Less than 10,000	0	0
10, 000-24,000	2	3.3
25,000-49,999	5	8.2
50,000-74,999	6	9.8
75,000-99,999	9	14.75
Over 100,000	33	54.1
No Response	6	9.8
Education Level of Parent One		
Less than high school diploma	0	0
High School/GED	3	4.9
2-Year College	12	19.7
4-Year University	19	31.1
Some University/College	6	9.8
Advanced/Professional Degree	20	32.8
No Response	1	1.6
Education Level of Parent Two		
Less than high school diploma	2	3.3
High School/GED	8	13.1
2-Year College	11	18
4-Year University	24	39.3
Some University/College	4	6.6
Advanced/Professional Degree	8	13.1
No Response	4	6.6

Appendix C

Technical Report 1: Discussions about Artifacts-Waterloo Region Museum (based off Chapter Two)



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ACKNOWLEDGMENTS

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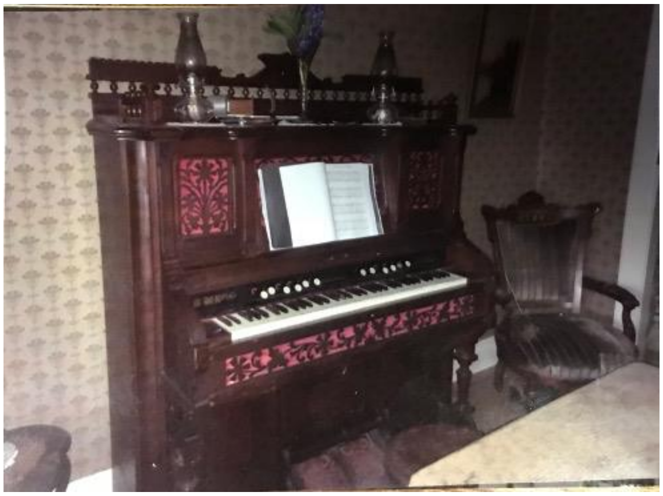
BACKGROUND

Imagine you encounter a coffee grinder from 1914. You would probably be eager to learn about it, asking questions like: What is it called? What does it do? How does it work? Upon discovering the answers to these questions, your newly acquired knowledge would allow you to use the coffee grinder yourself, teach others how to use it, and to think about how it is similar to or different from other machines you know about.

Young children find themselves in this kind of situation very frequently. They are constantly encountering artifacts that they must quickly and efficiently acquire information about.



INTERACTIONS IN MUSEUMS

Some exciting research has examined how children learn in museum settings such as the Doon Heritage Village. It has found that the way parents and their children interact with each other and with exhibit features, greatly influences what these young visitors learn.

For example:

- Children will discover more about how an artifact works when they explore it with their parents as opposed to with their peers or on their own (Crowley et al., 2001).

- Children and parents who can touch and interact with artifacts in an exhibit will discuss more details, spend more time with it, and talk more about it afterwards (Leinhart et al., 2003).

- Parents who use more science specific language, ask more questions, and relate the experience to children's past experiences, will have children who mimic these great learning behaviours by also doing so (Callanan et al., 2017).

THE INVESTIGATION

We studied conversations about artifacts at the Doon Heritage Village. We focused on understanding how children (ages 4 to 8) interacted with their parents, interpreters, and artifacts inside the Dry Goods and Grocery Store, and the Siebert House.

RESEARCH QUESTIONS

1) What do children, their parents, and museum interpreters discuss about artifacts?

2) How do parents teach their children about artifacts?

3) What kinds of educational opportunities do conversations about artifacts provide to young children?

METHOD

To understand how children, parents, and interpreters interacted with artifacts at the museum, we coded what they said about them. To do this, we first created a transcript of everything that was discussed. Second, to understand said the content of the discussions about artifacts, we gave children, interpreters, and parents a "score", which represented how often they each spoke about the topics in **Table 1.**

TABLE 1 – ARTIFACT DISCUSSIONS

Talk	Definition	Examples
Identification	Talk related to the name of the artifact or what category it belongs to.	**That's the gramophone.* **What are the shoe signs?* **It doesn't look like grandma's.*
Function	Talk that discusses how an artifact works or is used.	**How does it work?* **You have to pump with your feet.* **You're supposed to wind it up.*
Purpose	Talk that explains why the artifact was designed like it was, and/or describes the problem it solved for people.	**But uh this this sewing machine, this is how they would make their clothes.* **It's for shaving wood.* **So instead of having a light in your room you would have one of these in your bedroom.*
Composition	Talk related to meaningful physical attributes of an artifact including its material, shape, weight, and age.	**It's just made with wood and ribbons.* **And it's like a -- shaped like a big horn almost.* **Yeah, it's much bigger.*

Third, we gave parents a score for using any of evidence-based teaching methods shown in **Table 2.** This was done to understand what sorts of methods they were using to teach their children about artifacts.

TABLE 2 – PARENT TEACHING METHODS

Talk	Definition	Examples
Critical Thinking Questions	Parent asks questions that trigger interesting learning opportunities like comparison, inference, or explanation.	**What do you think this is used for?* **What do you think this is?* **How is that different than an organ today?*
Causal Reasoning	Parent provides casual information as to why something works the way it does, by explaining "why" or "how come".	**That turns this belt, which turns a gear in there that pumps up the needle up and down.* **Well there's no electricity to continue continuously heat the iron like we have at home cause it was in -- it was used when -- with the stove.* **This is a scale. So they put a weight on there that they know how heavy it is.*
Comparisons or Analogies	Parent compares artifact to another similar object. Analogies phrased as questions are also placed here.	**Grandma has something like this.* **It looks kind of like a piano doesn't it?* **It's like gran and grandad's clock except way smaller.*
Simple Procedural Information	Parent provides simple procedural information about some sort of step involved in using the artifact. They explain what you do, not why you do it, or how it works internally.	**So that little jar would have, be filled with ink.* **That's where people put money.* **You're supposed to wind it up.*

FINDINGS

WHAT DID THEY DISCUSS ABOUT ARTIFACTS?

