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HOW DO YOUNG CHILDREN LEARN SCIENCE THROUGH NARRATIVE, EMBODIMENT, AND PLAY?

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Kyungjin Cho

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The dissertation of Kyungjin Cho was reviewed and approved by the following:

Julia D. Plummer
Associate Professor of Science Education
Dissertation Advisor
Chair of Committee

Carla M. Zembal-Saul
Kahn Professor of STEM Education
Interim Department Head, Curriculum and Instruction

Jacqueline J. Reid-Walsh
Associate Professor of Education (Language & Literacy Education) and
Women's Studies

Heather T. Zimmerman
Associate Professor of Education (Learning, Design, and Technology)

Elisa S. Hopkins
Associate Professor of Education (Language & Literacy Education)
Special Member

Kimberly A. Powell
Professor of Education, (Language, Culture & Society), Art Education, Music
Education and Asian Studies
Department Head, Curriculum and Instruction

ABSTRACT

Narrative, embodiment, and play are central pedagogical strategies in young children's science learning. However, there is a limited understanding of how these three pedagogical functions interact to support young children's construction of explanations. This dissertation is motivated by this gap in our understanding and accordingly fulfills the following set of goals: (a) develop and design two learning environments, Story Driven Embodied Play and Embodied Play, that integrate narrative, embodiment, and play, and embodiment and play, respectively; (b) investigate how the Story Driven Embodied Play learning environment supports young children in constructing evidence-based explanations about science phenomena; and (c) compare the two learning environments to identify the role and effect of narrative on children's learning. The participants in the study were young children aged 3- to 5-years old (N=44), who participated in either the SDEP (N=22) or EP (N=22) programs. Both programs focused on encouraging children to engage in embodied guided play about shadows with or without narrative from the book. I used *Conjecture Mapping* analysis to identify the most salient patterns of SDEP and EP learning environments.

Analysis of SDEP and EP program suggests that together the use of body movements, engagement in guided play, and making observations and testing predictions strongly supported children in constructing evidence-based explanations during the investigation. However, there were significant differences between the SDEP and EP programs in that during the SDEP program, children constructed fewer evidence-based explanations because the educator provides fewer questions and prompts because the children were more engaged in play and imaginary experience. Another salient finding from the study is that narrative plays an important role in the SDEP program and provides children with the opportunity to 'reproduce' narrative with agency.

Thematic analysis of the intersection of narrative theory, embodied cognition, and play theory provides a holistic view of young children's science learning. The combination of these three theories more explains both young children's conceptual understanding of shadows through science investigation and their social-emotional development in terms of social interactions, agency, and motivation in learning.

The results demonstrate the importance of narrative, embodiment, and guided play for supporting children's co-construction of evidence-based explanations. Further, this dissertation study suggests that narrative plays a critical role in promoting children's playful moments and active engagements in the learning context. Not only does this research contribute to the gaps in our understandings about the intersections and interanimations of narrative, embodiment, and play in children's learning, but it also has implications and recommendations for how these three theories might be integrated in SDEP learning environment designs for children's science learning.

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Chapter 1

Introduction

As young children begin to understand the world around them in more structured learning environments, like classrooms or educational settings, they come to understand natural phenomena through doing science. For young children, meaningful ways of doing science to understand natural phenomena involve engaging in science practices and communicating their ideas with others. Through communicating with others and engaging in science practices, children construct their understanding of scientific phenomena in the world around them (National Research Council [NRC] 2007; Siry, Ziegler, & Max, 2012). Science learning includes both content knowledge and scientific practices (NRC, 2007; Zembal-Saul, McNeill, & Hershberger, 2013). In science learning, not only do children learn scientific concepts, but they also generate scientific evidence, and construct and negotiate explanations by participating in science discourse. In general, young children can become quite competent at engaging in science practices and reasoning (Gelman, Brenneman, MacDonald, & Román, 2009; NRC, 2007).

Prior literature suggests some specific pedagogical functions to help children's science learning. For the purposes of this study, I have identified three key pedagogical functions—narrative, embodiment, and play—that can support children's engagement in science practices and be used to design learning environments. Narrative with children's literature (Avraamidou & Osborne, 2009; Cho & Plummer, 2018; Murmann & Avraamidou, 2014), body-based actions and gestures (Danish, Enyedy, Saleh, Lee, & Andrade, 2015), and play-based learning (Fleer, 2009; 2017) can support scientific investigations in meaningful ways. I also found potential theoretical underpinnings for these pedagogical functions that can be used together to explain children's science learning: narrative theory (Bakhtin, 1986; Chatman, 1978; Norris, Guilbert, Smith,

Hakimelahi, & Phillips, 2005), embodied cognition (Abrahamson & Lindgren, 2014; Alibili & Nathan, 2012; DeSutter & Steiff, 2017; Wilson, 2002), and play theory (Fisher, Hirsh-Pasek, & Golinkoff, 2012).

There is a gap in the literature on how these three important pedagogical functions could work together in ways that support children's use of science practices and how these three pedagogical functions can be explained through theories of learning. Therefore, the goal of this study is to investigate how narrative, embodiment, and play can be integrated to support young children's use of science practices, and in particular, constructing evidence-based explanations in a designed learning environment. Further, I will explore how theories of narrative, embodiment, and play can be used together to explain young children's learning in science. To achieve this, I designed a specific learning environment called story-driven embodied play (SDEP) by integrating three pedagogical functions including narrative, embodiment, and play to promote young children's engagement in science practices. In this way, SDEP is a play-based learning environment guided by narrative and embodiment.

In this chapter, I discuss how my research study comprises an investigation of a designed science learning environment for young children that features integrated pedagogical functions of narrative, embodied cognition, and play. The study focuses on preschool-age children, 3 to 5 years old, and employs the term young children to broadly refer to preschool and elementary-age children. The following section offers the rationale for my study and is followed by a brief discussion of the study frameworks and research questions.

Rationale of the study

In general, a growing body of literature and policy documents have shown that students learn science by engaging in diverse practices of science. In other words, science learning occurs

when students engage in science practices to understand science phenomena around them (NRC, 2012). Through opportunities to engage in science practices, students generate and evaluate scientific evidence, construct or debate evidence-based explanations, and participate productively in a community of science learners. Therefore, science practices are fundamental in science learning.

Limited studies have focused on young children's engagement in science practices, and in particular, the science practices of preschool-age children (Monteira & Jiménez-Alexandre, 2016; Siry et al., 2012). Despite the lack of research on preschool-age children learning science, policy documents and resources demonstrate evidence that suggest young children's capacity for science learning through engaging in science practices (Gelman et al., 2009; NRC, 2012; Siry, 2014; Siry et al., 2012). What emerges from the literature is evidence that young children can engage in a diverse range of practices; it is important, therefore, for educators, teachers, and parents to provide young children with opportunities to investigate scientific phenomena with appropriate learning environments. One such environment might offer meaningful investigation opportunities by facilitating children's experiences with science practices with peers, educators, and the physical environment (Siry et al., 2012). As young children's science learning might be more effectively supported through doing and communicating across modalities and through a variety of resources, this dissertation study is interested in exploring the ways in which such multifaceted approaches can encourage young children to begin to take up science practices as a way to understand their world.

When children engage with narrative in science learning, they have opportunities to communicate their ideas through familiar communication tools (Avraamidou & Osborne, 2009; Millar & Osborne, 1998; Norris, Guilbert, Smith, Hakimelahi, & Phillips, 2005). Researchers found evidence that the use of narratives helps students to understand scientific phenomena because narratives support the sharing of thoughts and ideas to specific contexts as a

communication tool (Avraamidou & Osborne, 2009; Millar & Osborne, 1998; Norris et al., 2005). Science learning is not simply conveying knowledge, but rather the building of understanding of science phenomena through learners' experiences and interactions with physical and social environments. Therefore, narrative has an important role for young children's science learning processes by combining their everyday concepts with scientific concepts.

In recent years, growing attention to the role of embodiment in learning environments demonstrates that instructional designs are often used to support learning (Abrahamson & Lindgren, 2014; Danish, et al, 2015; DeLiema, Enyedy, & Danish; 2019; Lindgren & Johnson-Glenberg, 2013). Body-based actions, such as body movements and gestures, support learners' interactions with physical environments and engender their representations of abstract conceptual knowledge (Alibali & Nathan, 2012; Wilson, 2002). Danish and colleagues (2015) designed a learning environment called embodied play that integrates embodiment with play-based learning for early elementary students to promote their understanding of science concepts. They suggest that embodied play supported students in making sense of concepts but that embodiment alone was not enough. They suggest that an educator's feedback and guidance are needed for students to understand key principles through their embodied play. Therefore, the role of an educator is essential in embodied play to support young children's science learning through communicating their ideas and providing guidance. However, there are limited studies on embodiment for preschool-age children concerning how embodiment supports young children in building their understanding of science phenomena. This lack of scholarship demonstrates potential for future investigation of how embodiment can be used to support young children's understanding of science phenomena and representation of their ideas to each other.

In the field of early childhood education, numerous research studies suggest that one of the most crucial tools for learning is play (Akman & Ozgul, 2015; Fleer, 2009; Vygotsky, 1987). Learning and playing are intertwined phenomena for young children (Osborne & Brady, 2001) as

play allows young children to bring their everyday experiences to learning contexts (Sliogeris & Almeida, 2019; Vygotsky, 1987). Therefore, young children can engage in learning processes in natural and appropriate ways through play. Research on play and science learning indicates that children who learned science through play had a greater understanding of science concepts than children who were taught science through direct instruction (Bulunuz, 2013; Fleer, 2017). However, there is limited research on how young children build their conceptual understandings of science in play learning environments (Fleer, 2009; Fleer, 2017). In addition, the role of play in science learning as engagement in science practices, specifically in constructing science explanations, is understudied. Thus, I consider play as a pedagogical tool for designing learning environments as well as a theoretical lens to understand young children's learning.

All three key pedagogical approaches presented above, narrative, embodiment, and play, are central for young children's science learning. However, there is no literature on how the three pedagogical approaches work together to support young children's science learning. The integration of these three pedagogical approaches is promising; only a few studies have suggested potential relationships between two of these approaches, and no studies have considered a relationship of all three. First, there is a potential relationship between narrative and play in children's learning. Narrative is used every day as a way of making sense of and communicating about events in the world (Avraamidou & Osborne, 2009). Using narrative, children can easily bring their everyday concepts into their learning context (Bruner, 1986). Play is an essential learning environment to provide an opportunity to transfer children's everyday concepts to science concepts (Fleer, 2009; Vygotsky, 1978). In particular, guided play is effective in supporting learning because children are active, engaged collaborators in the learning process (Fisher et al., 2010; Weisberg et al., 2016). Vygotsky (1978) highlights imagination as a key factor for young children's play since imaginary play could be supportive of children's understanding of the world because children reflect and practice their understanding without any

concern of failures (Saracho & Spodek, 2003; Vygotsky, 1978). Therefore, these potential relationships suggest narrative and play could be integrated to support young children's learning science in meaningful ways.

There is also a potential relationship between narrative and embodiment. Narratives might be used to communicate students' ideas and support construction of their own narrative for understanding natural phenomena in meaningful ways (Avraamidou & Osborne, 2009). Narrative can help generate our interests and improve our memories and understanding (Norris et al., 2005). Embodiment, gestures in particular, could also be used to communicate and reflect our understanding of making sense of the phenomenon in teaching and learning settings (Alibali & Nathan, 2012; DeSutter & Stieff, 2017; Vygotsky, 1978). Therefore, research is needed to understand how narrative and embodiment together could support young children's science learning through communicating and representing their ideas in meaningful ways.

The last potential relationship is between embodiment and play. Children use their bodies as a learning tool to construct their thinking and to communicate their understanding (DeSutter & Stieff, 2017). Play is a central learning medium for young children as it provides a rich learning environment where young children have the opportunity to explore, interact, and represent their ideas (Pelegrini, 2009). Danish and colleagues (2015) suggest that embodied play—where children's guided play allows them to use their bodies to explore scientific concepts—affords opportunities to reflect and explore new concepts. This research suggests that embodiment, including gestures and whole-body movements, and play might be useful for young children's science learning when children are engaged in play-based learning environments through embodiment. However, prior research was exclusively conducted for early elementary and older students so research is needed to understand how preschool-age children can be supported in their early experiences by narrative and embodied play to engage in science practices.

Therefore, these three potential relationships suggest new insights to support young children's science learning. Narrative, embodiment, and play could be integrated in a learning environment since they are essential pedagogical approaches for young children's science learning. This integrated learning environment might provide a way to understand how these individual pedagogies can together facilitate young children's science learning and support their engagements in science practices.

In my research study, I focus on the relationship between narrative, embodiment, and play to understand how this relationship can support young children's engagement in science practices, and in particular, co-construction of evidence-based explanations. To investigate this relationship, I designed a specific learning environment using these three important pedagogical functions called story-driven embodied play (SDEP). Further, I also designed an embodied play (EP) learning environment to identify the role of narrative in young children's science learning through constructing explanations by comparing the SDEP and EP programs. First, I chose shadow as a science concept for this study which is a popular theme in young children's science learning and children's books (Backman, 2020). Shadow is an everyday concept but also a science phenomenon that is portrayed and illustrated within diverse genres of art and literature for children. Since shadow can be represented in many ways, there are also several ways to illustrate shadow in children's books. For this study, I selected two different genres of children's books for these learning environments. For the SDEP program, I selected a children's picturebook, *Moonbear's Shadow* by Frank Asch, which follows Moonbear's challenge as his shadow scares the fish away while fishing. This picturebook provided opportunities for children to observe the phenomenon of how shadows are formed in relation to the Sun's location. The *Moonbear's Shadow* included both accurate illustrations and sequential storylines that are easy for children to follow. I also selected this book as prior research by the My Sky Tonight project (Plummer & Cho, 2020; Plummer & Ricketts, 2018) found promising results using this book to support

preschool-age children in constructing explanations about shadows. To compare with the SDEP environment, I selected an informational book for the EP program (see Appendix A for Glossary) titled *Guess Whose Shadow*? by Stephen Swinburne. To select an informational book about shadows, I visited a university library and a local public library. After reviewing informational books on shadows, I selected Swinburne's book because it includes diverse photos with short descriptive sentences. Other informational books on shadows included either heavy explanatory texts or inappropriate illustrations. During the EP program, the educator used this book by selecting some photos to discuss the concept of shadow with the children.

SDEP is a play-based learning environment guided by story and embodiment to support young children's engagement in science practices to construct evidence-based explanations. Narrative, embodiment, and play work together and offer a variety of opportunities for young children to engage in science practices. For example, SDEP provides a narrative in which the main character from the book has a problem to solve in order to understand the surrounding science phenomena. Young children act as a main character following the narrative to solve the problem. They use their bodies to figure out specific problems and observe other children's body-based actions in a playful activity. These opportunities lead to engagement in science practices such as generating evidence, making observations, carrying out investigations, analyzing and interpreting data, and constructing explanations. To understand how the SDEP learning environment promotes young children's science learning, I use three theoretical perspectives to understand how science learning occurs. To better understand how these theories can be integrated in a learning environment to explain young children's science learning, I analyze students' and educators' verbal and non-verbal interactions and representations during the activity. In the next section, I introduce my theoretical framework by integrating three theories of narrative, embodiment, and play.

Theoretical framework

Theories of narrative, embodiment, and play

Children learn through interacting with physical and social environments. Narrative, embodiment, and play are essential pedagogical approaches founded in three theoretical perspectives on learning through interactions and communications. In this study, I bring together narrative theory as conceptualizing narrative elements (Norris et al., 2005), narrative communication (Chatman, 1978), and narrative responsivity (Bakhtin, 1986) in science learning. I also use embodied cognition to explain learning through the body (Abrahamson & Lindgren, 2014; Barsalou, 1999; Desutter & Stieff, 2017). Finally, I view play theory from a sociocultural perspective connecting everyday concepts to scientific concepts through an educator's guidance (Fisher et al., 2012; Fleer, 2011; Vygotsky, 1978). These three theoretical frameworks from narrative theory, embodied cognition, and play theory might provide multidimensional understanding of young children's learning. In this section, I describe narrative theory, embodied cognition, and play theory for young children's science learning and how I use these theoretical perspectives to design a specific learning environment for young children's engagement in science practices.

Narrative is a vehicle through which experiences and ideas are communicated to others, and while there are many approaches to narrative theory, the present study brings together work specific to narrative elements, narrative communication, and narrative responsivity. Norris and his colleagues (2005) focus on narrative effects and propose narrative elements as useful to generating interest and improving memories and comprehension. Chatman (1978) emphasizes narrative as communication. He suggests that narrative is not only content but also transmission between narrator and narratee for communication. Bakhtin (1986) also indicates the notion of

"responsivity," which applies to both speaker and listener for enhancing their understanding of each other's words during communication. The communication through science discourse provides opportunities to engage in science practices for students to develop their problem-solving and reasoning (Zembal-Saul et al., 2013). Therefore, narrative theory in this manner offers a perspective on how students might engage in science practices to construct their understanding of science phenomena.

Embodiment is described as "the process by which physical action in the world generates, stores and reactivates mental representations abstracted from bodily experiences" (DeSutter & Stieff, 2017, p.4). In other words, bodily actions help in creating body-based representations of abstract cognitive mental imagery built in the mind. This phenomenon is called embodied cognition. DeSutter and Stieff (2017) suggest that embodied actions may provide students with ways of representing and structuring information for problem-solving. Students use gestures to show an imagined aspect of their mental imagery (Plummer, Bower, & Liben, 2016). Plummer and colleagues (2016) suggest that the use of gestures to support students' explanations of phenomena and knowledge is embodied. Therefore, embodied cognition helps to understand how students use their bodies to represent their thinking and engage in embodied actions in a learning environment.

Play is a key component in understanding the nature of children's learning (Osborne & Brady, 2001; Saracho & Spodek, 2003). From a sociocultural perspective, play acts as a "learning medium" that bridges everyday concepts with scientific concepts through children's engagement in play-based learning environments (Sliogeris & Almeida, 2019; Pellegrini, 2009; Vygotsky, 1978). Play provides diverse contexts to develop relationships between everyday and scientific concepts for young children (Fleer, 2010; Vygotsky, 1978). In particular, guided play, which is in between directional instruction and free play, provides the joyful child-directed aspects of free play but adds an additional focus on learning goals with adult scaffolding (Weisberg et al. 2016).

Weisberg et al. (2016) suggests that guided play is a successful pedagogical tool for young children in various disciplinary areas (Weisberg et al. 2016). In these ways, play theory suggests that play can support young children's active engagement in their own developing understandings of the world around them.

These three theories help explain children's learning and also suggest pedagogies to support children's learning in science. As few studies have considered the synthesis of two of these theories and none have considered the combination of all, integration of all three theories is promising. Therefore, I designed two specific learning environments, story-driven embodied play (SDEP) and embodied play (EP), by integrating narrative, embodiment, play pedagogical approaches, which are grounded in the three aforementioned theories, to investigate how these three theories can work together to explain young children's science learning, especially their engagements in science practices. To investigate what practices might be useful in supporting young children's science learning, I focus on science practices to examine how young children construct evidence-based explanations. In the next section, I conceptualize constructing evidence-based explanations for young children. I developed a glossary to justify the terms that I used in my dissertation because I use three theories from different fields to understand young children's science learning (see Appendix A for the glossary).

Conceptual framework

Science practices as constructing evidence-based explanations

Science is a practice that includes more than just concepts and facts, but also encompasses scientific ways of thinking and reasoning (Lehrer & Schauble, 2006). Children engage in science practices and they construct their understanding of natural phenomena through

communicating with others (National Research Council [NRC] 2007; Siry et al., 2012). This view of science learning includes both content knowledge and scientific practices (NRC, 2007; Zembal-Saul et al, 2013). *The Framework for K-12 Science Education* (NRC, 2012) identifies and outlines pertinent science practices which educators are encouraged to implement into their learning environments; these practices include asking questions, developing and using models, planning and carrying out investigations, analyzing and interpreting data, constructing explanations, and engaging in argument.

In order to fully construct their understanding of science phenomena, students need to engage in diverse discourses and ways of knowing, doing, talking, reading, and writing. According to the National Research Council Report (NRC, 2007), *Taking Science to School* provides a framework for proficiency in elementary science, which includes a focus on students' ability to ''generate and evaluate scientific evidence and explanations'' and ''participate productively in scientific practices and discourses'' (p. 2). Zembal-Saul and her colleagues (2013) found that kindergarteners can begin to use the term evidence when talking about their observations; similarly, first-grade students used their observations as evidence for their claims. Science explanations across the grade levels involve co-constructing claims from evidence through science talking which is an essential scaffold for learning, especially in the early grades. Preschool-age children are also capable of engaging productively with others to use science practices, including asking questions, collecting and analyzing data, and constructing explanations (Gelman et al., 2009).

The research literature on science practices is limited to students in the elementary grades and older. However, Metz (1995) argues that when provided opportunity and support, young children have the potential to engage in scientific inquiry. McNeill, Berland, and Pelletier (2017) argue that students can go beyond memorizing facts from textbooks or other authoritative sources, and should be able to articulate how evidence can provide support for an idea. Evidence

provides a catalyst for connecting explanations to the natural world by supporting a claim—an answer to the question posed—about a science phenomenon; scientific principles are used to provide a mechanism for how or why the phenomenon occurs (McNeill et al., 2017). Plummer and Ricketts (2018) found that preschool-age children developed evidence-based explanations through interaction with educators, peers, and their physical environment. Young children who built simple claims were often guided by the educator, and the evidence was used either implicitly, such as making claims based on their observations without verbal description, or they drew on data, as indicated through verbal descriptions or gestures. Yet additional research needs to be conducted to understand preschool-age children's constructing processes of evidence-based explanations and how and what guidance and support are needed.

Many policy documents and resources for preschool teachers discuss what it means to engage children in the practices of science (Gelman et al., 2009; NRC, 2012). Based on these documents, this research study includes a synthesis of the science practices that children might engage in to construct evidence-based explanations. I focus on the following science practices: (a) asking questions about science phenomena; (b) making and testing predictions; (c) analyzing data (observations); (d) constructing explanations; (e) investigating scientific phenomena; (f) representing ideas. It is important to recognize that the goal is to identify where children have the opportunity to engage in these practices and build their explanations, not only measure their level of knowledge from their verbal and non-verbal explanations.

In my research study, I focus on "constructing evidence-based explanation" through children's engagement in science practices. Through engaging in different science practices, young children are capable of constructing their explanations based on evidence for the development of "big" science ideas. I designed specific learning environments that, when implemented, include an educator's prompts and questions to promote children's engagement in science practices, such as observing and analyzing data through body movements, gestures, and

verbal and nonverbal interactions. In Chapter 2, I further elaborate on how I identified these science practices and created a codebook and initial conjecture map for data analysis. To establish a link between children's engagement in science practices and how they learn from them as constructing evidence-based explanations, I apply theories of narrative, embodiment, and play. In the next section, the study overview, I describe how this conceptual framework is applicable to design-based research.

Overview of study

In my research, I designed two learning environments to support young children's engagement in science practices, particularly their construction of evidence-based explanations: story-driven embodied play (SDEP) and embodied play (EP). These two learning environments were designed by integrating three pedagogical functions of narrative, embodiment, and play drawn from theoretical frameworks—narrative theory, embodied cognition, and play theory. The SDEP learning environment was designed to integrate story, embodiment, and play; and, EP was designed by combining embodiment and play without story. I planned and conducted two programs based on these two designed learning environments which covered the same science phenomena topic of shadows. Preschool-age children, from 3 to 5 years old, participated in either SDEP or EP program at a local children's science museum and three local preschools. The conjecture mapping approach was used to design these learning environments and is used to analyze data.

Based on the conceptual framework of construction of evidence-based explanations and the theoretical frameworks of narrative theory, embodied cognition, and play theory, I present three research questions for this dissertation study. The main goal of these questions is to gain insights about (a) how narrative theory, embodied cognition, and play theory can be integrated to

explain young children's science learning, and (b) how SDEP and EP learning environments can support learners' engagement in science practices, particularly constructing evidence-based explanations.

Research questions

First, this dissertation study is motivated by an investigation of how the three theoretical frameworks can be used together to explain learning in ways that go beyond what they can explain as individual theories. There is no literature that looks at the connections between all three of these theories and how they can explain learning together. Young children bring their everyday knowledge through their narratives and stories into their learning environment. Play-based learning environment may help children's everyday concepts to transfer scientific concepts by providing diverse contexts for children to practice and understand the relationships between them. During the play-based learning, children use their bodies and gestures to represent their ideas and communicate with each other. Therefore, a learning environment developed using these three theories could provide new insights into how to support young children's science learning. To answer the first research question (see below), I identify all interactions between educators and children using these theoretical perspectives to understand how the three theories can be integrated to explain young children's science learning.

Second, this research study explores how the narrative, embodiment, and play as pedagogical approaches work together in a learning environment for young children's science learning. There is no literature on the relation between narrative, embodiment, and play as pedagogical approaches and theoretical understandings together. However, many studies have been conducted on these three pedagogical approaches individually, and demonstrate how each is essential for young children's learning. Therefore, SDEP could provide a new insight into how

the three pedagogical approaches support young children's science learning and how the three theories explain learning through their outcomes. To answer the second question (see below), I examine how these three pedagogical functions in SDEP work together and support children's engagement in science practices and representations of their explanations during the program. I analyzed all elements from conjecture maps and identified all connections to see how they interact and integrate into the SDEP learning environment.

Third, this dissertation study compares SDEP and EP learning environments. Narrative is a key tool for children and educators to communicate and share their ideas (Avraamidou & Osborne, 2009; Millar & Osborne, 1998). There are a series of studies on the use of stories in science learning that could support children's science learning through both conceptual understandings and emotional achievements (Murmann & Avraamidou, 2014; Plummer & Cho, 2020; Prins, Avraamidou, & Goedhart, 2017). In particular, the imaginary aspect from the children's literature is a key element for young children's playful learning. Imaginative play supports young children's development in abstract thinking (Vygotsky, 1978). However, there is limited research on the relationship between narrative and play for young children's science learning. Few research studies explored the relationship between narrative and embodiment (Bobick et al., 1999) or narrative and play in science learning (Fleer, 2011; Fleer & Pramling, 2015). These series of research studies indicate the role of narrative in learning, but I also want to further investigate the role of narrative in science learning for young children and how narrative affects different science learning outcomes. Therefore, two learning environments, SDEP and EP, were designed to identify the role of narrative in young children's science learning. To answer the third question (see below), I compare two learning environments by highlighting the combination of pedagogical functions of story, embodiment, and play during children's construction of evidence-based explanations. Thus, this study is guided by the following research questions:

1. How and to what extent does the combination of narrative theory, embodied cognition, and play theory do more to explain preschool-age children's science learning in ways that go beyond what each theory can explain on its own?
2. In what ways does *story-driven embodied play* support or constrain preschool-age children and educators in co-constructing evidence-based explanations?
3. How do *story-driven embodied play* and *embodied play* environments compare in terms of how they support or constrain preschool-age children's constructing evidence-based explanations?

Chapter 2 offers a detailed literature review supporting the aforementioned rationales and arguments, and a thorough explanation of the methodology employed to design the SDEP and EP programs and analyze data.

Chapter 2

Literature Review

This chapter reviews the theoretical literature of narrative theory, embodied cognition, and play theory and empirical literature of pedagogical functions drawn from these three theories to support young children's engagement in science practices and their constructing of evidence-based explanations. Narrative is a communication tool for students and educators in learning contexts. We share our thoughts through verbal (e.g., storytelling) or written (e.g., books) versions of narrative. Narrative theory provides a view of identifying narrative elements and how narrative plays a role of learning medium to transmit between students and educators through engaging in discourse to understand the world around them (Chatman, 1978; Norris et al., 2005).

The human body is another way with which we communicate with the world. Children often use their fingers to represent the concept of numbers and use their gestures to demonstrate the concept of the slope about increasing and decreasing values (Alibali & Nathan, 2012). These processes of body-based actions can generate, store, and reactivate mental representations which collectively is referred to as embodiment (DeSutter & Stieff, 2017). Embodied cognition suggests that bodily actions help in creating physical representations for abstract cognitive imagery built in our minds (Alibali & Nathan, 2012). As such, children need to be provided with opportunities to use their bodies to interact with learning environments.

Play is a central learning medium for young children. Young children learn from experiences, explorations, interactions (Broadhead, 2006), and imitations with the world (Lindahl & Samuelsson, 2002). Play has the potential to provide a rich learning environment where young children have the opportunity to explore and interact with the world and represent their thinking

(Pellegrini, 2009). Play theory from a sociocultural perspective (Vygotsky, 1987) helps in understanding the role of play for children's learning and development.

Figure **2-1** shows how each theory views young children's science learning and provides evidence of the integration between two of theories from prior research. These three essential theories in young children's learning shape my theoretical frameworks and allow me to design specific learning environments which I call story-driven embodied play (SDEP) and embodied play (EP) for young children. In this chapter, I explain narrative theory, embodied cognition, and play theory with theoretical literature by providing empirical evidence (see Figure **2-1**). Then, I analyze previous research about any connections among these three theories to explain young children's science learning. I identify a gap in the literature that I investigate in this dissertation. Finally, I describe my conceptual framework which is science practices—constructing evidence-based explanations—for the types of learning outcomes that I want to investigate in this dissertation.

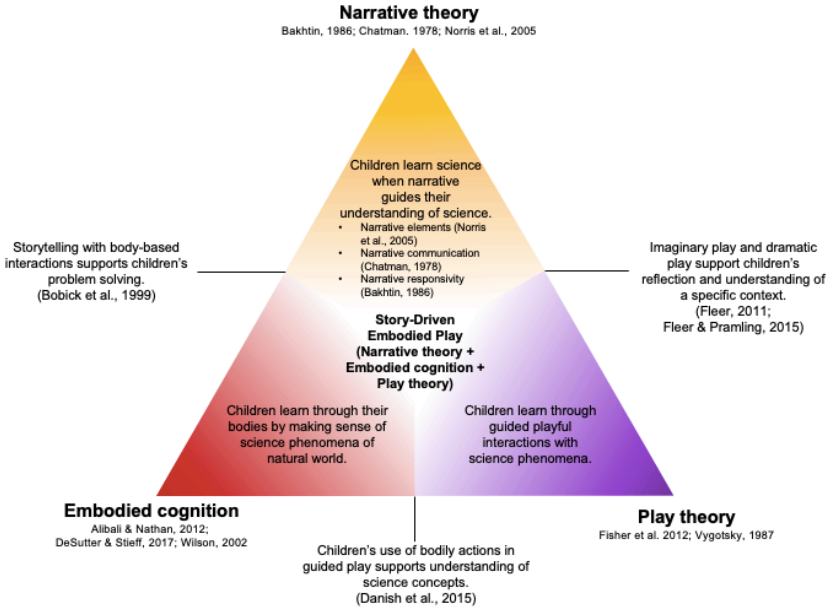

Figure **2-1:** Narrative theory, embodied cognition, and play theory as theoretical frameworks

Narrative theory

What is narrative?

Narrative contains a mixture of elements including the telling of stories, knowing, and knowledge (Solomon, 2002). Bruner (1986) differentiated the order of human experience in two distinct ways: paradigmatic and narrative. First, paradigmatic refers to organizing thought that is logical-scientific and based on reasons. Second, narrative deals with the creation of stories. According to Bruner, narrative is used to refer to a way of structuring information through expressions. Avraamidou and Osborne (2009) and Norris et al. (2005) also define essential components of narrative such as purpose, events (event-tokens), structures, time, agency, narrator, and readers. Norris and his colleagues (2005) studied narrative elements and their hierarchy of importance and how narrative can be used for teaching and learning to generate narrative effect.

According to prior research on defining narrative elements (Avraamidou & Osborne, 2009l Norris, et al., 2005), I view narrative as an integrated form of elements including events, agency, structure, and purpose for telling a message to readers. I specifically chose four essential narrative elements: events, structure, agency, and purpose (see Appendix A for glossary). For designing the SDEP program, event-tokens, structure, agency, and purpose are central elements to shape narrative and are integrated with other program features such as children's body movements, and engaging in science practices. Therefore, this dissertation is concerned with narrative as a story that includes event-token, structure, agency, and purpose; *Moonbear's Shadow* picturebook is the narrative used in this dissertation. This research study focuses on how narrative as story from a children's picturebook can support preschool-age children's construction of explanations by guiding their engagement in science investigations. In the next section, I

describe three authors' views of narrative theory (Bakhtin, 1986; Chatman, 1978; Norris et al., 2005) that help me understand young children's learning in science.

Narrative theory

Narrative theory is outlined in this dissertation in both narrow and broad views. A narrow view of narrative theory focuses on narrative elements (Norris et al., 2005) and helps us understand how narrative elements support science learning by generating narrative effect. A broader view of narrative theory, constituted by Chatman's narrative communication (1978) and Bakhtin's narrative responsivity (1986), provides a perspective on how narrative moves through discourse between children and the educator and how narrative is reproduced in the learning moments by engaging in responsivity. I offer these three theories as the core narrative framework for this dissertation.

Narrative elements

Norris and colleagues (2005) suggest that a theoretical framework for narrative explanations in science is a set of narrative elements which I draw on to determine and identify the use of narrative in the program for this dissertation. A narrative explanation is one which "explains an event by narrating the events leading up to its occurrence, cites unique events as explanatory of other unique events" (Norris et al., 2005, p. 550). Norris et al. (2005) indicates eight elements of narrative; however, I apply only four essential narrative elements—event-token, agency, structure, and purpose—because narrative in a written text is different with narrative in physical and social interactions in learning contexts. In this dissertation, I analyze narrative elements drawn from the *Moonbear's Shadow* picturebook because its narrative introduces

components of scientific explanations through the meaning making that happens as an intelligible series of events to develop explanations of a natural phenomenon.

Event-token is a series of particular occurrences including actors at a particular place and time (Norris et al., 2005). Events can lead to change of situation and are central to narrative (Norris et al., 2005; Toolan, 2001). Event-token in *Moonbear's Shadow* story is considered as sequential events including how Moonbear goes fishing but fails because of his shadow. To define event-token as code for data analysis, event-token is "educator or child references a specific occurrence from the storybook's narrative" (Plummer, Cho, & Botch, 2021).

Agency is actors or characters who cause and experience events in narratives and actors have responsibility for their actions (Norris et al., 2005). Agents do not need to be human beings, and could be animals or inanimate agents (Bal, 1985). Agency in *Moonbear's Shadow* story is considered the main character, Moonbear; agency in the program happens when children take this agency to act like Moonbear from the narrative. To define agency as a code for data analysis, agency is "children either engage in same actions as storybook characters" (Plummer, Cho, & Botch, 2021).

Structure is "the sequence of plot events and the sequence in which the events are related" (Norris et al., 2005, p.545). Narrative has a traditional beginning-middle-end structure of story (Bal, 1985; Roth, 1989). Structure in *Moonbear's Shadow* story is considered a specific plot of events from the story involving Moonbear's actions to solve the shadow problem. Structure in the program happens when children engage in a series of explorations drawn from the story. As a code for data analysis, structure is "activities engage children in similar series of events to the storybook narrative" (Plummer, Cho, & Botch, 2021).

Purpose is to help better understand the natural world and feel the experience of others (Norris et al., 2005). Norris et al. (2005) indicates that purpose is of secondary importance for narrative; however, narrative purpose is closely related to characters' actions and feelings in the

story. Purpose of *Moonbear's Shadow* book is considered as an understanding of the relationship between the location of the Sun and shadows. This purpose applies to the design of the program for young children when they work to figure out Sun and shadow relationships in investigations. To define purpose as a code for data analysis, purpose is "activities engage children with aspects of the same phenomenon as the storybook as a way to help them understand the natural world" (Plummer, Cho, & Botch, 2021).

These four essential narrative elements help me understand which narrative elements lead to children's engagement science practices and how narrative elements affect children and the educator's physical and social interactions for their co-constructing explanations. The integration of these narrative elements might generate narrative effect for children to promote their understanding of the relationship between the Sun and shadow. Thus, a theoretical view of narrative elements is needed to interpret children's learning in science.

Narrative communication

Chatman (1978) contributed to the theory of narrative by providing insight of narrative as communication. Grounded structuralists theory of narrative indicates that narrative has two parts. The first part is the story which consists of content. The second part is discourse which is the means by which the content is expressed and communicated (Chatman, 1978, see Figure **2-2**).