We found that children, parents, and interpreters engaged in rich conversations about artifacts. They spoke about many different kinds of artifacts (e.g., coffee grinders, stereoscopes, sewing machines), and talked about everything from their purpose (i.e., why they were invented) to their composition (i.e., what they were made of).

When we dove deeper into the data, we noticed that conversations about artifacts differed depending on how old the child was, and who was talking (i.e., child, parent, or interpreter):

- Children talked more about the **function** of artifacts as they got older, but talked about the **identity** of artifacts at all ages. For example, as children got older, they were more likely to ask questions like "What is it for?". This shows that with age, children did not just want to know what artifacts were called, but also valued learning about their purpose and functions. Here is an example of an older child discussing the function of the coffee grinder:

  Child: Hmmm I think they put it in a machine. And the coffee comes out at the bottom?

- **Parents** provided more **identifying** information to children. For example, parents often asked their children "What do you think that is?" or labelled new artifacts for their children. Here is an example of a parent identifying the cash register:

  Parent: Do you see that? Is that the cash register?

- **Interpreters** provided more **purpose** and **function** information to children. Here is an example of an interpreter explaining how the pump organ works (i.e., its function):

  Interpreter: You have to pump with your feet to get the air to come out.

  Here is a related example of an interpreter explaining what the stereoscope was used for (i.e., its purpose):

  Interpreter: So it's supposed to make an image 3D so like it's popping out at you.

These findings shed light on how children learn about artifacts at the Doon Heritage Village. As children grew older, they discussed more details about the artifact. At all ages, parents were excellent at identifying the artifacts their children wanted to learn about, whereas the interpreters excelled at providing specific information about why the artifacts existed in 1914 (i.e., their purpose), and how they worked (i.e., their function).

HOW DID PARENTS TEACH THEIR CHILDREN ABOUT ARTIFACTS?

We found that parents talked about artifacts to their children in interesting ways. They didn't use all teaching methods to discuss every aspect of the artifacts, instead they tailored the method they used to their target. They showed a real sensitivity to the needs of their young learners.

We found some notable patterns in their discussions:

- When **identifying** artifacts, parents used critical thinking questions, and comparisons. Here is an example of a parent using a comparison to identify a telephone to their child:

  Parent: Does that look like my telephone?
  Child: Uh, our cellphone doesn't look like that right.

  Here is a related example of a parent using critical thinking questions and comparisons to identify a pump organ:

  Parent: What does this remind you of?... What did we have in our house?
  Child: A piano.
  Parent: It looks kind of like a piano doesn't it? It's very similar.

- When describing the **function** of an artifact, parents provided causal explanations, and simple procedural information. Here is an example of a parent using simple procedural information to describe the function of a kaleidoscope:

  Parent: Look if you look at the light through the hole and turn it you see different stuff. Can you see--- nope. [Helping child with the kaleidoscope] You gotta turn it here.

  Here is a related example of a parent using causal explanations to describe the function of the sewing machine:

Parent: That turns this belt, which turns a gear in there that pumps up the needle up and down.

- When discussing the **purpose** of an artifact, parents used critical thinking questions, provided causal explanations, and used comparisons. Here is an example of a parent using causal explanations to describe the purpose of “the lanterns” in the house:

  Parent: When this house was made there was no electricity at that time, so they had to work with lanterns.

- When explaining the **composition** of an artifact, parents used critical thinking questions, and comparisons. Here is an example of a parent using a comparison to explain the composition of the gumball machine:

  Child: Mommy where’s the gumball machine?
  Parent: Right here. It it’s wooden. It’s not plastic like yours.

These patterns reflect what we know about the best ways to teach children about new facts. For example, much research shows that analogies are a great way to teach children new information, as they allow children to relate what they are learning to what they already know (Goswami, 2001). Similarly, there is research showing that many of the methods parents employed, like explanations, aid in the long-term retention of new information (e.g., Jant et al., 2014; Walker et al., 2016; Legare et al., 2017). As we all would guess, parents clearly play an important role in their children’s learning in these spaces.

WHAT EDUCATIONAL OPPORTUNITIES ARE THESE CONVERSATIONS PROVIDING?

When we discovered that children, parents, and interpreters engaged in talk about all sorts of artifacts, we also discovered their conversations were providing **important educational opportunities.**

Most **early childhood science curricula** emphasize the importance of teaching children about simple machines and forces (see Ontario Ministry of Education, 2007; Michigan Department of Education, 2015). For example, the Ontario Science Curriculum includes goals related to developing children's understanding of forces and work; advancing their knowledge of how simple machines operate; and fostering children's understanding of the impact of technology (like simple machines) on society. We found lots of related discussions.

- Here is an example of a discussion about the different **forces and work** that allow an organ to play:

  Interpreter: So we have to first pull out the stops. So these are what control the air. And then down here I'm gonna go like this with my feet and that's pushing air inside.

- Here is an example of a discussion about the **simple machines** (e.g., levers and cranks) that are a part of a cheese keeper:

  Interpreter: But you could measure out how much somebody wanted using this crank. And then they would lift up the lever, cut it down, and they would cut the perfect size of cheese for you.

- Here are two excerpts from discussions about **the impact of technology on society**. This first excerpt is from a discussion about the impact of lamps and electricity on daily life:

  Parent: When this house was made there was no electricity at the time, so they had to work with lanterns. They didn't have a light switch they could turn off and on.

This second excerpt is from a conversation about the impact of the modern washing machine on daily life:

Interpreter: This is our laundry machine. Does it look like the one you have at home?.....We did our laundry on Mondays. And it took the entire day!

We also captured some **interesting methods** that were used to teach children about these important science concepts.

- Here is an example of a parent using lots of causal explanations to teach their about how scales operate:

Parent: This is a weight scale. So you put this weight on, five pounds, ten pounds. What does it say on that?
Child: Twenty
Parent: So you'd put twenty on here. And then you'd put your meat or whatever on here until it was balanced. And once it balances, then you would know that it was twenty pound of whatever you had.

During these conversations, interpreters and parents provided different learning opportunities for young children. **Interpreters often provided highly detailed information** regarding how simple machines in the museum operated and impacted society. This finding is not surprising as it seems likely that interpreters are more well versed than parents about the purpose and function of the specialized artifacts found in the village.

- Here is an example of an interpreter discussing a coffee grinder. They facilitated an in-depth discussion about how gears work, and what they do:

Child: What's this?
Interpreter: That is a coffee grinder. So you put the coffee beans in the top. And you just turn this handle, the gears inside the machine grind the beans, and then the grinds come out the bottom there.

Here is a related example of an interpreter explaining how a series of pulleys and gears allow a sewing machine to work:

Parent: It's a sewing machine.
Interpreter: So in here it's hard to see but there's a big pedal, almost like in a car. I'm going to sew this here for you and show you how it works. So we're just going to put this right under there. And that's where the needle is. So you're going to see a needle that goes up and down and up and down. So what we do is start with our hand, and now I pedal with my foot.

Such discussions also have **implications for school readiness.** We found that the museum's artifacts provided great opportunities for children to practice their critical thinking and problem-solving skills. For example, whenever children encountered a new artifact, they had to solve the problem of figuring out: how to categorize it; what it was for; how it functions; and finally how its composition allowed those functions. Research shows that it is important for children to develop these problem solving skills as early as possible as they are related to later school performance (Pianta et al., 2020).

- Here is an example of a child thinking about how a pen works:

  Parent: Long long long long time ago, when people went to school, this is the stuff that they had for school. Looks different from your stuff doesn't it?
  Child: Are they pen? Wait, why is that sharp?

IMPLICATIONS

The Doon Heritage Village provided children and their parents with a great opportunity to learn about and engage with artifacts. We found that children, parents, and interpreters discussed many different kinds of artifacts. Parents were sophisticated in how they discussed artifacts with their children, as they tailored their teaching methods to what they were trying to teach their children about. Many discussions touched on important STEM topics. These findings have implications for the Waterloo Region Museum. Please see the attached manuscript for further implications for the field of child development.

First, they suggest that parents should be empowered as teachers in these environments. Because parents are showing a sensitivity to how to best teach their children, improving parents' knowledge of exhibits might in turn improve children's learning in these settings. Developing materials such as informational pamphlets and signs specifically targeted to parents visiting with children may help parents better explain artifacts in the living history exhibits to their children and improve their children's experience. Second, and relatedly, they suggest that interpreters might benefit from receiving explicit training on how to support parents, and how to best leverage the teaching techniques parents are naturally using when talking to kids.

Third, they suggest that the WRM is a space where science learning is occurring. Many of the children's discussions about artifacts were well aligned with the Ontario science curriculum expectations for grades K-2. This suggests an opportunity for WRM to seek funding for STEM programming, as the findings in this report suggest that children engage in STEM learning at this site. We hope to share a report soon that explores these STEM learning opportunities in greater depth.

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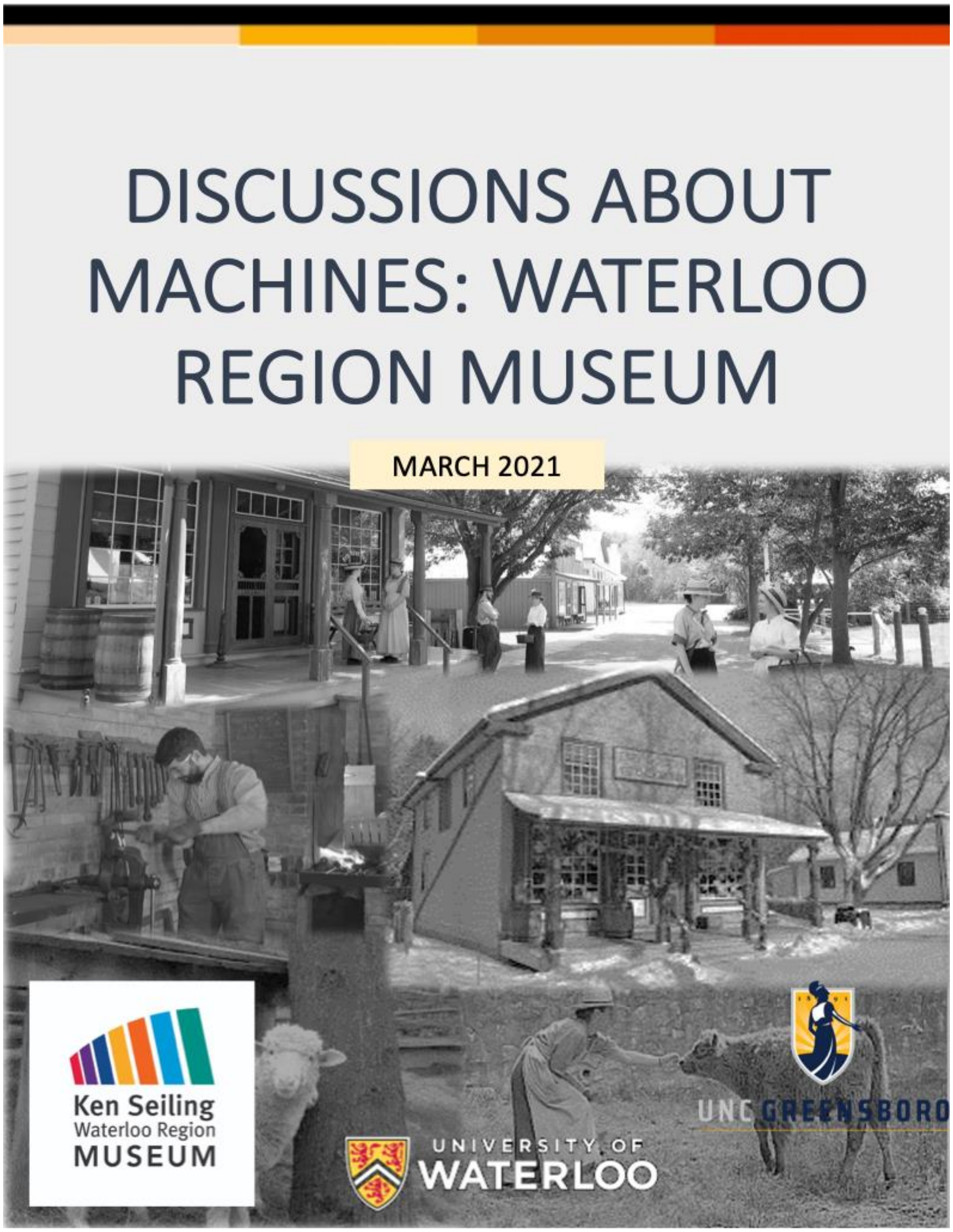
Appendix D