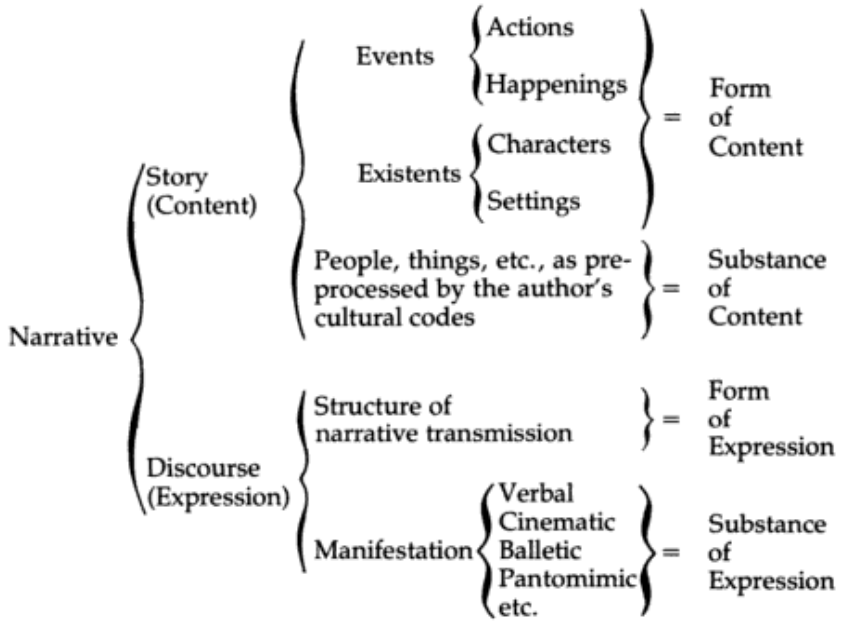

Figure **2-2**: Chatman's narrative components (Chatman, 1978)

According to Chatman (1978), narrative theory can be understood as a system of conveying narrative between author (narrator) and reader (narratee). Chatman (1978) indicates a distinction between the author, the person who devised the story, and the person who narrates the story. In this system, the real author is the person who devised the story to communicate (a set of elements of narrative) by discourse (the expression) to real audiences through implied authors and an implied audience (Chatman, 1978, see Figure **2-3**). Implied author and implied readers are more related to text-based narrative as a version of capacities of the real author and real reader.

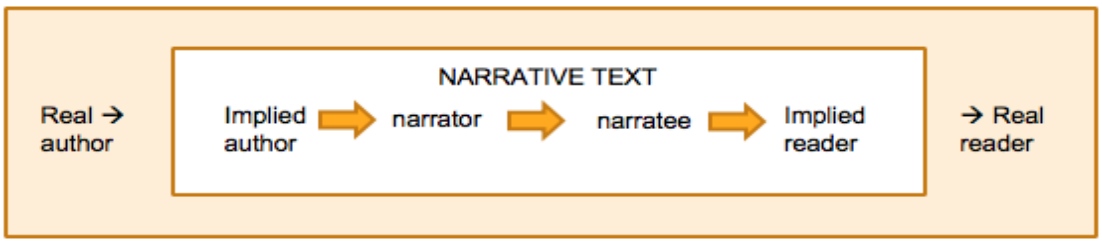

Figure **2-3**: Chatman's six-part model of narrative communication (Chatman, 1978)

Figure **2-3** shows how narratives transmit from real authors to real readers, a process that can be applied to teaching and learning context. Using narrative from the literature, the educator as a narrator in the learning context can transmit narrative to students to trigger their interest and enhance understanding of specific concepts. Avraamidou and Osborne (2009) highlighted the narrator and the reader as important components of narrative and narrative can be a useful tool not only in the hands of teachers but also for students as ways to communicate their understanding of science. Therefore, narrative theory from Chatman's narrative communication model can extend our understanding of how narrative can be communicated and transmitted and why narrative can be a meaningful tool in learning contexts.

Narrative responsivity

Bakhtin (1986), who influenced the structuralists, provided a guide to understand narrative theory as responsivity. He suggests that a story is like a dialogue as the meanings of words and expressions are "borrowed" from the speaker. He noted that "utterance is a link in a very complexly organized chain of other utterances" (p.69). He indicated especially the notion of "responsivity," which applies to both speaker and listener in communication; thus, narrative is a means of telling stories but also a relationship between speaker and listener for understanding each other's words. Taking this view, narrative is a continuous process of sharing, questioning, and revising thoughts that lead to "a new understanding that is progressively constructed by the participants, move by move, meaning by meaning, so that its meaning and structure are constantly emerging" (Well, 1999, p.4).

Bakhtin's perspective on narrative as responsivity (1986) helps us understand how narrative plays an essential role in learning contexts for educators and students. Using narrative from children's literature that educators and students already read together, educators and

children can have shared knowledge that lead to further discourse related to specific concepts. Therefore, this understanding of narrative theory from Bakhtin (1986) provides a view on how narrative plays an important role by promoting shared knowledge and contexts for students and educators in learning.

Three views of narrative theory from Norris et al. (2005), Chatman (1978), Bakhtin (1986) provide both narrow and broad perspectives to understand the role of narrative in learning contexts. Drawn from these understandings of narrative theory, I see a potential to use narrative in the design of learning environments for children's science learning. In the following section, I describe prior research on how narrative is used as a pedagogical function for children's science learning.

Pedagogical function of narrative theory

Murmann and Avraamidou (2013) studied the use of narrative as a learning tool for third to sixth graders in the context of an inquiry-based investigation. They used a designed story about animals' senses. The researchers found that the story supported motivation and immersion during learning activities. Students created mental images of the story that represented an emotional attachment to their characters, which supported their understanding of the learning activities. They suggested that a teacher needs to recognize the story as a tool for providing opportunities to problematize, reflect, and articulate the learning activity. They suggest that the educator mediates cognitive elements from the story, facilitating its use as a learning tool. In their study, a designed story functioned as a mediator between teachers and students to lead engagement in inquiry-based learning.

Narrative supports inquiry-based learning as well as the understanding of natural phenomena. Prins et al. (2017) examined the use of a fictional story as a tool for teaching about

natural selection in the context of high-school science. The researchers found that most of the students developed adequate scientific understanding about natural selection and they identified that the narrative is more enjoyable and easier to understand than the textbook. In addition, they also found that the teachers were enthusiastic about the use of narrative and thought that the students engaged with high motivation. They suggested that the use of narrative in communicating scientific information offers potential for science teaching and learning.

Based on these empirical research studies, it is clear that narrative supports both teachers and students to engage in inquiry-based learning. In the perspective on narrative theory, teachers and students could generate meanings of natural phenomena and communicate scientific ideas through narrative (Avraamidou & Osborne, 2009; Norris et al, 2005). The studies reviewed above used designed stories to promote opportunities that lead to problem-solving. These connections between story and inquiry-based activities provide deeper engagement in learning contexts such as creating motivation, immersion, and a sense of agency (Murmann & Avraamidou, 2009).

Narrative is not only considered as a component of written text, but also integral to the ways in which students and educators engage in discourse (Chatman 1978). The narratives that students and educators produce and reproduce might show how they build their knowledge together through narrative; thus, narrative theory will be useful in understanding how narrative transmits and supports learning. In the context of story-driven embodied play, narrative theory might be helpful in giving us insight about how narrative can support children's engagement in a play-based learning environment.

For this study, preschool-age children engaged in either the story-driven embodied play (SDEP) or embodied play (EP) learning environment. For SDEP program design, I integrated the pedagogical function of narrative with other two essential pedagogies of embodiment and play. The SDEP program was designed to explicitly include narrative elements such as event-token, agency, structure, and purpose from the picturebook *Moonbear's Shadow* to guide and support

children's engagement in narrative mediated science investigation. The pedagogical function of narrative was drawn from narrative theory and is used to explain how preschool-age children learn science in a narrative driven learning environment through narrative communications and responsivity.

In the next section, I introduce embodied cognition as my second theoretical framework and embodiment as the second pedagogical function in my research study that is drawn from embodied cognition.

Embodied cognition

Scholars of embodied cognition generally agree that mental processes are mediated by body-based systems including body shape, movement, and the neural systems that engage in action planning (Alibali & Nathan, 2012). Embodied cognition is a theory of learning that explains the formation of conceptual representation and cognitive processing as embedded in the shape of the human body and body-based interactions with the environment. In a broad sense, embodiment is characterized by a shared assumption that the body's particular form, sensory capacities including visual, auditory, kinesthetic, olfactory, and somatosensory experiences that supply the cognitive system with a rich input range, shapes knowledge representation and subsequent cognitive processing of those representations. In this way, the features of those representations, including abstract relationships and states, can be generalized beyond the immediate situation (Barsalou, 1999; DeSutter & Stieff, 2017).

What is embodiment?

Since embodied cognition can explain how people learn new knowledge, especially abstract knowledge, it also demonstrates how abstracted concepts are involved in broader cognitive representations (DeSutter & Stieff, 2017). In this research study, I defined "embodiment" as body-based actions including the educator and children's gestures and whole-body movements to internalize and represent their understanding in learning context (see Appendix A for glossary). To understand the educator and children's embodiment, I used embodied cognition as a theoretical perspective to help explain how children and the educator use their body-based actions to communicate their ideas and how children use their bodies to investigate and represent conceptual understanding.

Theory of embodied cognition

Embodied cognition does not have a singular view; rather the term embodiment is best understood as broad reference to the many multifaceted and multimodal ways in which our cognition is shaped by body-based interaction. Meteyard and colleagues (2012) reviewed a number of theories of embodiment and claims about semantic processing and they indicated that the theories of embodiment were graded on a continuum and characterized as: (a) non-embodied, (b) secondary embodiment, (c) weakly embodied, or (d) strongly embodied. At the end of the continuum, non-embodied theories include traditional cognitivist views of representation. At the other end, strongly embodied theories suggest that sensory impressions are stimulated during semantic grounding. In the middle of the continuum, in particular, the group of weak embodied cognition proposes that "semantic representations are at least partly constituted by sensory-motor information" (Meteyard et al., 2012). This group states that there is a partial dependence on

sensory and motor systems as sensory and motor information have a representational role. To address questions about how embodiment is integrated with narrative and play to support young children's science learning through their bodily actions and gestures, I primarily take this view of 'weak' embodiment.

To delve into the research questions about how preschool-age children interact with learning environments using their bodies and how they use their body to represent their understanding of the science concepts, I propose the following mechanisms of embodied cognition as fundamental to designing learning environments: (a) building embodied analogies; (b) the role of body movements; and (c) constructing and interpreting representations. I focus on embodied cognition that takes place in the mind but relies on knowledge structures that emerge from body-based experiences (Weisberg & Newcombe, 2017; Wilson, 2002).

Embodied cognition as body-based actions

Embodied cognition proposes that human cognition and linguistic processes are fundamentally grounded in physical interactions of the human body with the physical environment (Alibali & Nathan, 2012; Barsalou, 2008; Wilson, 2002). By investigating the implicit conceptual structure rooted in human language, Lakoff and Johnson (1999) indicated that human concepts are fundamentally grounded in bodily experience and emerge from those experiences with the world. In particular, Lakoff and Johnson provided evidence that spatial concepts are primarily embodied. Embodied actions might provide students with new ways of representations for structuring information and problem solving. In this view, body movement might provide children with new representations, such as representational gestures. These body-based representations might become learning tools for children as a way to construct their thinking (DeSutter & Stieff, 2017).

The use of gestures in communicating and problem-solving is often considered evidence that knowledge is embodied (Alibali & Nathan, 2012; Hostetter & Alibali, 2008). Hostetter and Alibali (2007) developed the gesture-as-simulated action framework, asserting that "gestures emerge from the perceptual and motor simulations that underlie embodied language and mental imagery" (p. 502). The cognitive processes of young children, in particular preschool-age children, are not yet fully separated from actual concrete objects and actions, and the representational processes in preschool play are closely intertwined with the use of concrete objects as mediators and the enactment of representational gestures in the production of meaning (Duncan & Tarulli, 2003).

Young children and embodiment

In developmental psychology, scholars broadly agree that bodily action plays a central role in conceptual development at an early age. According to Vygotsky, "the word was not the beginning, action was there first" (1986, p. 255). Piaget (1968) also stated that "the roots of logical thought are not to be found in language alone...but...more generally in the coordination of actions, which are the basis of reflective abstraction" (1968, p.18). In cognitive science, researchers have suggested models to explain how abstract concepts are constructed from concrete sensorimotor experiences. Regarding the cognitive semantics theory of conceptual metaphor, children's bodily orientations, movements, and interactions are imaginatively developed to shape their abstract inferences (Lakoff & Johnson, 1980).

Children's thinking "is separated from objects and action arises from ideas rather than from things" (Vygotsky, 1978, p.97). According to Vygotsky, children partially free themselves from the situational constraints of the actual physical context and the ordinary meaning of objects or actions, enabling the indirect satisfaction of unrealizable desires through pretense. For young

children's gesture use, Vygotsky (1978) uses the example of a hobbyhorse, a stick held between the legs to represent a horse, explaining that "a stick becomes a riding-horse for a child because it can be placed between the legs and a gesture can be employed that communicates that the stick designates a horse" (p.108). The representation of meaning has not yet been fully separated from action, and object-based semiosis in play must rely heavily on "gestures that communicate and indicate the meaning of playthings" (p. 108). Vygotsky believed that gestures and objects together produce cognitive changes in play activity for leading school activity toward the next period of development. Therefore, gestures are essential for young children to develop abstract thinking of natural phenomena around them by promoting their experience through their body-based actions.

The view of embodied cognition from Alibali & Nathan (2012), DeSutter & Stieff (2017), Vygotsky (1978), and Wilson (2002) provide theoretical understandings of the role of body-based actions including gestures and whole-body movements in learning. Drawn from these understandings of embodied cognition, I see a potential to use embodiment in designing a learning environment for young children's science learning. In the following section, I describe prior research on how embodiment is used as a pedagogical function for children's science learning.

Pedagogical function of embodied cognition

Alibali and Nathan (2012) studied gestures that both teachers and students produced in their explanations of mathematical concepts. They found evidence of two main embodied cognition claims that are based on perception and action, and grounded in the physical environment. They argued three findings from their examples: (a) pointing gestures reflect the grounding of cognition in the physical environment; (b) representational gestures (i.e., iconic and

metaphoric) manifest mental simulations of action and perception; and (c) some metaphoric gestures reflect body-based conceptual metaphors. The researchers suggest that the use of gestures in teaching and learning settings can facilitate communication of teachers' and students' understanding.

Ping and Goldin-Meadow (2010) studied how gesturing shows cognitive benefits for second- and third-grade students. The researchers found that the use of gestures during conversational explanations resulted in better performance when speakers talk about objects, not only when they are present but also when they are not present. They suggest that when novice learners produce gestures, this practice adds to the information expressed in speaking rather than simply producing gestures to deliver the same information as their speech. Therefore, children's gestures are meaningful to produce understanding and to reduce the cognitive load when problem-solving.

Plummer, Bower and Liben (2016) studied how 7 to 9-year-old students used gestures in their explanations of apparent motion of stars and seasonal change in constellations. They found that the connections between students' mental imagery and the physical environment were apparent in students' use of gestures. In their research, students used pointing gestures to support their verbal explanations. Students also used pointing and representational gestures to show imagined aspects of their mental imagery. For example, the students used their hands or arms to indicate the position of a constellation. Therefore, the researchers suggested that the use of gestures to support students' explanations of the phenomena and the knowledge was embodied.

Therefore, body-based actions and gestures may help conceptual development but might not naturally lead to conceptual understanding for all learners (Abrahamson & Lindgren, 2014). In other words, students may need accurate guidance and scaffolding by teachers for using their bodies in an appropriate learning environment. Embodied cognition, then, goes beyond individual actions and social interactions for students to understand the world in a different way.

In summary, the literature provides perspectives concerning how our bodily actions help in generating representations of abstract thinking. A general theme seems to be that embodiment supports cognitive work and learning experiences in certain learning environments. Children use gestures to communicate their understanding with others. However, body movement or engagement that facilitates conceptual understanding will not always occur naturally. Students will often need guidance to take action and move their bodies in ways that simulate the core mechanism (Abrahamson & Lindgren, 2014). Therefore, scaffolding or guided instruction might be needed for some children to activate their body-based actions. Therefore, I use the theory of embodied cognition to understand how children use their bodily actions to communicate with and in their physical (e.g., instructional materials) and social (e.g., peer(s), educators) environments. In particular, a play-based learning environment is crucial for young children's learning because of the opportunities to communicate their ideas and interact with others.

In the next section, I introduce the theory of play as a crucial perspective on young children's learning and how researchers have used play as an analytic framework to understand learning.

Play theory

Play is an essential and integral part of young children's development and learning (Isenberg & Quisenberry, 2002). Play and learning are intertwined for young children (Osborne & Brady, 2001; Saracho & Spodek, 2003; Uttal, 2003). The National Association for the Education of Young Children [NAEYC] emphasizes that play should be the focus of preschool, kindergarten education, and further early elementary education (Uttal, Scudder, & DeLoache, 1997). The term "play" does not mean only free play which is lacking guidance or purpose (Saracho & Spodek, 2003). Play can also refer to structured and guided activities in which

teachers (or parents and adults) intentionally scaffold children's activities. In the early childhood educational field, teachers often plan activities and choose specific plays with the goal of facilitating children's development and learning.

Definition of play from sociocultural perspective

In sociocultural theory, Vygotsky (1978) discussed the overarching role of play in child development. Vygotsky believed that play as a *leading activity* can promote cognitive, social, and emotional development in early childhood (Bodrova & Leong, 2007; Scharer, 2017; Verenikina, Harris, & Lysaght, 2003; Vygotsky, 1978). Vygotsky (1978) described play as a leading activity:

> Though the play-development relationship can be compared to the instruction-development relationship, play provides a much wider background for changes in needs and consciousness. Action in the imaginative sphere, in an imaginary situation, the creation of voluntary intentions, and the formation of real-life plans and volitional motives—all appear in play and make it the highest level of preschool development. The child moves forward essentially through play activity. Only in this sense can play be considered a leading activity that determines the child's development (p. 102–103).