Technical Report 2: Discussions about Machines- Waterloo Region Museum (based off Chapter Four)



CONTENTS

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BACKGROUND

Imagine you encounter a 1914 coffee grinder for the first time. You would probably be eager to learn about:

- Facts related to the whole machine, such as its name, what its made out of, and its purpose
- Facts related to its components/parts, such as the role of a specific part of the machine

Mechanical machines like the coffee grinder provide a unique learning challenge for young children, as they contain non-obvious internal mechanisms that allow them to function, such as gears and levers.

HOW CHILDREN THINK ABOUT MACHINES

There has been really interesting research on how children think about machines. It has found that children are very sensitive to the internal mechanisms found in machines.

For example:

- Children understand that a machine's internal components are necessary for the machine to operate (Sobel et al., 2007).
- Children view someone as more knowledgeable when they were told information about how the parts of the machine worked (Chuey et al., 2020).
- Children view a machine's insides as more complex when the machine has more functions and parts (Ahl & Keil, 2017; Ahl et al., 2020).
- Children who explore a machine with their parents will learn more about the internal parts of the machine, and how it works, rather than when they explore the machine on their own or with a friend (Crowley et al., 2001; Fender & Crowley, 2007).

THE INVESTIGATION

We studied how children learned about machines at the Doon Heritage Village. We focused on understanding what children (ages 4 to 8) want to learn about machines like the coffee grinder inside the Dry Goods and Grocery Store and how short verbal instructions might influence what they learn.

SPECIFIC RESEARCH QUESTIONS

1) What information do children discuss when exploring machines in museum exhibits?

2) After exploring a machine, what information did children learn?

3) What educational opportunities are their discussions providing?

METHOD

Before children and their parents went to explore the coffee grinder, children were given one of two prompts.

Half of the children received a prompt that was designed to focus children on the machine's **internal components/parts**.

- "This is a machine. The parts inside of it make it work the way it does. Go inside and see what you can learn about this machine".

The other half of the children received a **neutral** prompt.

- "This is a machine. It has worked the way it does for a long time. Go inside and see what you can learn about this machine".

After receiving the prompt, children and their parents then explored the coffee grinder (i.e., **exploring phase**) for five minutes, with the aid of an interpreter.

After the exploring phase, children were asked how they thought the coffee grinder worked (i.e., **test phase**). This was done to assess what they learned.

To understand how children learn about machines in a museum, we coded what they said about the coffee grinder both during the exploring phase and the test phase. To do this, we created a transcript of everything that was discussed and then coded their answers.

For the first part of our coding, we gave children a "score" for how much they talked about different topics related to the coffee grinder during **both the exploring and test phase**. **Table 1** gives examples of what we coded.

After this coding was done, we also gave children a score for how knowledgeable they appeared when asked how the coffee grinder worked **during the test phase** (0- knew nothing at all, 5-knew almost everything).

TABLE 1 – HOW CHILDREN DISCUSS MACHINES

Talk	Operational Definition	Examples
Whole Machine	These statements included information about the entire coffee grinder. This might include what the coffee grinder is for, its name, its history, and/or its composition like its color.	*Coffee beans are large, so you cannot make coffee with them, one needs to grind the beans first in order to make coffee.* *It was made in Philadelphia Pennsylvania* *It is one hundred and five years old*
Part of the Machine	These statements referenced a part or component of the coffee grinder in some way. This might include its handle, gears, knobs, and wheels	*If you turn this, it grinds the coffee.* *There is a hole at the bottom (for coffee grind to fall out)* *It has a handle.* *You can change the size of the grinds with a knob at the top of the machine.*
Internal Mechanisms	These statements included information on how the internal mechanism of the coffee grinder operates, and can be generalized to other similar coffee grinders.	*So small wheel makes it really hard while the big wheel makes it really easy.* *It's like a hammer that is flat but can still crush things* *There's stuff inside of it that um, makes it into grind.*

FINDINGS

WHAT DID CHILDREN DISCUSS WHEN EXPLORING THE MACHINE?

During the **exploring phase**, we found that children spoke a lot about the coffee grinder, and engaged in discussions about everything from its purpose of the whole machine (e.g., to grind coffee) and its history (e.g., made in Philadelphia) to how particular components of it work (e.g., open the top, turn the handle).

When we dove deeper into the data, we noticed that children's conversations about the coffee grinder differed depending on how old the child was:

- Children talked more about the **whole coffee grinder** as they got older. Here is an example of an older child engaging in discussions about the whole coffee grinder:

  Child: Hmmm I think they put it in a machine. And the coffee comes out at the bottom?

- Regardless of age, children discussed the **parts and mechanism** of the coffee grinder equally (i.e., how the gears inside turn once you turn the handle, grinding up the coffee beans). Here is an example of a child discovering the internal mechanism of the coffee grinder:

  Child: And there's like these little things that cut them as they go down

  Child: Oh, I can hear the parts moving inside, grinding the coffee.