There are many definitions of play from various theoretical perspectives, but most researchers in the field of play reach consensus on the following aspects of play: (a) play is self-directed; (b) play is exploratory and active; (c) play is social interactions or communication; (d) play is process-oriented; (e) play is guided by mental rules that leave room for creativity (Gray, 2017; Rubin, 1983; Saracho & Spodek, 2003). My theoretical perspective of play is drawn from sociocultural perspectives about "learning through interactions." From this perspective, researchers emphasize the importance of play for children's development through interactions.

According to this view, children gradually understand the world around them based on interactions through facilitated experiences (Saracho, 2020; Wong & Logan, 2016).

Play theory: Learning through play

Educational play has a greater degree of activity compared to other forms of play, and a greater degree of teacher guidance in the activity. In particular, imaginary play and dramatic play support children's understanding of the world because children reflect on their understandings in a play environment (Saracho & Spodek, 2003; Vygotsky, 1978). Through this continuous process of demonstrating and reflecting in a play environment, children can extend their understanding of the world through the learning process. Children could engage in activities that draw on their familiar everyday experience and develop understandings of concepts that go beyond their everyday knowledge and experience, such as science concepts (Siraj-Blatchford, 2009; Sliogeris & Almeida, 2019). Fleer (2009) suggested that children experience science phenomena in their daily experiences and these experiences provide meaning for abstract thinking about science concepts. Play also allows teachers to recognize children' ideas (Saracho & Spodek, 2003). Therefore, play has a central pedagogical role in both teaching and learning.

Vygotsky (1978) emphasized play as a medium for children's learning. Vygotsky (1967) argued that play in preschool-age children is a learning activity that children lead to their development by generating the zone of proximal development. According to Vygotsky (1967), "a child is always above his average age, above his daily behavior; in play it is as though he were a head taller than himself" (p. 107). When children engage in play, social and physical environmental supports that are integral to the activity enable children to act in ways that are beyond their actual developmental levels (Bodrova & Leong, 1996; Duncan & Tarulli, 2003). Play as part of a facilitated learning environment, then, provides children with opportunities to

carry out actions which are in advance of their everyday experience and correspond to their potential learning ability (Duncan & Tarulli, 2003; Saracho & Spodek, 1995).

A significant example of play as a leading activity is imaginary play. Imaginary play on development is the separation of thought from action and objects and the development of mental representation and symbolic function (Scharer, 2017). Children pretend in a play situation and create an imaginative dimension in which they use substitution of things and acts in imaginative play and dramatic play. Separation of the meaning from the physical object supports the development of abstract thinking. For example, in the traditional example of a child riding a broomstick as if it were a horse, a child can separate the literal meaning of the object from its imagined meaning. Through imaginative and dramatic play, children can decontextualize meaning, that is, they can think about something even when the object is not present or evident (Scharer, 2017). Therefore, Vygotsky's view of play provides insight to understanding young children's play with imagination as the first step in the development of abstract thinking (Vygotsky, 1978).

Vygotsky (1987) indicates that play supports children's development of scientific concepts. He argues that there are two types of concepts, everyday concepts and scientific concepts. Children's everyday experience is foundational for concept formation, and without experiencing everyday events, educational activities by engaging in activities, concept building would not be possible. Everyday concepts and scientific concepts interact with each other to support building a foundation of scientific concepts in a play-based learning context (Fleer, 2009; Fleer et al., 2014). And in turn, Vygotsky (1978) noted that scientific concepts influence how children make sense of everyday contexts and concepts.

Children need to have opportunities to practice transferring everyday concepts to scientific concepts (Vygotsky, 1978). Play-based learning environments provide diverse contexts for children to practice and understand the relationships between everyday concepts and scientific

concepts. Conceptually-oriented play that is a structured and planned activity supports children in making connections between everyday concepts and scientific concepts for understanding science phenomenon (Fleer, 2010). Therefore, children's play necessitates adult guidance through scaffolding (Fleer, 2009; Weisberg et al., 2016). Guided play includes modeling activities and scientific investigations for engagement in science practices. With teachers' guidance, children are encouraged to explore through their natural curiosity, active engagement, and "sense-making processes" (Fisher et al., 2012).

The view of play theory from Saracho & Spodek (2003) and Vygotsky (1978) provides theoretical understandings of the role of play in children's learning. Drawn from these sociocultural perspectives of play, I identify a potential to use play in the design of learning environments for young children's science learning. In the following section, I present prior studies on how play can be used as a pedagogy for children's science learning.

Pedagogical function of play theory

Guided play

Guided play is a pedagogical approach that combines the benefit of free play and adult guidance (Fisher et al., 2012). Guided play is a discovery learning approach in between direct-instruction and free play that is effective in promoting learning as children are active, engaged collaborators in learning processes (Fisher et al., 2012; Weisberg et al., 2016). During guided play, children are free to choose the best way to carry out their abilities and inquiries with adults' guidance. Weisberg et al. (2016) defined guided play as two possible scenarios: (a) adults design the play environment and emphasize learning goals while children have opportunities to explore in play; (b) adults' guidance occurs when adults watch child-directed activities (free play) and

make comments or ask questions that encourage children to extend their activities with critical thinking. In this way, the educator provides guidance to support children's explorations and learning by enhancing children's discoveries by asking questions, co-playing with children, and suggesting extended concept-related free play moments (Fisher et al., 2012; Weisberg et al., 2016).

Guided play carries the joyful child-directed aspects (free play) and is enhanced with learning goals from adults' guidance (Weisberg et al., 2016). This approach to play offers learning opportunities for educators and researchers to support and facilitate learning environments for young children. I draw from these perspectives on guided play in learning and operationalize the following definition: *A guided play environment involves an educator who provides guidance to support children's exploration and learning by encouraging children's discoveries such as co-playing, asking open-ended questions, and suggesting concept related free play monuments*. This guided play definition maintains the essential aspects of play: self-directed, active, social interactions, process-oriented, and guided by mental rules.

Play in science

Fleer (2009) studied scientific play in two different learning environments. In the first preschool, a teacher implemented science play by providing children with materials without any intentional and direct teaching of the science concepts. The children engaged in the activity that was meaningful in an everyday way but their engagement did not lead to learning outcomes of science concepts. In contrast, the teacher in the second preschool asked questions which promoted children's conversations in which children used their everyday knowledge and experience to develop understandings of the science concepts. For example, the teacher encouraged the children to explore a representation of the environment through creating maps,

providing tools for orienteering and exploration (e.g., binoculars, treasure maps), reading scientific books and charts (introduced by the research assistant), and initiating conceptually oriented interactions. In both settings, children's play meaningfully connected to their everyday lives, but only the play in the second preschool setting included science learning. Therefore, play informed by planning could mediate children's science learning.

Imaginative play is an important aspect of learning (Fleer, 2011) because imaginative play supports connections between children's everyday concepts with science concepts by providing diverse and natural contexts. Dramatic play is "the creation of an imaginary situation, in which children and adults change the meaning of objects and actions, giving them a new sense" (Fleer & Pramling, 2015, p.2). Sliogeris and Almeida (2019) studied play-based science learning in a primary school to examine how play-based experiences support children's science learning through imaginative play. During imaginary play with small invertebrate toys, the children meaningfully explored and expanded their knowledge of science concepts through role-playing, talking about, and examining a toy. The children demonstrated their emerging scientific knowledge of animals (insects and spiders) and adapted that knowledge to their dramatic play. In one moment, two children were curious about bull ants and if they were friends with spiders. The teacher responded with a guiding question, "how can we find out?" (identifying spiders and bull ants in the same category of 'predators'), and suggested looking at the book to find the information about ants. Imaginary play presents a context for meaningful science learning opportunities with a teacher's guidance at the appropriate moment (Fleer, 2011; Hedegaard & Fleer, 2008; Sliogeris & Almeida, 2019).

Further, Fleer (2017) developed scientific narratives in play-based setting, named *Scientific Playworlds*, and found that this play-based setting changed children's everyday practices into a scientific narrative and engagement by creating imaginary scientific situations, collectively building scientific problems situations, and imagining the relationships between

observable contexts and non-observable concepts. This research suggested that play-based learning pedagogy may potentially provide an approach for teaching science concepts to early childhood teachers since imaginary play is something early childhood teachers are familiar with. Yet, this area of play-based science learning remains under-researched in science practices about how children actually develop their claims, collect data from the play-based experience, and connect their claims to evidence and generate explanations.

In summary, I use play theory from sociocultural perspectives (Saracho & Spodek, 2003; Rubin, 1983; Vygotsky, 1978) to understand young children's learning and apply the pedagogical functions of guided play in a facilitated learning environment with educators' guidance through social interactions. Therefore, play theory provides a theoretical perspective for this dissertation as well as pedagogical strategies in design of the learning environment for this research.

Integrating theories of narrative, embodiment, and play

None of the literature that I have been able to find has combined the theories of narrative, embodiment, and play. However, I have found literature that used two of the theories, but all three theories have yet to be integrated. Theories of narrative, embodiment, and play have been discussed in the literature and used in various ways to support students' learning and the design of learning environments. In this section, I provide a literature review about work in which two of the theories have been used together. Based on these examples, I see potential relationships between all three theories. In this way, I demonstrate a gap in the existing literature and describe how these three theories can be used together to understand young children's science learning and to design learning environments.

First, interactive storytelling (Alborzi et al., 2000; Bers & Cassell, 1998; Bobick et al., 1999) provides a potential relationship between narrative theory and embodied cognition.

Interactive storytelling is a learning environment in which narrative combines interactions with people, environment, and technology. Here, interactions are not only between technology and a child, but also the interactions between children and their environment, as well as children and other people (e.g., friends or parents) (Fails, Druin, & Guha, 2014). Interactive storytelling research emphasizes storytelling as a powerful tool for communication, collaboration, and creativity. Storytelling provides opportunities that support the development of language, social and cognitive skills. Empirical studies such as "StoryRoom," "SAGE (Storytelling Agent Generation Environment)," or "KidsRoom combined storytelling and interactions (e.g., bodily actions) in a physical environment. Interactive storytellings are designed to support children's interactions with information that is reactive to their senses such as touch, bodily movement or voice.

One interactive storytelling design is *KidsRoom*, a perceptually-based, interactive, narrative play space for 6 to 10-year-old children (Bobick et al., 1999). The researchers included images, music, narration, light, and sound effects to transform a normal child's bedroom into a fantasy land where children are guided through a reactive story. The KidsRoom environment is inspired by famous children's stories in which children are transported from their bedrooms to magical places (e.g., Sendak, 1988). In *The River World*, one of the stories in the KidsRoom environment, the children have to imagine the bed is a boat. They take the boat and start making rowing motions to avoid logs and rock obstacles in the river. As instructed by the narrator, the children must engage in collaborative rowing (making rowing motions on the correct side of the bed) to avoid the obstacles. The actions and interactions of the children drive the narrative action forward. KidsRoom combined the contextual information provided by the story to recognize more than individual and group actions in specific contexts. The research presented that narrative can be integrated with bodily actions to solve a problem or engage in wondering that encourages both individual bodily actions and group actions. From this research, embodied actions may

provide students ways of representing and structuring information for problem-solving. These bodily action-based activities might be a part of the learner's "toolbox" by providing new ways to shape knowledge to support their thinking (DeSutter & Stieff, 2017). However, this study was limited in presenting findings on how the perceptually-based, interactive, narrative play-based environment supports children's science learning.

Another study also described the relationship between narrative and embodiment. Glenberg et al. (2004) investigated how an embodied approach to language comprehension can be applied to enhance early reading performance for second-grade students. The researchers provided manipulating toy objects referred to in the text to simulate the actions described in the text. They found that actual manipulation and imagined manipulation significantly improve (compared with re-reading group) comprehension of the text. The researchers suggested that manipulation using models and imagined manipulations are powerful tools to enhance young children's reading comprehension. Marley, Szabo, Levin, and Glenberg (2011) also studied the relationship between embodiment and narrative outcomes. The researchers examined activity-based text with first- and third-grade children in mixed-aged groups. They found that children in activity-based learning contexts were able to improve their recollection of story content. In addition, they compared narrative outcomes for children of different ages and found that imagining stories supported narrative comprehension in older children (third grade), but younger children (first grade) needed the physical activity for further learning. These studies of the relationship between embodiment and reading comprehensions argue that bodily movement and interaction with imagination could shape our abstract inferences (Lakoff & Johnson, 1980). Yet, these studies only focused on children's recollections and reading comprehension. These studies were limited in presenting findings on how embodiment and narrative could be used together in young children's science learning.

A research team (Danish et al., 2015; DeLiema, Enyedy, & Danish, 2019) has studied embodiment and play by supporting collaborative science inquiry for first- and second-grade students. This research team developed Science Through Technology-Enhanced Play (STEP) in which students use their bodies to imaginatively become microscopic particles inside of a collaborative simulation of state change (e.g., liquid to gas). Danish et al. (2015) suggests that embodied play—where children's guided play allows them to use their bodily actions for scientific concepts—affords opportunities to reflect and explore new concepts. They designed three sequential activities: (a) macro-level costume play; (b) particle-embodiment play; and (c) energy-embodiment play. In these activities, they focused on promoting opportunities for groups of students to move throughout the classroom, using their positions and motions to shape the activity. They promote dramatic play by encouraging students to take on a role within an imaginary situation and to explore their role. Imaginary play and dramatic play can support children's reflection and understanding of a specific context (Fleer, 2005; Vygotsky, 1978). The research team found that embodied play supported children's understanding of scientific concepts by providing opportunities to see and reflect on their movement in group activity. There is evidence that demonstrates how embodiment and play can be integrated in a learning environment to promote social interactions for young children (Abrahamson & Lindgren, 2014).

In the literature reviewed above, learning can be explained by integrating narrative theory, embodied cognition, and play theory. The main theme from these three theories is learning through communication. All three theories explore how learning occurs in a specific learning environment through communication. Narrative theory suggests that if narrative is a communication tool (Avraamidou & Osborne, 2009; Millar & Osborne, 1998; Norris et al., 2005), teachers and students or students and their peers communicate their ideas through narrative. According to Bakhtin (1986) and Chatman (1978), teachers and students play the role of narrator or narratee in their communication in the learning context. Narrative might be

important not only for knowledge of content, but also for ways of knowing through communication. Narrative theory, then, is crucial to understanding how teachers' and students' interactions are critical for learning.

Young children's cognitive processes are not yet fully separated from actual concrete objects and actions (Duncan & Tarulli, 2003); therefore, young children need more help to support their ways of representation for abstract thinking. Embodied cognition suggests that bodily actions help in creating physical representations for abstract thinking in the learning context (Alibali & Nathan, 2012). By using gestures, teachers and students might better communicate their narratives through verbal and non-verbal communication tools in their learning environment.

Play and learning are intertwined in early childhood. In early childhood educational fields, imaginary play and dramatic play are supportive of children's understanding of the world because children reflect their understanding in this play environment (Saracho & Spodek, 2003; Vygotsky, 1978). Play can be possible for the teacher to engage in sustained shared thinking with children (Siraj-Blatchford, 2004). Children bring their everyday knowledge to play and share and develop understanding through science concepts (Fleer, 2009). According to Vygotsky (1987), children develop their understanding of the world by communicating the role and rule of imaginary or dramatic play. Therefore, play is an essential place for communication.

These three theoretical perspectives allow me to understand preschool-age children's learning through communication. In my research study, I designed a learning environment grounded in narrative theory, embodied cognition, and play theory called "story-driven embodied play" (SDEP). In SDEP, each theory can serve a pedagogical function in the learning environment towards science learning for preschool-age children. Narrative theory serves narrative-based learning. Embodied cognition provides learning through bodily actions. Play provides an imaginary and guided play learning environment. SDEP integrates each pedagogical

function to explore the specific science content of shadows in a specific context. Narrative-based play, body movements including gestures and whole-body movements, and play might generate diverse ways of interactions for teachers and children to engage in co-constructing evidence-based explanations. For learning about shadows, using narrative from a picturebook provides an imaginary situation in which children can get involved as the main character. Children engage in the imaginary situation, follow the story, and try to solve the problem as if they were the main character in the story. In this SDEP learning environment, the educator provides prompts and questions to encourage children's use of their bodies to engage in diverse practices of science. All pedagogical strategies are integrated and work together to support children's engagement in science practices to construct explanations through verbal and non-verbal interactions with educators, peers, and the physical environment.

In summary, I investigate the function of the SDEP learning environment in supporting young children's science learning as an emergent process generated by participation and "doing science" (Siry et al., 2012). As discourse emerges from what the participants are doing, science is emergent through interaction and discursive formats. Therefore, young children can develop their understanding of science through communication and interaction with their physical and social environments, relying on available resources and producing new resources to further their engagement. The SDEP learning environment may illustrate the nature of preschool-age children's emergent practices of "doing science" through discursive practices and multimodal interactions with others during science learning (Siry et al., 2012).

In the next section, I introduce science practices, in particular, evidence-based explanations, as my conceptual framework and how it is used to understand what practices young children engage in when they understand a science phenomenon.

Constructing evidence-based explanations for young children

To examine how narrative theory, embodied cognition, and play theory can be applied to young children's science learning, I identify science practices as constructing evidence-based explanations based on science learning as an emergent process that is generated by those participating together in "doing science" (Siry et al., 2012). In this section, I explain the concept of science practices and then define constructing evidence-based explanations for young children.

Children engage in science practices and then construct their understanding of natural phenomena by communicating with others (National Research Council [NRC] 2007; Siry et al., 2012). This suggests that children develop understandings of science through discourse in interaction around science phenomena in formal and informal learning contexts (Ash, 2004; Siry et al., 2012). Siry and colleagues (2012) examined the interactive process of science learning for young children to understand the emergence of practices through classroom discourse in interaction. Actively participating in group discourse through which knowledge is co-constructed enables students to develop a more thorough understanding than if they only worked individually (Newton, Driver, & Osborne, 1999).

A large portion of studies about practices of science focus on secondary or middle school (e.g., Pluta, Chinn, & Duncan, 2011). Although there is a small body of research about inquiry in early primary (e.g., Metz, 2008, 2011; Varelas & Pappas, 2013) and kindergarten (e.g., Mantzicopoulos, Samarapungavan, & Patrick, 2009; Siry & Max, 2013), young children's scientific explanations using evidence to build claims is an understudied issue. Young children have been referred to as "scientists-in-waiting" due to their notable capacity for scientific reasoning (Gelman et al., 2009). However, this capacity may not be fully realized without support to develop their abilities. In my dissertation research, I focus on young children's constructing evidence-based explanations through engaging in diverse science practices to generate evidence

and support claims about science phenomena. In this dissertation study, I use the term young children to refer to preschool-age children, from 3 to 5 years of age, but use the term broadly to include early elementary age children when discussing previous literature.