Here is an example of a child engaging in discussions about specific parts of the coffee grinder:

Child: Like you open that up and then put the coffee beans in there.

Child: You need to turn the wheel there.

- The **prompt** did not change how children discussed the coffee grinder.

- Children's discussions about the whole coffee grinder and its parts were related to their parent's and interpreters discussions. Here is an example of a parent discussing the whole coffee grinder with their child:

  Parent: What's different about it than ours?

  Parent: What happens, what kind of material do you think it's made out of?

  Here is an example of an interpreter discussing a part of the coffee grinder:

  Interpreter: When we spin this wheel here, the coffee beans here go down into this little compartment right here.

  Interpreter: They're like sort of gears that come together.

These findings shed light on how children explore machines at the Doon Heritage Village. As children got older, they generally discuss the machine more, but are sensitive to its mechanism from a young age. The prompt also increased children's discussions of the coffee grinder's parts.

WHAT INFORMATION DID CHILDREN LEARN?

During the **test phase**, we found that children were able to recall varied facts about the coffee grinder. They learned quite a bit about the coffee grinder, suggesting that this space is excellent for teaching children about machines.

We found some interesting findings in what they recalled in the test phase:

- Children recalled more about the **whole coffee grinder**, its **parts,** and the **mechanisms** as they got older. Here is an example of a child recalling facts about the coffee grinder:

  Child: So you spin the top, and then you have to put the coffee beans
  in, and then spin that back and forth. And it goes into the hole there as tiny beans.

  Here is another example of a child recalling facts about the coffee grinder.

  Child: There's two wheels on the ends. And one has a handle. And when you turn ir um beans that you have in there are cut into small pieces. And there's a tube that allows them to go out and in the bucket that's under it.

- Children also appeared more **knowledgeable** as they got older. Here is an example of a younger child that did not appear too knowledgeable about the coffee grinder:

  Child: Mmm, I wonder what happens right, I wonder what happens right in the middle.

  Here is an example of an older child that did appear knowledgeable about that coffee grinder.

  Child: So you turn the handle to grind the beans into the tiny specks that make coffee. How it works is there's something sharp in there *that cuts the big beans into little seeds to make coffee.*

- The **prompt** also changed what children recalled about the **parts** of the coffee grinder. Younger children who heard the prompt that focused on the internal components/parts recalled more about the coffee grinder's parts than younger children who heard the neutral prompt.
- The **prompt** also changed how **knowledgeable** children appeared when talking about the coffee grinder. Children who heard the prompt that focused on the internal components/parts appeared more knowledgeable than children who heard the neutral prompt. Here is an example of a child who heard the component prompt who appeared knowledgeable:

These patterns reflect laboratory work arguing that children are interested in and motivated to learn not only facts about an entire artifact, but also its less obvious parts and mechanisms (Chuey et al., 2020; Lockhart et al., 2019; Sobel, 2007). As expected, children's age influenced how recalled information about machines in the test phase.

WHAT EDUCATIONAL OPPORTUNITIES ARE THEIR DISCUSSIONS PROVIDING?

Similar to our findings with artifacts, children's discussions about the coffee grinder (a simple machine) were providing **important educational opportunities.**

Again, the **early childhood science curricula** in Ontario emphasize the importance of teaching children about simple machines and forces (see Ontario Ministry of Education, 2007). For example, the Ontario Science Curriculum includes goals related to assessing the purpose of simple machines; advancing their knowledge of how simple machines operate; and fostering children's understanding of the impact of technology (like simple machines) on society (i.e., how our lives are made easier by these machines). We found lots of related discussions.

- Here is an example of a discussion about how the coffee grinder made life easier for people:

  Parent: How long do you think it would take for one person to grind a whole pot of coffee beans? A long time?

  Parent: Does it plug into the wall like mine does at home?

- Here is an example of a discussion about the **simple machines** (e.g., gears) that are a part of a coffee grinder:

  Parent: What kind of mechanism is in here, the actual grinding part?
  Interpreter: It's basically just gears rubbing against each other and grinding those coffee beans into small powder.

IMPLICATIONS

The Doon Heritage Village is filled with simple machines that children and their parents can learn about and engage with. We found that children as young as 4-years-old, are actively engaging with these simple machines and want to learn about them. We also found that a simple prompt encouraged children to learn more about the parts of the machine that allowed it to work the way it does. These findings have implications for the Waterloo Region Museum. Please see the attached manuscript for further implications for the field of child development.

First, they help to confirm that the Waterloo Region Museum's exhibits are supporting young children's learning, including learning about machines and their mechanisms, which is aligned with the Ontario curriculum guidelines for science education for grades 1 and 2.

Second, they demonstrate how a simple verbal prompt given to children before engaging with an exhibit can positively influence children's learning. As the Doon Heritage Village does not contain signage such as plaques to keep the integrity of the exhibit intact, this is a particularly powerful finding. The accompanying guidebooks can then include prompts for children to focus on specific aspects of exhibits or artifacts to hit different curriculum guidelines. For instance, one might create a variety of the guidebook that include prompts for parents and information that focuses their interactions on different topics like: simple machines and their components, biology, and of course social history.