Young children's engagement in science practices

The National Research Council report *Taking Science to School* (2007) outlines a framework for the meaning of 'proficiency of science.' Science practices are key elements needed to construct understandings of science because scientific practices reflect the multiple ways in which scientists explore and understand scientific phenomena. Science practices include asking questions, developing and using models, planning and carrying out investigations, analyzing and interpreting data, constructing explanations, and engaging in arguments (NRC, 2012). Prior research on children's thinking suggests that they can become quite competent at engaging in science reasoning and practices (NRC, 2007). Therefore, science learning includes content knowledge and scientific practices together (NRC, 2007; Zembal-Saul et al., 2013).

A research-based guide *Preschool Pathways to Science* suggests that young children (around three years old) have the capacity for abstract thinking (Gelman et al., 2009; NRC 2007, 2009). This document identifies five keys science practices appropriate for young children: (a) observe, predict, check; (b) compare, contrast, experiment; (c) vocabulary, discourse, and language; (d) counting, measurement, and math; and (e) recording and documenting. According to these policy documents, young children can understand scientific ideas as well as generate scientific evidence and construct explanations by participating in science discourse. Young children are capable of sophisticated scientific thinking and reasoning, an ability that has been historically underestimated (NRC, 2007). When children are provided with appropriate opportunities and guidance, even elementary students can move beyond simply observing and

describing to negotiate and debate meanings and explanations (Varelas, Pappas, Kane, & Arsenault, 2008).

Young children's construction of evidence-based explanations

McNeill and colleagues (2017) suggest that for children to develop evidence-based explanations in science, they should: (a) address a question about a scientific phenomenon; (b) provide evidence to support the explanation; (c) provide a how or why account for the occurrence of the phenomenon. Evidence is provided to support a claim—an answer to the question posed—about a science phenomenon; scientific principles are used to provide a mechanism for how or why the phenomenon occurs (McNeill et al., 2017). Constructing scientific explanations provides students opportunities to participate in authentic science practices through discourses for developing their problem-solving, reasoning, and communication skills (Zembal-Saul et al., 2013). Therefore, a goal of science education is to help students understand not just the achievement of scientific knowledge, but also how we know and why we believe a fact, and ways to share how evidence is used in science for constructing explanations (NRC, 2007).

Siry and colleagues (2012) conducted a study with five and six-year-old children. They provided stations where children could explore the properties of water in different ways. The researchers focused on children's and teachers' verbal and non-verbal discourses. They found that children do participate in the processes of science. The children's science practices and discursive formats are co-constructed in a particular goal-oriented situation. For example, two children were surprised and suggested further exploration around the notion that the bowl of water can float although it has water in it. Through their discourse, they recognized that they need to regulate the amount of water that will still allow the bowl to float. In this example, the children often demonstrated their approaches to the processes of science investigations. In doing so, young

children are quite capable of explanatory reasoning and can be engaged in science observations, especially as they explain and describe what they have noticed (Varelas et al., 2008). Therefore, the researchers argue that "what might appear as being messy at first sight when young children engage in 'doing science' is revealed as being a discursively organized process, which increasingly bears the features of the (often not immediately detected) emergent normative practices of science" (Siry et al., 2012, p. 315).

Monteira and Jiménez-Aleixandre (2016) examined kindergarten children's (5–6 years old) engagement in scientific practices, with a focus on generating and using evidence to support claims. In the study, the children engaged in a project about snails, in which they pursued their own questions, carried out experiments and purposeful observations, collected data, and drew conclusions with the teacher's guidance. The researchers found that the children developed meanings of a certain level of sophistication about evidence. Further, the children distinguished empirical evidence from planned experiments and purposeful observation. The children also combined different types of evidence in the revision of their ideas about snails. The researchers highlighted that purposeful observation, which has a clear focus and is guided by the teacher, has affordances in young children's science learning.

The studies presented above show that young children have a capacity for constructing explanations using evidence that they experienced in purposeful activities. From these empirical studies, I derive two main points for young children's constructing evidence-based explanations. First, the students provided goal-oriented activities and the opportunities to engage in discourse (Monteira & Jiménez-Aleixandre, 2016). The second is the opportunity for multimodal representations (Siry et al., 2012). During the activity, the opportunity for multimodal representations provided children to understand science phenomena in diverse ways and support their science explanations. Children's talk and actions were interconnected and showed their explanations (Siry et al., 2012). However, these studies were limited in presenting the ways in

which the researchers considered and analyzed children's engagement in science practices and constructions of explanations during the activity.

Plummer and Ricketts (2018) studied preschool-age children's constructing explanations and engaging in modeling practices. The researchers found that young children can engage in emergent forms of scientific explanations. Their simple claims were often guided by the educator's prompts and questions, and the evidence was used either implicitly, such as making claims based on their observations without verbal description, or relied on data from observations as indicated through verbal or gestured cues. The researchers also found that modeling practices and gestures served as supports for children as they co-constructed evidence-based explanations for astronomical phenomena. Modeling and representations provided opportunities for children to either clarify their understanding of evidence or produce evidence for their claims. This study provides clear examples of how young children can construct evidence-based explanations in an investigation activity and how educators support and guide young children's engagement in science practices.

I adopt the aforementioned way to define constructing evidence-based explanations (Plummer & Rickett, 2018) in my research study when children engage in the SDEP learning environment related to the phenomena of shadows. To identify learning as engaging in constructing evidence-based explanations, I use the science practice codebook (see appendix B) to refine the level of children's explanations with evidence and claim as well as other practices of science.

Chapter 3

Conjecture Mapping

Conjecture mapping is "a means of specifying theoretically salient features of a learning environment design and mapping out how they are predicted to work together to produce design outcomes" (Sandoval, 2014, p.19). Conjecture mapping allows a researcher to propose theory-oriented ideas and design and implement interventions for practical understanding in a specific context (McKenney & Reeves, 2018). The SDEP learning environment is designed to create a specific learning environment that focuses on supporting young children's engagement in science practices by integrating three pedagogical functions: narrative, body movements, and play. These three pedagogical functions are drawn from three corresponding theoretical frameworks of narrative theory, embodied cognition, and play theory. Therefore, conjecture mapping is an appropriate approach to investigate how different elements of the learning environment from three theories may work together to generate interconnections for supporting preschoolers' outcomes of evidence-based explanations.

In this study, I focus on identifying interrelationships between the elements of conjecture mapping which are drawn from narrative theory, embodied cognition, and play theory. The elements of conjecture map include embodiments, mediating processes, and outcomes that form the nature of story-driven embodied play during structured museum programs. Conjecture mapping allows me to show how I designed a SDEP program through the elements of embodiment as well as how SDEP might support outcomes of constructing evidence-based explanations for preschool-age children through specific mediating processes during the programs.

I adopt a conjecture mapping approach specifically as an analytical tool for coding processes to explain how a story-driven embodied play learning environment might support constructing evidence-based explanations when preschool-age children engage in an activity. In particular, I compare story-driven embodied play to identify the roles of narrative and synergy created by story, embodiment, and play all working together. An embodied play learning environment provides opportunities for children to engage in play with physical movements without a picturebook narrative. The EP program, then, was developed to be similar in structure and duration to the SDEP program but without the inclusion of a narrative. According to these two different learning environments, I generated two initial conjecture maps, one for both SDEP and EP programs. Next, I introduce two revised conjecture maps to compare SDEP and EP programs.

Initial and revised conjecture maps

Conjecture mapping provides a framework to organize design-based methods and practices. In a conjecture mapping approach, the goals are framed as outcomes and initial conjectures, and environmental designs describe how to support learning desired outcomes. Figure **3-1** shows the initial conjecture maps I created for SDEP learning environments. I used a frame of conjecture mapping from My Sky Tonight project to build my two initial conjecture maps. I created these initial conjecture maps by connecting elements from the design of SDEP and EP learning environment and theory to test my high-level conjecture. The advantage of initial conjecture maps is that one is able to identify the most salient relationships in the design of learning environments (Sandoval, 2014). In initial conjecture mapping, I defined each element to guide the design and described potential connections between each element of SDEP and EP.

I used the initial conjecture maps (see Figure **3-1**) to design learning environments and made hypotheses about potential mediating processes that I expected to see during the programs. I started with initial codes from initial conjecture maps to explore how story-driven embodied play supports preschool-age children and educators in co-constructing evidence-based explanations. Through iterative analysis of video data with initial conjecture map elements as codes, I defined and revised codes from conjecture map elements (see Figure **3-2** and Figure **3-3**). In the following section, I describe the revised conjecture map and how I used conjecture map elements as codes.

High-level conjecture

Conjecture mapping begins with a high-level conjecture to portray how features of the learning environment design lead to desired outcomes (Sandoval, 2014). The learning goal for both the SDEP and EP learning environments is to support preschool-age children in engaging in constructing evidence-based explanations. During the SDEP program, young children intentionally engaged in guided play through narrative and embodiment, allowing young children to investigate the scientific phenomenon using their body in connection to a narrative from the book. A main educator led the program and provided guidance for young children to encourage their engagement and interactions. The design of this learning environment was achieved by the educator supporting children through the use of physical tools, activity structures, and discourse practices which provided opportunities for children to build their explanations based on evidence from the program experience. Thus, this design of SDEP might be achieved through children's engagement in story-driven embodied play investigation or embodied play investigation to understand science phenomena, build their own claims, find evidence from the investigation, and make connections to generate reasoning. Therefore, I propose an initial conjecture about how

learning is facilitated through all of these design elements from three perspectives of narrative theory, embodied cognition, and play theory.

According to narrative-based learning literature, story and narrative from children's literature can lead to scientific investigations in meaningful ways (Avraamidou & Osborne, 2009; Cho & Plummer, 2018; Murmann & Avraamidou, 2014) by supporting communication (Bakhtin, 1986; Chatman, 1978). Embodied cognition (DeSutter & Stieff, 2017) allows children to understand scientific concepts through their bodies while reflecting on and exploring new scientific concepts (Danish et al., 2015). Play provides opportunities for young children to meaningfully bring their everyday experiences to activities designed for their learning in contexts (Fleer, 2018; Sliogeris & Almeida, 2019). Therefore, I propose a high-level conjecture about how story-driven embodied play can support preschool-age children's constructing evidence-based explanations: *SDEP can support preschool-age children's constructing evidence-based explanations by promoting children's engagement in a narratively and physically mediated discourses that centers the attention on the storybook narrative*. This high-level conjecture is grounded in narrative theory, embodied cognition, and play. This conjecture was clarified according to the findings from data analysis. Figure **3-2** shows the revised conjecture map beginning with the high-level conjecture that I propose to implement for this study.

For the EP program, I developed an initial conjecture map, and then through analysis of video data, I defined the codes and revised the initial codebook (see Figure **3-3**). The EP program high-level conjecture concerns how embodied play can support preschool-age children's constructing evidence-based explanations: *EP can support preschool-age children's constructing evidence-based explanations by promoting children's engagement in physically mediated discourses.* In the following section, I describe conjecture map elements from the revised conjecture map of the SDEP learning environment. Only the EP conjecture mapping elements do

not include narrative features such as narrative elements (Embodiments) or children's engagement in discourse about narrative elements (Mediating Processes).

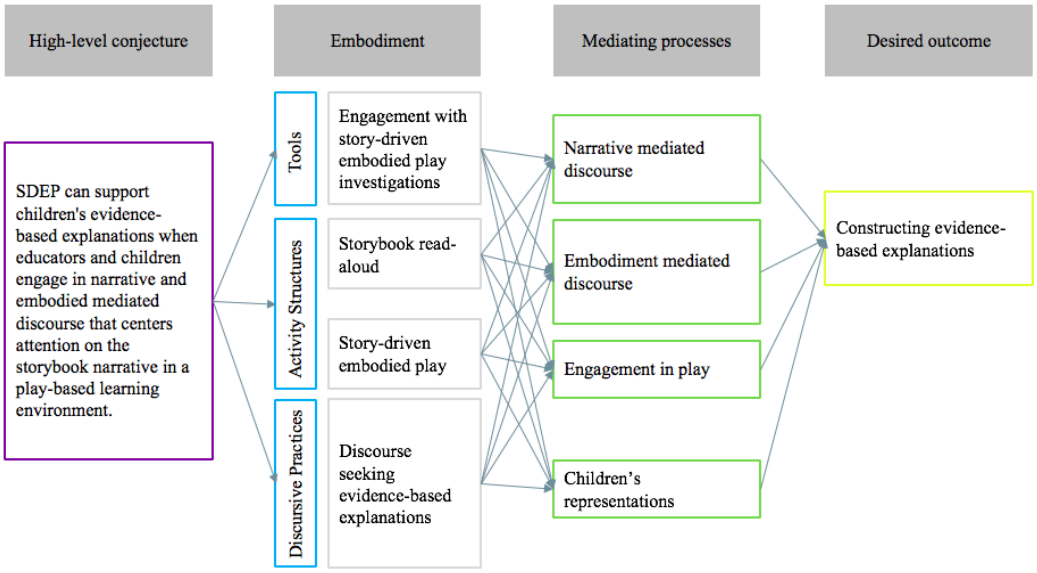

Figure **3-1**: Initial conjecture map of story-driven embodied play learning environment

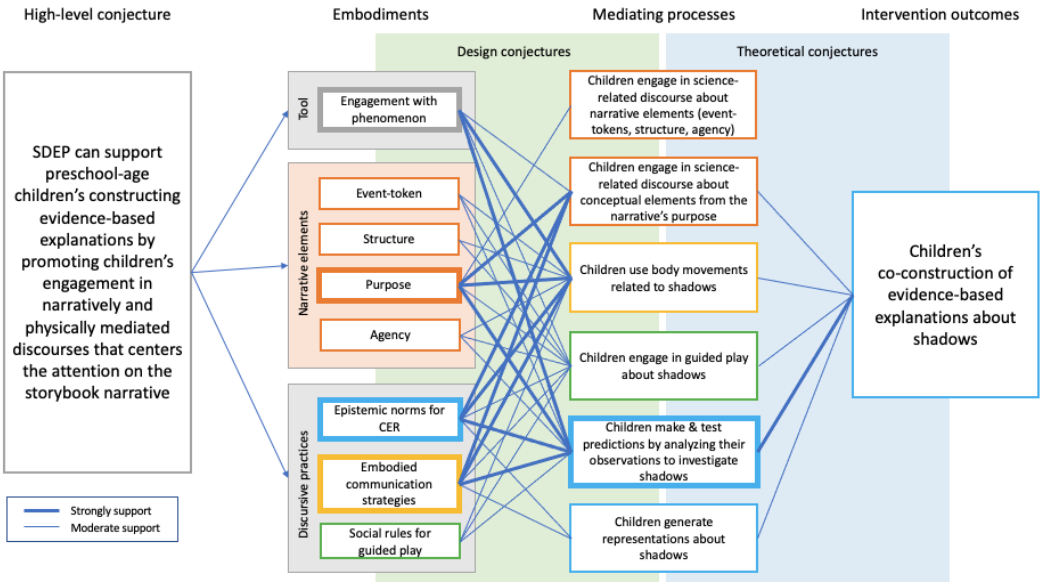

Figure **3-2**: Revised conjecture map of story-driven embodied play learning environment

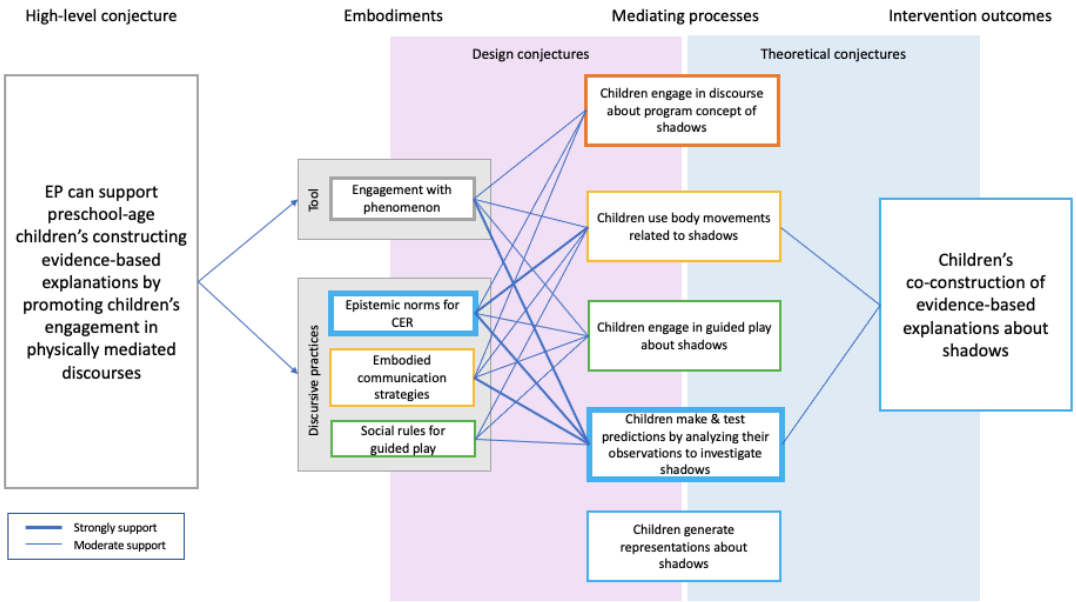

Figure **3-3**: Revised conjecture map of embodied play learning environment

Embodiments

A conjecture becomes reified within *embodiment*, which represents elements of learning environments such as tools, activity structures, participants structure, and discursive practices (Sandoval, 2014). Drawing from Sandoval (2014), I developed conjecture mapping elements for my dissertation to include: Tool (engagement with phenomenon), Narrative elements (instead activity structures), and Discursive Practices (epistemic norms for CER, embodied communication strategies, and social rules for guided play). I did not incorporate participant structure as the nature of the SDEP and EP programs involve young children's enactments and interactions as dynamic and deeply embedded within other conjecture map elements. The second column of Figure **3-1** shows the elements of embodiment in the context of this study. In the initial conjecture map, embodiment includes *Tools*, *Activity structures*, and *Discursive practices*. The *Tools* and *Activity structures* describe how the learning environment is designed to provide opportunities for children to engage in diverse discourse guided by story and embodied actions in

order to support constructing evidence-based explanations. *Discursive practices* refer to "ways of talking" and it can be at least partially designed (Sandoval, 2014, p. 22). For example, educators can provide prompts and questions to lead discourse with children during the program. The elements of embodiment from EP include engagement with embodied-play investigation as a tool and embodied play as an activity structure. After iteratively coding as conjecture mapping analysis, I found that narrative elements were a central part of the SDEP program structure.