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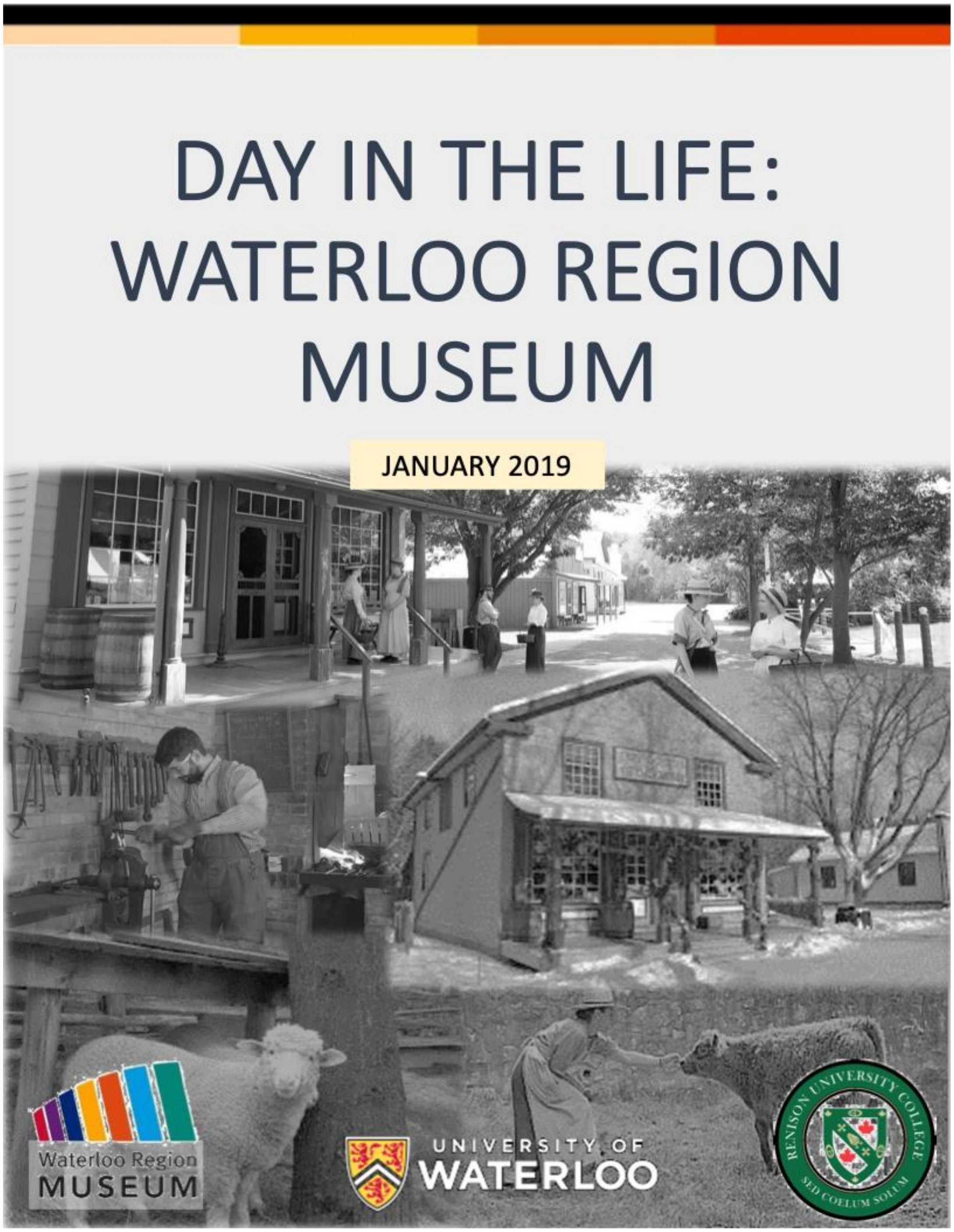
Appendix E

Technical Report 3: Day in the Life: Waterloo Region Museum (Chapter Five)



CONTENT

ACKNOWLEDGMENTS

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BACKGROUND

The museum provides day-in-the-life activities that are an excellent opportunity for children to learn about different topics through conversation and play. Past research shows that children learn effectively in museums through a combination of social interaction and hands-on engagement with objects (Henderson & Atencio, 2007; Jant, Haden, Uttal, & Babcock, 2014). Children's natural inclination towards learning is enhanced when they are given the opportunity to interact with people and the environment around them (Henderson & Atencio, 2007).

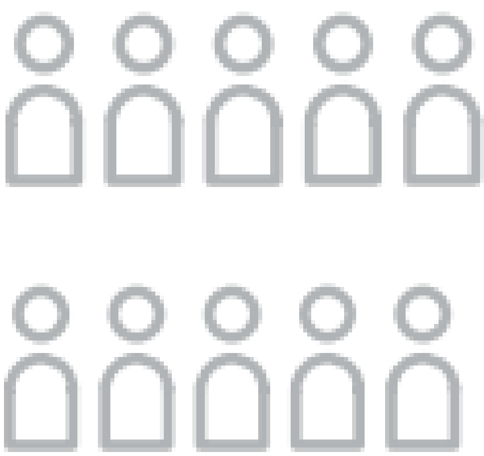
Adults provide support and guidance that is crucial to children's learning (Jant et al., 2014; Wolf & Wood, 2012). They enhance children's learning by simplifying complex ideas and providing additional resources in order to help children understand a task or concept (Wolf & Wood, 2012). For instance, linking children's past personal experiences with present learning material supports children's learning and helps them remember what they learn (Anderson, Piscitelli, Weier, Everett, & Tayler, 2002; Jant et al., 2014). Further, posing open-ended questions to children (e.g., What, Why, and How) is similarly beneficial to learning, as they direct their attention to important aspects of the activity (Haden et al., 2014; Jant et al., 2014). For example, these types of questions help adults identify gaps in children's knowledge (Jant et al., 2014).

In addition to the guidance provided by adults, children learn through engagement with their environment (Jant et al., 2014; Krakowski, 2012). When children spend time in play and in active engagement, they interact with more people and objects, and thus, learn more (Henderson & Atencio, 2007; Krakowski, 2012). In fact, total time spent actively engaged with the environment has been shown to affect how much children learn (Krakowski, 2012). Through play, learning also becomes an enjoyable and pleasant task, rather than a tedious one (Henderson & Atencio, 2007). Moreover, children become more interested in content when learning experiences are construed as play. When children are highly interested in material, they are more likely to engage themselves at a deeper level and acquire more in-depth knowledge (Henderson & Atencio, 2007; Krakowski, 2012). Thus, a combination of adult guidance and hands-on play enhances learning (Jant et al., 2014).

THE INVESTIGATION

Guided by the prior work reviewed above, we investigated the quality of learning opportunities in the museum's day-in-the-life activities. This report focused mostly on interactions with young children (ages 4 to 8).

Our analysis is divided into two parts. Part 1 highlights the most effective behaviours demonstrated by highly skilled interpreters, who facilitate the activities. Part 2 focuses on the quality of the individual day-in-the-life activities.



AGES 4-8

☑ **Part 1:** Highlights the most effective behaviours demonstrated by highly skilled interpreters, who facilitate the activities.

☑ **Part 2:** Focuses on the quality of the individual day-in-the-life activities.

SKILLED INTERPRETATION

Qualitative analyses revealed many high quality interactions during the day-in-the-life activities. Compatible with the literature on museum learning, skilled interpreters:

- Provided supportive learning opportunities by helping children relate the learning material to their own lives.
    - **Barn chores:** The interpreter explained how the pellets that each animal ate are composed of different ingredients. She related this concept to how different breakfast cereals are also made up of different ingredients.
    - **Telegraphy:** The interpreter stated that the process of sending telegrams was similar to sending a text message in 1914.

- Asked children open-ended questions during the activities, which helped them focus on relevant information and promoted further thinking about the topic.
  - **Cream separating:** The interpreter asked the children, "What are the differences between whole milk and skim milk?" This question promoted children to think about fat content in milk and helped them understand the purpose of separating fat from milk.
  - **Telegraphy:** The interpreter asked the child, "How do you communicate with people today?" This question helped children view telegraphy as a method of communication and encouraged them to think about how it was used to send messages in the past.

- Featured opportunities for children to interact with various objects or animals. These hands-on opportunities stimulated children's interest and enjoyment in the activity.
  - **Quilting:** Children were given a needle and taught how to sew three layers of fabric together to make a blanket.
  - **Telegraphy:** Children developed a message and transmitted it to their parent through Morse Code with the assistance of the interpreter.

SUMMARY

Museum training should continue to target simplifying material, relating information to children's experiences, and actively engaging children through hands-on play, in order to maximize their learning in these activities.

INDIVIDUAL ACTIVITIES

Each day-in-the-life activity was rated on three dimensions: its learning potential, the perceived level of enjoyment that children experienced, and its capacity. Two coders assessed each day-in-the-life activity on each of these three dimensions. Any discrepancies in the scores were settled by a third coder.

The learning potential of the activity was measured on a 5-point Likert scale (1 = *limited learning potential* to 5 = *high learning potential*). The learning potential of a particular activity was assessed in relation to the clarity of its learning objectives and the perceived ability of the activity to achieve them. Factors that were considered when evaluating whether an activity could achieve its learning objectives included the opportunities for guidance provided by a knowledgeable adult (e.g., parent or museum interpreter) and the interactivity of the activity (see work by Andre, Durksen, & Volman, 2017; Henderson & Atencio, 2007). For example, coders considered whether activities were “hands-on” and provided opportunity for learning through exploration.

The perceived level of enjoyment that children experienced from the activity was measured using a 5-point Likert scale (1 = *limited enjoyment* to 5 = *high enjoyment*). Factors that were reviewed when assessing whether children enjoyed the activity were outward signs of interest in the activity and the extent that children were actively involved in the activity (Henderson & Atencio, 2007). Testimony from parents regarding their child's experience also influenced the rating of the activity. After they visited the museum, follow-up surveys were sent to parents. Parents were asked to respond on what their child said was the most fun thing they did and to provide an example of something their child learned. Responses that referred to the day-in-the-life activities are included in the sample testimony table. Of the 31 parents who responded to the follow-up survey, 20 parents mentioned the day-in-the-life activities in their feedback (see Table 1).

Capacity reflects the ideal upper limit on group size for each activity. This capacity limit was determined by considering the maximum number of individuals that could actively participate in an activity at one time while maintaining a high quality experience for all.

TABLE 1

Summary of Learning Potential, Enjoyment Level & Capacity

Activity	Learning Objectives	Learning Potential	Enjoyment Level	Capacity
Barn Chores	To explore the lifestyle of farmers in 1914 and biological needs of animals (food, water, shelter)	5/5	5/5	Up to 10
Cream Separating	To understand the purpose and process of cream separating	4/5	3/5	Up to 5
Crokinole	To learn how to play crokinole	2/5	4/5	Up to 10
Dress-Up	To explore how individuals dressed in 1914 by trying on historical clothing	3/5	5/5	Up to 10
Fishing	To learn how to fish	3/5	4/5	11+
Harness	To explore how leather goods were made	2/5	2/5	Up to 5
Ice Cream Making	To understand the process of making ice cream	3/5	5/5	Up to 10
Indoor Games	To explore indoor toys that children played with in 1914	2/5	4/5	Up to 10
Medical Mystery	To learn about common illnesses in 1914 and disease prevention	5/5	2/5	Up to 10
Outdoor Games	To explore outdoor toys that children played with in 1914	2/5	4/5	11+
Paper Dolls	To explore children's lives in 1914	1/5	3/5	11+
Quilting	To explore the process of making quilts	3/5	4/5	Up to 10
S-Hooks	To explore the responsibilities of a blacksmith and the process of softening and shaping metal	5/5	5/5	Up to 5
Telegraphy	To understand how telegraphy was used for communication	4/5	4/5	Up to 5

THE FINDINGS

As shown in the summary tables (see Tables 1 and 2) both barn chores and S-hooks are activities that demonstrate significant learning potential and are highly enjoyable for children. Barn chores provide children with the opportunity to learn about the various responsibilities of farmers and the needs of biological organisms through caring for farm animals and connecting with the natural world. Barn chores effectively combine experiential learning (e.g., feeding tasks) with adult guidance, which serves to maximize children's learning (Jant et al., 2014; Smeds, Jeronen, & Kurppa, 2015). The interpreters give explanations on the purpose of each task, which helps children develop knowledge about biology and its applications in the real world (Haden et al., 2014; Uitto, Juuti, Lavonen, & Meisalo, 2006). This further helps to promote an interest in ecology and a positive attitude towards environmental responsibility in children (Smeds et al., 2015; Uitto et al. 2006). Learning about biology in an authentic learning environment, such as the barn, also increases long-term memory retention and improves comprehension because children can simultaneously use multiple senses to learn (e.g., seeing and doing; Smeds et al., 2015).