Accordingly, as narrative elements emerged through my iterative coding process as integral to defining conjecture map elements, I revised *activity structures* to be *narrative elements*. In the following section, I describe each embodiment element from the conjecture map of the SDEP program (Figure **3-2**).

Tools: Engagement with phenomenon

Engagement with science phenomenon is an essential component of young children's science inquiry. Children engage with the science phenomenon through materials (including the actual phenomenon) or a representation of the phenomenon (pictures). The SDEP program provided interaction with the actual shadow phenomenon. For example, engagement with phenomenon was identified when children engage in the investigation by making shadows while interacting with the physical environment such as a lamp or the floor setting (i.e., fish in the pond) in the class.

Narrative elements

Narrative elements are central to the SDEP program design. For this study, I used a narrative elements codebook first developed in a previous study of My Sky Tonight based on

Norris et al. (2005) definitions of narrative elements to identify specific features of children's science picturebook embedded in this program design. My Sky Tonight team developed a coding scheme for narrative elements that includes essential elements for the study on story-driven investigation as follows: "event-tokens (educator or child references a specific instance from the storybook's narrative), structure (activities engage children in similar series of events to the storybook narrative), agency (children either engage in same actions as storybook characters or model those actions with external objects), and purpose (activities engage children with aspects of the same phenomena as the storybook as a way to help them understand the natural world)" (Plummer, Cho, & Botch, 2021). For example, an agency was identified when children and educators engage in the same actions as characters from the book. For the SDEP program studied in this dissertation, I designed opportunities for young children to exercise agency through an investigation of a problem the character tried to resolve in the book such as making a shadow not scare fish. Following this narrative, children engaged in the same actions as Moonbear to make their shadow not cast over the pond by pretending to be Moonbear experiencing this problem. Thus, the children had the similar agency to the character from the book.

Discursive practices 1: Epistemic norms for claim-evidence-explanations (CER)

As previously mentioned, discursive practices were able to be partially designed for this study. The SDEP and EP programs are designed accordingly, as the educator's questions and prompts that relate to the science concepts are considered a central factor to leading children in co-constructing evidence-based explanations. Educators, then, develop epistemic norms for CER by guiding children with questions about the science phenomenon of shadows. Often, the educator's epistemic norms for CER overlapped with other discursive practices such as embodied communication strategies and/or social rules for guided play.

The centrality of educator's discursive practices to leading children to desired outcomes in the SDEP and EP program designs is most notable when the educator and the children are engaged in discourse about science phenomenon that is initiated by the educator's questions and prompts. In short, the children made observations and claims based on their experiences with shadows in response to the educator's encouraging questions and prompts. For example, when the educator asked the children to make a shadow that doesn't scare fish, the discursive practice here is providing opportunities for children to generate a claim in response to the question through their observations and using their body movements. In turn, the educator reacts to the children's claims through gestures and a verbal response. The educator's development of epistemic norms for CER engages children in discourse about the science phenomenon as well as guided play and embodied communication.

Discursive practices 2: Embodied communication strategies

Cook and Goldin-Meadow (2006) suggest that meaningful gestures used by a teacher encourage students' gesture use. Further, they also state that copying a teacher's gestures support learners in problem-solving. Nathan (2008) suggests that teachers' gestures play a significant role in shaping students' ideas and conceptual knowledge. The SDEP and EP program, therefore, features an integrated pedagogical design that is drawn from and functions upon embodied cognition. Because shadows are spatial in nature, an educator's use of body movements and gestures appropriately encourages children to meaningfully discover the science phenomenon.

In this study, the educator used diverse embodied strategies including gestures and whole-body movements. She used her embodied communication strategies to offer questions and prompts to encourage children's engagement. For example, the educator used her gestures to represent the length of shadow when she asked the question, "is this shadow long or short?" She

also used her body's shadow while co-playing with children to hide them in her shadow. This exchange of embodied communication strategies between the educator and the children demonstrates how the SDEP and EP program designs effectively integrate pedagogical considerations of embodied cognition for achieving desired outcomes.

Discursive practice 3: Social rules for guided play

Guided play is one of the main pedagogical functions of this study. According to Fisher et al. (2010), "the dimension along which guided play varies is degree of adult guidance" (p. 5). In this dissertation study, I define guided play as when the "educator provides guidance to support children's exploration and learning by promoting (or enhancing) children's discoveries such as co-playing, asking questions, suggesting concept related freeful play moments." Operationally, guided play refers to how the educator might provide a level of guidance to help children engage in play through a series of social rules or cues.

During the SDEP and EP program, I observed the different ways an educator offers guidance to support guided play. For example, the educator asked children open-ended questions about making the biggest and smallest shadows. The educator also commented on children's shadows that they made which supported their observations. Across the SDEP and EP programs, the educator also co-played with the children to encourage their engagement in the phenomenon. In both the SDEP and EP program designs, discursive practices of establishing social rules for guided play cultivates meaningful learning environments that encourage and support children's experiences and discovery.

Mediating processes

The embodiment elements of the conjecture map for a designed learning environment do not lead directly to the desired outcomes; rather, in learning environments, they produce specific types of activities and interactions that lead to desired outcomes (Sandoval, 2014). These interactions are called *mediating processes* which show links between embodiment and intended outcomes. The mediating processes are indicated in the third column of Figure **3-2** and Figure **3-3**. The lines represent the interrelationships between embodiment, mediating processes, and desired outcomes, which will be refined after the process of data analysis.

In this study, SDEP program includes six mediating processes: (a) engagement in science-related discourse about narrative elements; (b) engagement in science-related discourse about conceptual elements from the narrative's purpose; (c) use of body movements related to shadows; (d) engagement in guided play about shadows; (e) making and testing predictions by analyzing their observations to investigate shadows; (f) generating representations about shadows. EP program includes five mediating processes: (a) engagement in discourse about program concept of shadows; (b) use of body movements related to shadows; (c) engagement in guided play about shadows; (d) making and testing predictions by analyzing their observations to investigate shadows; (e) generating representations about shadows. The mediating processes in the SDEP program are similar to the mediating processes in the EP program. The main difference is that SDEP include narrative aspects in the mediating processes. In the following section, I describe each mediating process with examples based on the SDEP program.

Mediating Processes 1: Discourse about narrative elements (event-token, structure, and/or agency)

As illustrated in Figure **3-2**, the first mediating process is *children's engagement in science-related discourse about narrative elements such as event-token, structure, and/or agency.* The use of narrative elements in the SDEP program design enables children to make observations, identify patterns, and provide support for explanations when educators' questions are drawn from picturebook narratives (Plummer & Cho, 2020; Plummer & Ricketts, 2018). Such narrative elements are used in the SDEP learning environment design—which centers around narrative-driven discourse—to promote children's engagement in constructing evidence-based explanations (Plummer & Cho, 2020). This first mediating process provides children with opportunities to co-construct evidence-based explanations while investigating phenomena built on prompts drawn from picturebook narratives.

To facilitate this first mediating process, educators can employ prompts and questions that reference particular *event-tokens*, *structures*, or *agency* from the picturebook. *Event-token* can be understood as an occurrence in the story; *structure* refers to the narrative arc organizing a broad set of events. *Agency* is the children's ability or capability to act like the main characters from a story as they engage in the same event or simulated structure. When the educator asks children to act like the Moonbear or imagine and engage in guided play through a series of events from the narrative, the educator is employing narrative elements of event-token, structure, and agency by referring to specific picturebook occurrences, simulating narrative structures, and encouraging children's agency to create their own shadows with their bodies.

Mediating Processes 2: Discourse about conceptual elements from the narrative's purpose

The second mediating process is *children's engagement in science-related discourse about conceptual elements from the narrative's purpose*. Recent work suggests that children and educators' engagement in discourse about concepts related to a children' science picturebook's science phenomenon helps children construct evidence-based explanations to understand science concepts (Plummer & Cho, 2020). Aligned with these findings, the SDEP program design involves children and educators' engagement in discourse around the same phenomena as the picturebook by including the narrative's purpose. In this way, children have the opportunity to explore science concepts for the same purposes as the characters in the picturebook's narrative. This first mediating process provides children with opportunities to engage in discourse concepts introduced from the picturebook during the read-aloud.

For example, during the SDEP program exploration phase, the educator asked children to make the biggest and/or smallest shadows that they can. The educator did not make specific reference to the narrative's event-token, structure, or agency, but only engaged the narrative's purpose about shadows. The children also engaged in discourse about the big or small shadow by describing their shadows but, like the educator, did not make reference to narrative elements from the picturebook.

Mediating Processes 3: Use of body movements related to shadows

The third mediating process is children's use of body movements related to shadows. Research concerned with young children engaged in "doing science" typically takes a multimodal approach as children develop understandings of science beyond interactions of verbal language to include actions, gestures, and physical engagements with science phenomena (Siry et al., 2012).

In particular, as young children's gesture use is connected with increased performance on spatial tasks, recent work suggests that engaging children with gestures may support spatial thinking (Ehrlich et al., 2006). Further, Plummer and Cho (2020) propose that children's use of gestures supports their making of evidence-based explanations of spatial phenomena as they are able to make sense of and communicate their understanding of science phenomena through embodied communication.

In the context of this study, the use of body movements in the SDEP and EP programs included gestures and whole-body actions. During the various phases of the programs, children and educators used gestures and body movements to support the construction of evidence-based explanations. Gestures enabled children to indicate evidence for claims, such as when a child pointed in the direction of a shadow or traced the length of a shadow. Whole-body movements generated children's evidence as they moved their bodies in response to the educator's questions. In this way, children's body movements represented their understanding of concepts.

Meditating Processes 4: Children engage in guided play about shadows

As one of the main pedagogical functions of the SDEP and EP programs, guided play is understood as a discovery learning approach that is less structured than didactic instruction but more supported than free play (Golbeck, 2001). In guided play, teachers are collaborative partners with children as they create experiences that are flexible and interest-driven; these experiences of guided play encourage children's curiosity, active engagement, and "sense-making" processes (e.g., Fisher et al., 2012). Guided play still has aspects of play (self-directed, exploratory and active, social interactions, process-oriented, and guided by mental rules that leave room for creativity) (Gray, 2017; Rubin, 1983; Saracho & Spodek, 2003) but is supported by an educator's

guidance. Following the educator's guidance during the program, children engage in diverse learning moments in a playful learning environment.

In the SDEP and EP programs, the educator engaged in guided play by asking open-ended questions, commenting on children's discoveries, and co-playing with children. During the guided play, children interacted with the educator's guidance which supported their investigation of the phenomenon and construction of explanations.

Mediating Processes 5: Making and testing predictions by analyzing their observations to investigate shadows

The fifth mediating process is children making observations and testing predictions to investigate science phenomena of shadows. Young children have been referred to as "scientists-in-waiting" due to their notable capacity for scientific reasoning (Gelman et al., 2009; NRC 2007, 2012). However, children are able to use science practices and generate evidence for explanations (Zembal-Saul et al., 2013). Preschool-age children are also capable of engaging productively with others to use science practices, including asking questions, collecting and analyzing data, and constructing explanations (Gelman et al., 2009). Therefore, the opportunity for engaging in science practices plays an essential role in constructing evidence-based explanations. Children's engagement in science practices can be supported by an educator's questions and guidance (Cho & Plummer, 2018).

In the SDEP and EP programs, children engaged in diverse science practices such as making predictions, testing predictions, observing the phenomenon, and analyzing their observations. During the exploration, children made predictions about the location of their shadow and the length of their shadows when the lamp was turned off. Next, children were able

to test their predictions with the lamp light on. During this testing of predictions, children's observations supported their claims.

Mediating Processes 6: Generating representations about shadows

The last mediating process is children's generating representations about shadows. Prior research on young children (Siry & Gorges, 2019; Siry & Max, 2013) indicates that children make sense of and communicate their ideas in multimodal ways including words, drawings, and gestures. In particular, young children demonstrated their understanding of concepts while drawing about their experiences from the investigation. While engaging in drawing, children also used gestures and verbal descriptions of the concepts to communicate their understanding (Plummer & Cho, 2020; Plummer & Rickett, 2018).

In the SDEP and EP programs, children were given a sheet of paper on which they drew representations of shadows. In the SDEP program, a bear was printed on a paper, and in the EP program, a child was printed on a paper. Children drew the sun and the shadow in response to educators' questions and prompts and reflected on their previously completed investigation.

Desired outcomes: Co-constructing evidence-based explanations

Mediating processes are intended to generate *desired outcomes*. Different design research studies could focus on a variety of outcomes and could use different approaches to collect evidence of their outcomes (Sandoval, 2014). In this dissertation study, I focus on how young children construct evidence-based explanations in the program. The outcomes in the fourth column of Figure **3-2** and Figure **3-3** are defined according to how they were observed through

the interactions between conjecture map elements. In this study, SDEP and EP programs have the same desired outcome of constructing evidence-based explanations.

The National Research Council Report (NRC, 2007), *Taking Science to School*, provides a framework for proficiency in elementary science, which includes a focus on students' ability to ''generate and evaluate scientific evidence and explanations'' and ''participate productively in scientific practices and discourses'' (p. 2). Zembal-Saul and her colleagues (2013) found that early elementary students used their observations as evidence for their claims. Preschool-age children are also capable of engaging productively with others to use science practices, including asking questions, collecting and analyzing data, and constructing explanations (Gelman et al., 2009). The goal of this study is to understand how young children engage in constructing evidence-based explanations in an integrated learning environment: story-driven embodied play. Plummer and Ricketts (2018) suggest when science programs are designed to engage children with science phenomena, young children have the opportunity to participate in co-constructing evidence-based explanations. An *evidence-based explanation* occurs when a child *makes a claim* (alone, or with peers or adults) that answers a question or response to a statement about a science phenomenon using their own observations of science phenomenon. Young children's claims might be simple, descriptive, or even not verbalized, and made either explicitly (using verbal descriptions or gestures) or implicitly (without verbal description). If children answer the educator's question using their own observations, they are engaging in constructing explanations based on evidence. This engagement differs from answering questions based on prior knowledge. At this age-level, explanations do not need to include reasoning, but the reasoning might be embedded in children's discourse around picturebook's narrative or/and science concepts.

For example, during the investigation, the educator asked questions to children, "can you make your shadow not scare the fish?" A child moved their body beside the pond to make his shadow not cast over the pond so that it did not cover the fish. For this instance, I coded

constructing evidence-based explanations as the child generated a claim (not verbalized) about evidence he had just engaged in as a response to the educator's questions prompted by narrative from the picturebook.

I use the conjecture mapping as analytical framework to address my three research questions for three reasons (see Chapter 4). First, the approach allows me to articulate how three theoretical perspectives, narrative theory, embodied cognition, and play theory are integrated into specific designed learning environments and how they can explain learning. Second, it offers design conjectures to test how story-driven embodied play (SDEP) learning environment grounded in these three theoretical perspectives might support preschoolers' constructing evidence-based explanations. Third, building connections between each element of the conjecture map provides a way to compare between the SDEP and EP learning environments.

Chapter 4

Methodology

In this chapter, I explain the methodological approach which I use to define interrelationships between theoretical understanding and empirical intervention to support a broad perception of narrative theory, embodied cognition, and play theory for preschool-age children's science learning. Through this study, my methodological approach of conjecture mapping allows me to answer the following research questions about story-driven embodied play learning environment:

1. How and to what extent does the combination of narrative theory, embodied cognition, and play theory do more to explain preschool-age children's science learning in ways that go beyond what each theory can explain on its own?
2. In what ways does *story-driven embodied play* support or constrain preschool-age children and educators in co-constructing evidence-based explanations?
3. How do *story-driven embodied play* and *embodied play* environments compare in terms of how they support or constrain preschool-age children's constructing evidence-based explanations?

In this chapter, I first discuss the influences of previous research from My Sky Tonight to more provide the context of this dissertation. Then I describe the characteristics of the SDEP and EP learning environments and discuss the processes of data analysis. Finally, I discuss how to answer these three research questions through coding processes based on conjecture mapping.

Influences of previous research from My Sky Tonight

This dissertation proposal draws from significant ideas about story-driven investigations generated by the My Sky Tonight project. "My Sky Tonight: Early Childhood Pathways to Astronomy" (NSF DRL #1217441; 2012-2018) has identified evidence-based constructions for how storybooks can be implemented to support preschoolers' use of science practices. Story-driven investigations during the My Sky Tonight project examined how stories interact with children's use of science practices during museum-based programs. In our implementation of the My Sky Tonight project, our research team developed a program prompted by a storybook's inquiry about science phenomenon. Findings from our study of story-driven investigations of the My Sky Tonight project indicated that (Cho & Plummer, 2018):

1. In story-driven investigation, questions or problems raised by characters in the story provided a guiding purpose for the investigation. Story-driven investigations generated children's representations that shaped opportunities for evidence-based explanations.
2. In story-driven investigation, all embodiment features of the conjecture map were strongly connected to the mediating process (e.g., conceptually mediated discourse, investigation of phenomenon, and gestures). These mediating processes led to children's constructing evidence-based explanations.

From these results, we found that narrative elements from the story are important to support children's engagement in constructing evidence-based explanations in all phases of the program. However, we also found that the opportunities for constructing explanations were different depending on the nature of science phenomena and children's picturebook features. Therefore, further research was needed to understand how narrative can make difference in young children's science learning in particular constructing explanations.

In my dissertation study, I investigated the role of narrative by designing two different learning environments: SDEP and EP learning environments. I designed a *story-driven embodied play* program by integrating three pedagogical functions of narrative, body movements, and play. Compared to the SDEP program, I also designed the EP program by integrating two pedagogical functions of body movements and play, without narrative. I propose mediating processes in my dissertation study such as narrative-mediated discourse, embodiment-mediated discourse, engagement in play, and children's representations. Contrastingly, the My Sky Tonight project's mediating processes consist of narrative and thematic mediating discourse, narrative and thematic gestures, children's investigation of scientific phenomenon, and children's representations. The differentiating features of my dissertation from the My Sky Tonight project include highlighting each narrative, embodiment, and play elements to understand both theoretical and empirical interactions with each other in SDEP and EP learning environments.

Setting

In this study, I collaborated with a museum educator at a local children's museum. The early childhood educator from a local children's science museum ran the SDEP and EP programs for this study as is further described in the Participants section below. I implemented two different learning environments about the same science concept about shadows through two different learning programs, SDEP and EP (see Table **4-1**). The first program was story-driven embodied play (SDEP) which integrated story, embodiment, and play into a learning activity to support young children's constructing evidence-based explanations. The second program was embodied play (EP) which incorporated embodiment and play in a learning environment.

Both the SDEP and EP programs maintained the same content and program structures. The programs both worked with the same topic of shadow and had similar phases of the program

including prediction, investigation, and reflection (except for the use of narrative from the picturebook). SDEP program was designed for the use of narrative and body movement together in play; however, EP program was designed only for the use of body movement in play to compare the role of narrative with the SDEP program. Therefore, the SDEP program was guided by the story during the whole program through embodied play learning, and EP was guided explicitly by alternative features without the story. The EP included an informational book with some pictures about shadow during the read-aloud time and embodied play without narrative elements during the investigation phase while the SDEP program used a picturebook during the read-aloud time and then used the narrative from the picturebook to guide children's embodied play during the investigation phase. The SDEP program ran three times at a local children's science museum and two local preschools and the EP program ran two times at two local preschools.

Overview of program

Two learning environments were designed for the same science concept about shadows and completed the same type of investigations. The SDEP and EP followed similar phases of the program including read-aloud (picturebook read-aloud in the SDEP and informational book read-aloud in the EP), exploration, investigations, reflections.

The *read-aloud* was designed differently for SDEP and EP, respectively. In SDEP, educators and children read a picturebook, *Moonbear's Shadow* by Frank Asch. This story follows Moonbear's challenges as his shadow scares away the fish while he is fishing. The narrative from this picturebook guided the investigation phases and reflections in the SDEP program. In the EP program, educators and children read an informational book about shadows, *Guess Whose Shadow?* By Stephen Swinburne. The informational book did not include narrative

but still had photos and short explanations about shadows. Both read-aloud phases provided opportunities for children to have some ideas about shadows before engaging in exploration, investigation, and reflections.

Exploration phase involved the same activity structures in which educators and children explored their shadow with a lamp in the SDEP and EP programs. In the exploration phase, the educator asked questions for children to find their shadow related to the Sun's locations. In the SDEP program, narrative elements were not included in the exploration phase therefore, exploration phases conducted the same structure in both the SDEP and EP programs.

Investigation phases were designed differently for the SDEP and EP programs. In the SDEP program, the educator and children engaged in story-based embodied play by making the bear's shadow. Participants acted like Moonbear from the story and moved around to make their shadows with the picturebook narrative and narrative-driven settings in the room. The educator provided prompts and questions motivated by the narrative from the picturebook to enable opportunities for the children to construct explanations. In the EP program, children and educators engaged in embodied play by making shadows using their bodies. Children moved their bodies to make different shadows, guided by the educator's questions without narrative, in order to make sense of the relationship between the Sun's location and their shadows.

Reflection phases were also designed differently for the SDEP and the EP programs. In SDEP program, children drew the Sun's location and the bear's shadow with educators' prompts and questions that were motivated by the picturebook narrative. The children were given a sheet of paper with a bear printed on it on which they drew the location of the sun and the bear's shadow. In EP program, children drew the location of the sun and shadows with guidance from the educators' reflection questions and prompts pulled from their EP learning experience. The children were given a sheet of paper with a child printed on it on which they drew the location of the sun and the child's shadow. Table **4-1** describes the structures of SDEP and EP programs.

Table **4-1**: Plan for Story-driven embodied play and embodied play programs about shadows

Phases	Story-driven embodied play (SDEP)	Embodied play (EP)
Read-aloud	Read *Moonbear's Shadow* picturebook with the educator's gesture use. • The educator delivered the story verbally and physically.	Read *Guess Whose Shadow?* informational book with the educator's gesture use. • The educator provided only some photos from the book to talk about the shadow.
Investigation	Make the bear's shadow • Children engaged in making a shadow while they acted like the bear in the picturebook. • On the floor, there was a pond (represented by a blue carpet) with a fish and a standing tree. A beam (or lamp) represented the Sun and this beam was moved and adjusted for height. • Children acted like bears who wanted to go fishing. They tried to make a shadow or change the direction of the shadow. • The educator provided questions and prompts based on the story to encourage children to think about the relationship between the Sun and the shadow. Questions and prompts based on story promoted bodily actions (e.g., pointing their shadow and the light).	Make my shadow • Children engaged in making a shadow. • Without any setting of story elements, a beam (or lamp) represented the Sun and moved and adjusted for height. • Children made their own shadows. They made various shadows (long and short) and changed the location of their shadows. • The educator provided questions and prompts for children to encourage them to think about the relationship between the Sun and the shadow.
Reflection	Draw • Children drew representations of their understanding about the relationship between the Sun and the bear's shadow when guided by the educators' prompts and questions motivated by the story. • Children were given a sheet of paper with a bear printed on it.	Draw • Children drew representations of their understanding about the relationship between the Sun and their shadow when guided by the educators' prompts and questions based on their investigation. • Children were given a sheet of paper with a child printed on it.

Participants

A museum educator and preschool-age audience were included in the programs. I worked with a museum educator from a local children's science museum who had access to these populations and who knew the context of this location. The museum educator ran this program at a local children's science museum and three local preschools. I explained and discussed the purpose of my dissertation and the program plans with the educator and then talked about any concerns about the museum and preschool context in which the programs were implemented. Through in-person and online conversations, I trained the educator to emphasize specific purposeful interactions to communicate with audiences.

Preschool-age children between 3-to-5 years old attended either the SDEP or EP program. At the local children's science museum, the children who participated in the program were part of the families who visited the local museum. I planned the programs at the museum and invited museum-goers to participate in the program while they were at the museum. I created the program for this research purpose and I emailed a museum educator and invited them to attend the program and participate in the research. At local preschools, the museum educators contacted local preschools with low-resources in these areas through email to invite participation in this research. For the preschools who wanted to be involved in this research, the museum educator emailed consent forms with a demographic survey. After confirming the date and schedule of the visit, the museum educator, one graduate student who video recorded, and I visited the local preschools to provide the program. For each visit, the SDEP and EP programs were delivered at each preschool.

A total of 44 children (age 3-5 yrs.) from five different preschools and one museum program participated in the programs. Twenty-two children (average age 4.045, SD=.75) from

two preschool class groups participated in the EP program and 22 children (average age 3.636, SD=.972) from two preschool classes and a museum program group participated in the SDEP program.

Data sources

I collected video-data of the interactions between the educator and the children in their learning contexts. Examining and comparing the nature of the SDEP and the EP learning environments shows the connections between the mediating processes and learning outcomes while highlighting differences between SDEP and EP. Therefore, I chose to video-record the programs during all activities in order to analyze verbal and physical interactions between children and the educator.

Data collection

To capture children's and adults' interactions closely, a total of two cameras were used for video recording. These two cameras were used for stationary and handheld recordings. At the beginning of the program, both cameras were set up in different corners of the room to capture the entire space, educator, and children from two different angles. As the program continued, one camera remained stationary in the corner and the other camera was used to walk around the room and capture small group interactions. The use of two cameras and stationery and handheld recording techniques was integral to capturing the events and activity of the whole room during the program but also to capture small group interaction and movement with the children. Each program lasted 30 to 45 minutes. Video-recording started when the program began and ended when the program was completed.

The video-recording captured participants' discourse in their interactions with each other. In addition, video-recording documented children and educator's body movements and gestures in their physical and social learning environments. In these ways, video-recording was the most appropriate method for data recording as it provided opportunities to analyze and revisit data for generating meaningful findings.

Data analysis

I analyzed three iterations of the SDEP program and two iterations of the EP program (total of five sets of video data for this research) to identify conjecture map elements to support children's co-construction of evidence-based explanations during the SDEP and EP programs. I used conjecture map elements as codes (e.g., one code is Engagement with Phenomenon, see Figure **3-2** or **3-3** in the chapter 3**)** to analyze the video data. For coding, I combined sections of a codebook developed by my team for the My Sky Tonight project with pieces of a codebook I developed explicitly for this dissertation study. The codebook (see Appendix B) for the conjecture map elements was based on the theoretical frameworks (narrative theory, embodied cognition, and play theory) and conceptual frameworks (constructing evidence-based explanations) described in chapter 1. I used V-Note to code and analyze the video data. Figure **4-1** shows a snapshot of the timeline with code labels. The left side of the image shows the codes from conjecture mapping elements and the right side of the image shows which instances were coded with these codes.

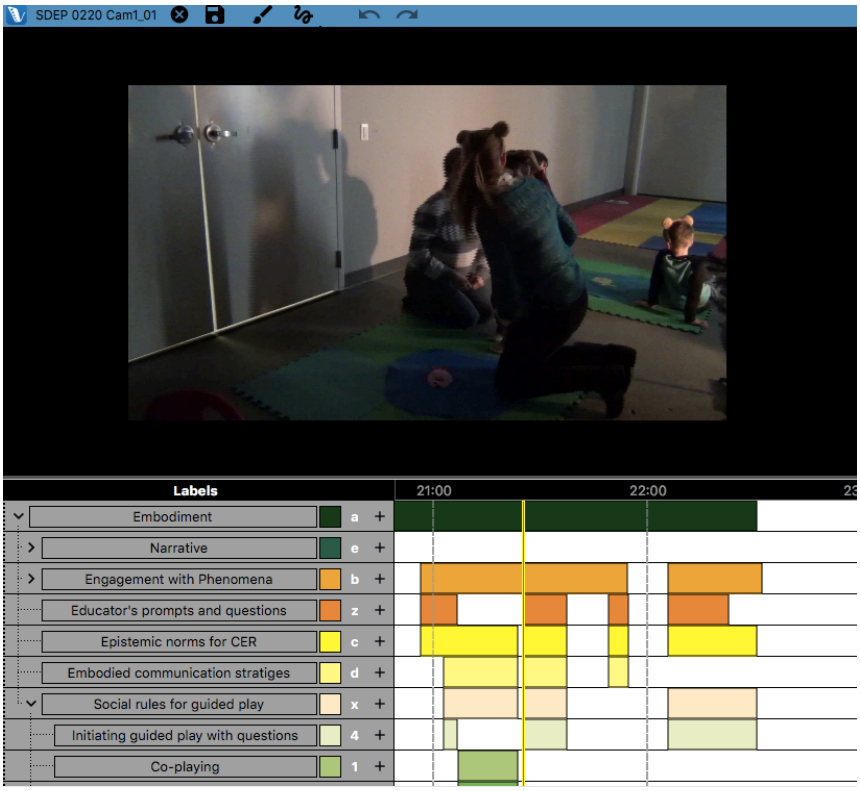

Figure **4-1**: Snapshot of a coded timeline from video data

Data analysis processes

First cycle of coding (a horizontal analysis): identified conjectures

I used the approach of inductive coding to understand the core mediating processes evident in the video-data. The first step in analyzing video-recording data was to map events to understand the general features of the program (Kelly, 2014). The first cycle coding process used science practices codebook and narrative elements codebook from My Sky Tonight project as initial categories. The initial codes for activity structures and discursive practices (see Figure **3-1**) were further defined as narrative elements and discursive practices (epistemic norms for CER, embodied communication strategies, and social rules for guided play) codes (see Figure **3-2**).

Another initial code for mediating processes (see Figure **3-1**) was further defined as six mediating processes in the SDEP program and five mediating processes in the EP program (see Figure **3-2** and Figure **3-3**). The codes from initial process coding are developed from the elements of conjecture mapping as code categories; then, the initial codes were further defined after reviewing video data. Process coding was used in the procedural step of the first cycle coding process. I coded video data using these categories from conjecture mapping elements (a detailed example of how I used elements from conjecture maps for the coding process in this research can be found in Appendix B). I used loose definitions of these codes for the first cycle coding process so I could explore each of these coding categories more freely and add new codes or change existing codes.

Application of codes to determine conjectures

The goal of this dissertation is to identify the evidence in the coded video data that supported individual conjectures on the conjecture map. I represent these conjectures on the conjecture map by lines that connect two conjecture map elements (e.g., Engagement with Phenomenon to Children Engaged in Discourse about Narrative Elements). Each line represents connections between conjecture map elements: how embodiment elements support mediating processes (design conjectures) and how mediating processes support the outcomes (theoretical conjectures). The evidence of connections between the conjecture map elements was identified by looking for temporal overlap in the coded instances. I represented evidence for the overlap instances using lines of different strengths (bold and solid). Using these different strengths of lines, the design conjectures and theoretical conjecture were labeled as strongly supported and moderately supported. In the conjecture map for this dissertation, I only drew bold lines (strongly supported) and solid lines (moderately supported) in the conjecture maps. I counted the number of code overlaps for each possible conjecture and then divided that number by the total number of code overlaps. Bold lines represent the top quartile of conjectures (strongest supported); solid lines represent the second and third quartile of conjectures (moderate supported).

Second cycle of coding (a vertical analysis) —identified relationship between mediating processes.

A limitation of this conjecture mapping analysis is that it does not represent the inter-relationships between mediating processes. The mediating processes represented the children's engagements during the program. Each mediating process often did not happen individually, but rather one mediating process happened together with one or two more other mediating processes to support children's co-construction of evidence-based explanations. Therefore, investigating the interactions between the mediating processes can expand the understanding of the nature of this program. To identify the interactions between the mediating process, I examined all possible theoretical conjectures based on coded video data. In the SDEP program, children often engaged in discourse about conceptual elements, use of body movements, and making and testing predictions by analyzing their observations during the program. I examined eight possible combinations in the mediating processes in SDEP and EP programs. These interactions between the mediating processes are described in the Theoretical Conjecture Sections in chapter 5.

Application of coding cycles

To answer the first research question about how narrative theory, embodied cognition, and play theory explain the learning observed during the programs, I looked for patterns of how co-constructing evidence-based explanations were supported by program designs and children's engagement during the SDEP and EP programs. After the first cycle of coding and generating all connections with different strength lines on the conjecture map, I compared the salient conjectures and program instances to find any evidence of these salient conjectures that can explain narrative, embodied cognition, and play theoretical perspectives.

To answer the second question about how the SDEP learning environment supports children's constructing evidence-based explanations, I focused on coding all elements of the conjecture map to find links between them that lead to the outcome. Every conjecture map

element was used as code for analyzing video data through V-Note. After coding all instances in video data, I drew different strengths lines to represent the level of connection between embodiment and mediating processes (design conjectures), and mediating processes and the outcomes (theoretical conjectures). After generating conjectures, I did a second cycle of coding which was vertical analysis. The conjecture mapping analysis has a limitation in that it does not represent how mediating processes work together to lead to the outcome during the learning. During the program, children engaged in diverse mediating processes simultaneously; for example, children engaged in discourse about concepts with their body movements. To identify these interactions between mediating processes, I counted all combinations of mediating processes and then looked for patterns of children's enactment during the SDEP and EP programs. Therefore, I used two ways of analysis, horizontal (define design conjecture and theoretical conjectures) and vertical (identify interaction between mediating processes).

The third research question of the comparison between SDEP and EP learning environments might be answered through the first and second cycle of coding processes as well as using numerical information of the frequency of explanations and other elements related to children's co-construction of evidence-based explanations. I first followed the same coding processes as the second research question to generate conjectures and relationships between mediating processes in the EP program. Then, I compared the final version of the SDEP conjecture map to the EP conjecture map to look at different patterns in the conjecture maps. I further investigate the potential differences between the SDEP and EP programs to count occurrences of explanations in the SDEP and EP programs as well as epistemic norms for CER and children's use of body movements about shadows which are the most relative elements to support children's co-construction of evidence-based explanations.

Validity

The methods of data collection and analysis as described above strengthen/demonstrate the validity of this study. Recording on videotape raised issues for qualitative researchers such as deciding on the best locations for the video camera and determining whether to provide close-up shots for a specific moment or distant shot for the entire group in the classroom (Creswell, 2007). However, video data helped capture what happened during the programs and had low researcher bias in comparison to other data collection methods.

Another method of data analysis to be included is inter-rater reliability (IRR) for the validity of data analysis. For this dissertation research, I used three codebooks: science practices codebook, embodiments codebook, and mediating processes codebook. Science practices codebooks were focused on children's engagement in science practices that are related to mediating processes and the outcomes for this study. Embodiment codebook includes engagement with phenomenon code (tool), narrative elements codes, and discursive practices codes. Our team for the My Sky Tonight project had developed and defined tool and narrative elements codes, but for this dissertation study, I needed to further develop discursive practices codes about educator's support of guided play. To define these codes, I first drew from the meaning of guided play from the literature on play (Gray, 2017; Rubin, 1983; Saracho & Spodek, 2003) and guided play (Fisher et al., 2010; Weisberg et al., 2016). Next, a doctoral student colleague who studies young children and play applied this codebook to their work, which in turn was a way to establish inter-rater reliability for this codebook. Two parts of video data were coded by two coders to prove inter-rater agreement for guide play codes. Inter-rater reliability provided a way to limit the researcher bias in identifying the educator's guided play as well as expand recognition and interpretation of multiple meanings of guided play supported in different ways by educators.

Limitations

Video-recording allowed me to understand the entire learning context by providing continuous data sources for the program. However, this research study not only focused on each individual child but also focused on every small group and their interactions. Therefore, it might be possible to miss some part of the children's and the educator's interactions during the programs. I tried to capture individual interactions using cameras with different views; however, several children's voices overlapped in some parts of the program and some children's body actions may have been obscured by other children given the angles of the camera.

Another limitation of this research study was the small number of data collection for SDEP and EP programs which yielded a small sample size of the group of children. In this research study, the unit of analysis was the program and not the individual child. Thus, the focus was less about the individual child and more about the group of children in one program. Even though the participants' ages were close between3 to 5 years old, the random delivery of the SDEP and EP programs meant that the age of the children was not controlled because they randomly participated in either program. Therefore, the engagements and explanations for participants in this program may not be generalizable.

This study was designed to understand specific learning environments for young children's co-construction of evidence-based explanations for preschool settings. For local preschools, they were in low-resourced areas. Therefore, many factors such as children's prior knowledge, socioeconomic status (SES), and parental factors might have affected children's engagement and their outcomes. Therefore, I would like to emphasize that the findings from this research study might be only understood in this particular context.