Barn chores received a high rating for perceived level of enjoyment because children are continuously engaged in a clear task and appear to be highly excited and motivated. Parents mentioned children remembering details about the animals after they left and that their children very much enjoyed the interactive aspects of feeding and taking care of the animals (see Table 2).

S-hooks demonstrates high learning potential because children are able to learn the historical role of blacksmiths and the science behind softening and shaping metal. In this activity, children and the interpreter collaboratively reshape a piece of metal into a S-hook by continuously heating and hammering it. Through observing and participating in the making of the hook, this activity stimulates curiosity about the natural world and supports the active construction of scientific knowledge in children (Gallenstein, 2005). For instance, engagement with the process builds skills (e.g., observing and inferring relationships) through hands-on experience and encourages children to question and investigate the scientific concepts behind the task (e.g. the relationship between heat and the malleability of metal; Gallenstein, 2005). In addition, the support and direction provided by the interpreter also strengthens retention and recall of what is learned (Haden et al., 2014; Jant et al., 2014). Because creating S-hooks is typically a novel activity for children, the interpreter's speech and actions play a crucial role in helping children reach a deeper understanding of the material (Jant et al., 2014; Krakowski, 2012).

S-hooks also received a high rating for perceived level of enjoyment because children were actively involved in the making of the hook for the entire activity. Children appeared to be highly intrigued by the task. Also, as shown in the summary table, parents mentioned that their children learned about the importance of heat in shaping metal and were excited during the activity.

All-in-all, barn chores and S-hooks present an environment that is highly conducive for learning through conversation and hands-on exploration (Jant et al., 2014).

In slight contrast to these activities, some of the day-in-the-life activities, such as paper dolls and indoor/outdoor games, revealed a pattern of relatively lower learning potential but high enjoyment. The learning potential of these activities can be improved through the interpreter's interactions with the children. For instance, for paper dolls, interpreters can mention the historical relevance of the activity by teaching children about historical attire worn in 1914 and discussing why making paper dolls was a popular activity for children in the past. Similarly, for indoor/outdoor games, interpreters can comment on how popular these activities were in the past due to the absence of technology. By increasing the guidance from interpreters, the learning potential of these activities can be improved (Andre, Durksen, & Volman, 2017; Henderson & Atencio, 2007).

On the other hand, the harness activity demonstrated lower learning potential and lower perceived enjoyment compared to other activities. Due to various constraints such as safety, this activity was not particularly engaging for children, but parents seemed to enjoy it very much. Modifications to the activity, such as allowing children to perform the activity on other materials (e.g., paper or felt) may serve to make the activity more kid-friendly if that is desired.

TABLE 2

Child and Parent Feedback

Activity	Testimony
Barn Chores	"Her favourite thing about the museum was feeding and taking care of the animals. She really enjoyed the interactive part of feeding them and seeing their stalls"
	"She enjoyed the barn and putting the animals in for the night"
	"They both said that they liked doing the chores with the animals and watching them run into the barn"
	"He enjoyed feeding the animals the most"
	"She said, 'Pigs are bigger than I thought'"
	"He learned about the look and feel of the animal feed"
	"She learned that animals need food and water"
	"She retained a lot of information from the animal exhibit at the end of our visit (details about the pigs and sheep)"
	"He learned lots about farm animals, especially how loud sheep can be and how goats like to play with each other"
Harness	"She mentions the leather circle with the E's on them the most"
Ice Cream Making	"I learned that when you make old fashioned ice cream, the salt helps the ice stay cold so you can have cold ice cream and not melted ice cream"
Indoor Games	"My child enjoyed learning the games of those times, especially Jacob's ladder and the pebble solitaire"
	"She enjoyed the games the best"
Quilting	"He learned about quilting, how a special needle is used, and how it is hard to keep the thread in the needle"
	"He learned how to quilt"
	"He learned about following the lines on the fabric to sew a quilt"
S-Hooks	"She learned that you need metal to be hot to twist it"
	"He seems to have really enjoyed making the S-hook. I think he enjoys more of the hands-on learning"
	"He was thrilled to use the hammer and pound the S-hook"
	"She mentions the twisted metal piece the most"
Telegraphy	"His favourite thing at the museum was trying to send the Morse code messages"

OPPORTUNITIES

Potential opportunities for the museum include providing age-related learning objectives to interpreters. By providing learning goals specific to children at different age ranges, interpreters can be aware of an activity's learning potential for children at different ages and tailor their interactions to promote acquisition and retention of knowledge.

In addition, handouts can be provided to parents before each day-in-the-life activity that outlines topics that parents can talk to their child about. For instance, for the cream separating activity, background information, such as where milk comes from or what cream is, can be listed as topics that parents can go over with their children before the activity.

Furthermore, opportunities exist to increase the amount of pretend play in many of the day-in-the-life activities. This type of play is easily enjoyed by children up to eight years old and allows children to engage more deeply with the learning material (Henderson & Atencio, 2007).

Another potential opportunity for the museum is incorporating elements into the day-in-the-life activities that support parental involvement. By fostering interactions between children and parents during activities, children's quality of engagement can be enhanced (Haden et al., 2014). Family interactions also support children's understanding and retention of museum content (Haden et al., 2014). Overall, the day-in-the-life activities that the museum provides are an excellent opportunity that introduces children to various scientific and historical concepts through a combination of adult guidance and hands-on interaction.

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