Chapter 5

Story-Driven Embodied Play

In this chapter I present findings from conjecture mapping analysis of the video-data from story-driven embodied play (SDEP) program. This study generated four conjecture maps: a master conjecture map and three individual conjecture maps for three different phases of the SDEP program. I produced conjecture maps for each of the three phases of the SDEP program—exploration, investigation, and reflection. The master conjecture map was formed by combining the three individual phase conjecture maps. In this chapter, I first present the master conjecture map to overview salient features of embodiments, mediating processes, and the desired outcomes. Second, I present three major themes from the SDEP program and each theme is drawn from analysis of each phase in the program. In each theme, I examine salient conjectures by connecting embodiments to mediating processes (design conjectures), and mediating processes to desired outcome (theoretical conjectures). This analysis was done by examining the conjecture maps from two directions, vertically and horizontally. The vertical analysis was performed to investigate the interactions between the meditating processes; the horizontal analysis was performed to understand the connections between embodiments, mediating processes, and the outcomes across the conjecture map elements.

This chapter answers the following research question: *In what ways does story-driven embodied play (SDEP) support or constrain preschool-age children and educators in co-constructing evidence-based explanations?*

Overview of master conjecture map

I used conjecture mapping (Sandoval, 2014) to drive data analysis and identify the most salient features of the SDEP learning environment in constructing children's evidence-based explanations. I tested the initial conjecture map (Figure **3-1**) to answer the research question above. I analyzed video-data using conjecture map elements as coding schemes. To test hypothesized conjectures from the initial conjectures, I examined all conjectures between conjecture map elements and then identified salient features of each conjecture from the initial SDEP program conjecture map. First, I examined the theoretical conjectures (Mediating Processes to Outcome) to understand which mediating processes led to the children's co-construction of evidence-based explanations. Then, I examined design conjectures (Embodiments to Mediating Processes) to understand what design features strongly supported mediating processes that children engaged in during the program.

The conjectures are represented by three different kinds of lines (solid and bold lines) to show salient features based on the frequency of connections between conjecture map elements. These different lines delineate how conjecture map elements engender other elements of the conjecture map. Bold lines represent the strongest connections and solid lines represent the moderate connections between conjecture map elements. After examining the analysis processes for all conjectures from the initial conjecture map, I revised the initial conjecture map to generate the master conjecture map of the SDEP program (Figure **5-1**). In the following section, I present the master conjecture map with a description of salient features in the SDEP program.

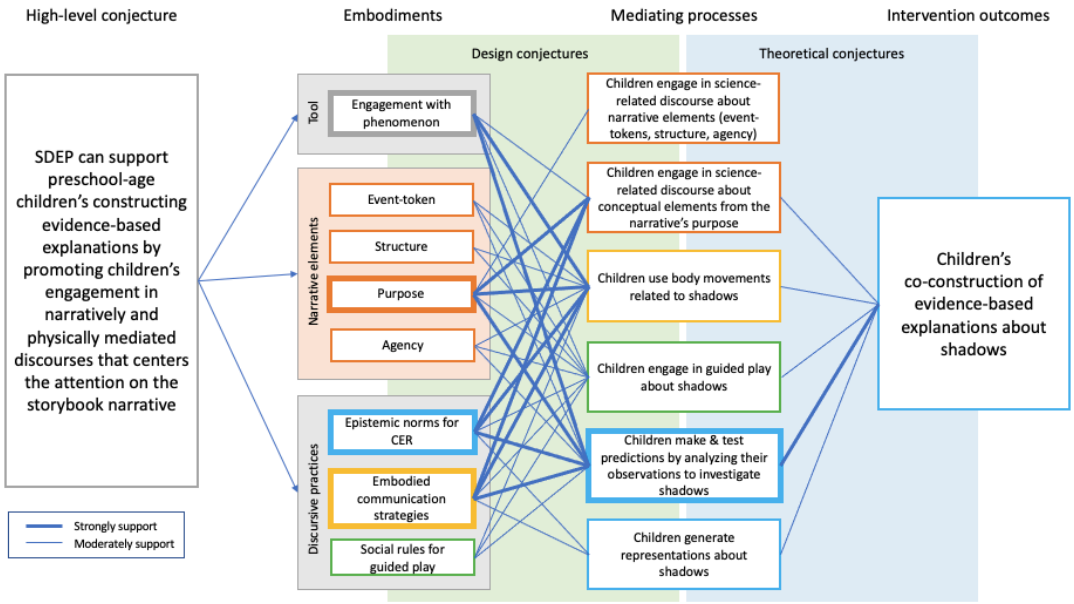

Figure **5-1**: The master conjecture map of the SDEP program

Theoretical Conjectures

In Figure **5-1**, five mediating processes were important in explaining when children engaged in co-constructing evidence-based explanations: *science-related discourse about conceptual elements from the narrative's purpose, use of body movements about shadows, engagement in guided play about shadows, making & testing predictions by analyzing their observations to investigate shadows*, and *generating representations* (represented by bold and solid lines). In particular, *children's making & testing predictions by analyzing their observations* (bold line) most strongly led to co-constructing evidence-based explanations. Discourse about conceptual elements from the narrative's purpose, children's use of body movements, engagement in guided play, and generating representations moderately led to co-constructing evidence-based explanations. Discourse about narrative elements (event-token, structure, and agency) rarely produced co-constructing evidence-based explanations.

Design Conjectures

To analyze the design conjectures in the conjecture maps, I only looked at the connections between the embodiment and the mediating process that most supported the outcomes. Four embodiments from this program design prompted two salient mediating processes (children's use of body movements and making & testing predictions by analyzing their observations) which strongly led to co-construction of evidence-based explanations: *engagement with phenomenon (tool), purpose (narrative elements), epistemic norms for CER*, and *embodied communication strategies (discursive practice*). *Engagement with phenomenon* strongly supported children's body movements and making observations & testing predictions. Narrative elements of *purpose* often prompted discourse about conceptual elements from the narrative's purpose, the use of body movements, and making observations & testing predictions. Two discursive practices, *educator's guidance for claim-evidence-reasoning (CER)* and *embodied communication strategies*, encouraged two mediating processes, use of body movements and making & testing predictions by analyzing their observations during the whole program.

Interaction between the mediating processes

There is a limitation of the conjecture map in that it shows only the individual connections between each element. After closely looking at the connections between all conjecture map elements, I found that each mediating process did not occur individually during the program. Each mediating process happened simultaneously with other mediating processes and supported children engaged in constructing evidence-based explanations together. To further understand the relationship between mediating processes of how they work together to support children's co-construction of evidence-based explanations, I looked across mediating processes of the

conjecture map vertically (at the same time) to try to find their interactions. I found three dominant relationships between mediating processes from each phase of the program—*exploration phase*, *investigation phase*, and *reflection phase*. I present these three relationships as themes in the following section; each theme represents the strong interaction between the mediating processes in each phase of the SDEP program.

To identify the interactions between mediating processes, I examined video-data segments in V-Note vertically while mediating processes were happening together (overlapped in V-Note) and producing co-constructed evidence-based explanations. I analyzed the combinations of all of the mediating processes that led to the outcomes. Each theme is explained as a theoretical conjecture first to represent the relationship between the mediating processes with an individual phase of the conjecture map. The follow-up description explains how embodiments support those mediating processes as a design conjecture in the program.

Theme 1: During the exploration phase, three mediating processes (children's engagement in science-related discourse about conceptual elements, use of body movements related to shadows, and making & testing predictions by analyzing their observations) happened together, often producing co-constructed evidence-based explanations.

The interactions between (a) children's science-related discourse about conceptual elements from the narrative's purpose, (b) use of body movements, and (c) making & testing predictions by analyzing their observations often occurred in the *exploration phase* of the SDEP program. *Children's science-related discourse about conceptual elements from the narrative' purpose* concerns children's talk and words about shadows as consistent with the story narrative. I coded the instances when children were talking about shadows given topics such as directions and dimensions. *Children's use of body movements related to shadows* includes gestures and whole-body actions that are related to the concept of shadows. I coded the instances when

children used gestures or moved their bodies to investigate shadows. Making & testing predictions by analyzing their observations is children's engagement in science practices—that is, doing something with the science phenomenon. For example, I coded the instances when children observed their shadows and predicted the location of their shadow when the light went on. These three mediating processes happened together and led to children co-constructing evidence-based explanations. In the following section, I present the conjecture map of the exploration phase (see Figure **5-2** below) and provide evidence for theme 1 with specific transcripts. In the exploration phase, children engaged in making predictions about shadows and testing them; children had an opportunity to use their body movements and predict where their shadow would be if the Sun (lamp) was shining (turned on). After making their predictions, the educator turned on the lamp to test the predictions.

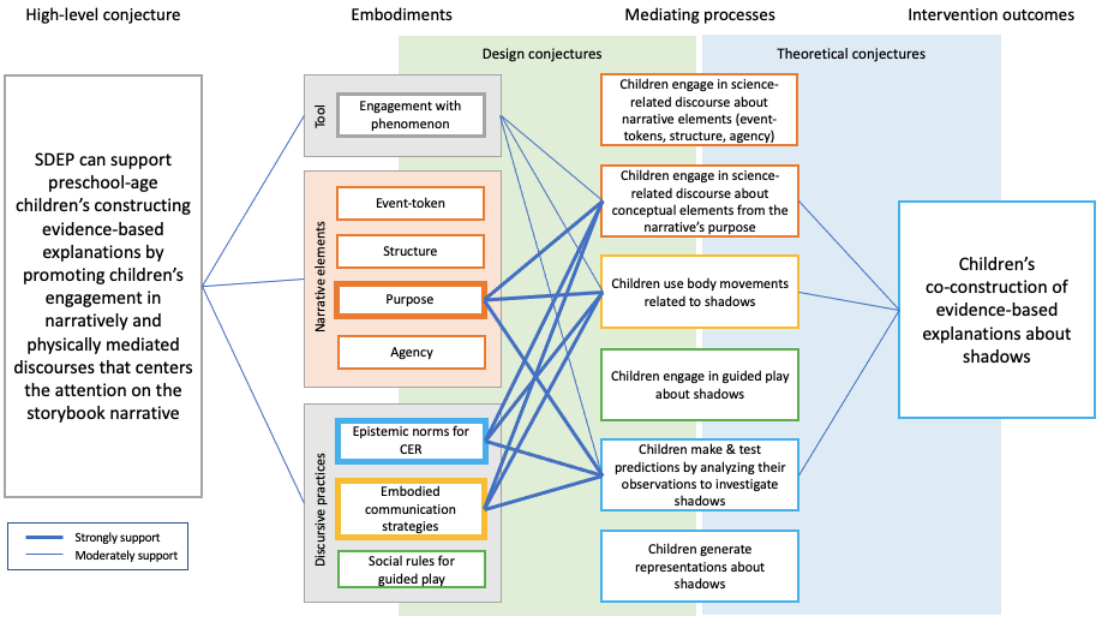

Figure **5-2**: An individual conjecture map of the exploration phase of the SDEP program

Theme 1: Theoretical conjectures

During the exploration phase, each of those three mediating processes—*discourse about conceptual elements from the narrative's purpose, use of body movements*, and *making & testing predictions by analyzing their observations*—often supported children co-constructing evidence-based explanations together. These three mediating processes happened together to encourage children's engagement in exploring their shadows. The following transcript demonstrates the interaction between these three mediating processes and how those mediating processes worked together to support children's co-construction of evidence-based explanations.

1 Jane: [To all children] Can I get everybody to point to where your shadow is?
2 Owen: [Turns his head to see his shadow and points to it] Behind us.
3 Amy: [Turns her head to see her shadow] Right here.
4 Jane: It's behind you. Can I get everybody to point to your shadow behind you?
5 Lucas: [Turns his head and points to his shadow] Look!
6 Amy: [Turns her body to see her shadow] Right there, that's my shadow.
7 Ryan: [Turns his body to see his shadow] I can see my shadow.

In this transcript, Jane (the educator) asked a question to encourage children to observe their shadows with pointing gestures (line 1). Owen and Amy pointed to their shadows using their gestures and engaged in discourse about the conceptual elements from the narrative's purpose which in this study is the shadow; the narrative's purpose for this program was to understand the relationship between the location of the Sun and the shadow. Owen and Amy used spatial words (i.e., behind, right here) to describe the location of their shadows while engaging in discourse with the same purpose of the narrative (line 2, 3). Jane then reacted to the children's spatial word, *'behind',* and encouraged other children to also point out their shadow behind them (line 4). Lucas, too, pointed to his shadow using gestures while turning his head to observe and locate his

shadow (line 5). Lucas, Amy, and Ryan turned their bodies to observe their shadows behind them (because they were facing the lamp) and engaged in discourse to describe the location of the shadow in relation to the Sun which aligned with the purpose of the narrative (line 5, 6, 7). Their body movements generated their observations as evidence that supported their claims (e.g., "behind us"). In this instance, the three mediating processes happened together to support children's engagement with the phenomenon and provided an opportunity to co-construct evidence-based explanations.

Owen's claim "behind us" was a simple response to the educator's question. His *use of body movements* (turn his bodies to observe his shadow) as evidence of shadow, supported his claim and clarified his understanding of the relationship between the location of the Sun and the shadow. The evidence generated by his body movements was implicit while he was *observing* his shadow (the phenomenon). Thus, Owen constructed his evidence-based explanation by *engaging discourse about conceptual elements, using body movements*, and *observing the phenomenon*. Amy, Lucas, and Ryan's claims (e.g., "Right there, that's my shadow) were also simple descriptions of the location of their shadows in response to Jane's question; and, their claims were also supported by evidence while they were *using body movements* (turning their bodies) to *observe the phenomenon*. The observation of the phenomenon as evidence supported their claim to construct evidence-based explanations. Therefore, Amy, Lucas, and Ryan also co-constructed evidence-based explanations by *engaging discourse about conceptual elements from the narrative purpose, using pointing gestures and body movements,* and *observing the phenomenon*. In these ways, the children were engaged in the three mediating processes by the educator's guidance; the three mediating processes were simultaneously shaping the children's co-construction of evidence-based explanations in the exploration phase.

Theme 1: Design conjectures

I created the initial conjecture map by generating design conjectures, which suggest how embodiments (i.e., embodied communication strategies) lead to mediating processes (i.e., children's use of body movements about shadows). In the following section, I present how the embodiments lead to the mediating processes described above but give particular attention to discourse about conceptual elements, use of body movements, and making & testing predictions by analyzing their observations.

Narrative elements of purpose in the program design prompted the three mediating processes

The program is designed according to the narrative elements of the picturebook and draws upon the narrative's central science phenomenon of shadows. Specifically, I integrated the following narrative elements into the program: event-token (educator or child references a specific instance from the storybook's narrative), structure (activities engage children in similar series of events to the storybook narrative), agency (children either engage in same actions as characters or model those actions with external objects), and purpose (activities engage children with aspects of the same phenomena as the picturebook as a way to help them understand the natural world) (Plummer & Cho, 2020). These design choices encourage children to make sense of the shadow based on the purpose of the picturebook. In the exploration phase, children explored the relationship between the Sun and the shadow which mirrored the purpose of the picturebook. When children explored their shadow, they used their body movements to make observations and test their predictions by engaging in discourse about conceptual elements from the narrative's purpose (i.e., "the Sun is lower in the sky", "[shadow is] long"). Therefore, narrative elements of purpose support these three mediating processes.

The educator's discursive practices (educator's guidance for claim-evidence-reasoning (CER) discourse and embodied communication strategies) in the program design prompted the three mediating processes

During the exploration phase, the educator's guidance for CER and embodied communication strategies strongly led to three mediating processes (discourse about conceptual elements, use of body movements, and making & testing predictions by analyzing their observations). The educator's guidance for CER supports children in generating claims with their evidence by providing questions and prompts. The embodied communication strategies are educator's gestures and whole-body actions to show spatial concepts (i.e., long, short, behind, in front of) which support children's spatial understanding and encourage them to use body movements. The following transcript shows how the educator's guidance for CER and embodied communication strategies prompted children's learning experience of the shadow that led to co-construction of evidence-based explanations. In this instance, children and the educator tested the predictions of their shadows by turning on the lamp in the exploration phase of the SDEP program.

1 Jane: What happens when you turn around [she turned around facing away from the Sun], this time you are back to the Sun [she touches her backside of the shoulder], where is your shadow now? Is it still behind you [points her back] or is it [point to the front] ...?

2 Leah: In front of you [pointing to her shadow].

3 Jane: [To Leah] It's in front of you.

In this instance, Jane provided questions about the relationship between the location of the shadow and the children's position. Her question, "what happens when you turn around, this time you are back to the Sun, where is your shadow now," provided an opportunity for children to build their claims about the location of the shadow. The follow-up question, "is it still behind you

or is it?" encourages children to generate observations about their shadows as evidence to support their claims. These questions played a role as guidance for children's claim-evidence-reasoning. Jane used her body movement (e.g., turning her body, pointing gesture) when she asked the question, "what happens when you turn around?" to show the relationship between the location of the Sun and their bodies. She also used gestures while pointing to the shadow's location, "is it still behind you or is it..." as embodied communication strategies. These two discursive practices—educator's guidance for CER and embodied communication strategies—promoted children's discourse about conceptual elements, use of body movements, and making & testing predictions by analyzing their observations. The children made claims in response to the educator's question by engaging in the conceptual discourse. The educator's CER question accompanied by body movements encouraged children to observe the phenomenon and reference implicit evidence while looking closely at their shadow from the observations.

Theme 2: During the investigation phase, three mediating processes (children's use of body movements related to shadows, children's engagement in guided play about shadows, and making & testing predictions by analyzing their observations to investigate shadows) happened together, often producing co-constructed evidence-based explanations.

The interaction between (a) children's use of body movements related to shadows, (b) engagement in guided play about shadows, and (c) making & testing predictions by analyzing their observations occurred often in the investigation phase of the SDEP program. These three mediating processes happened together and led to children's co-construction of evidence-based explanations. In the following section, I present the conjecture map of the investigation phase (see Figure **5-3**) and provide evidence for theme 2 with specific transcripts. In the investigation phase, children engaged in *story-driven embodied play* which is guided play centered on body

movements and narrative elements including specific event-token, structure, purpose, and agency from the book narrative.

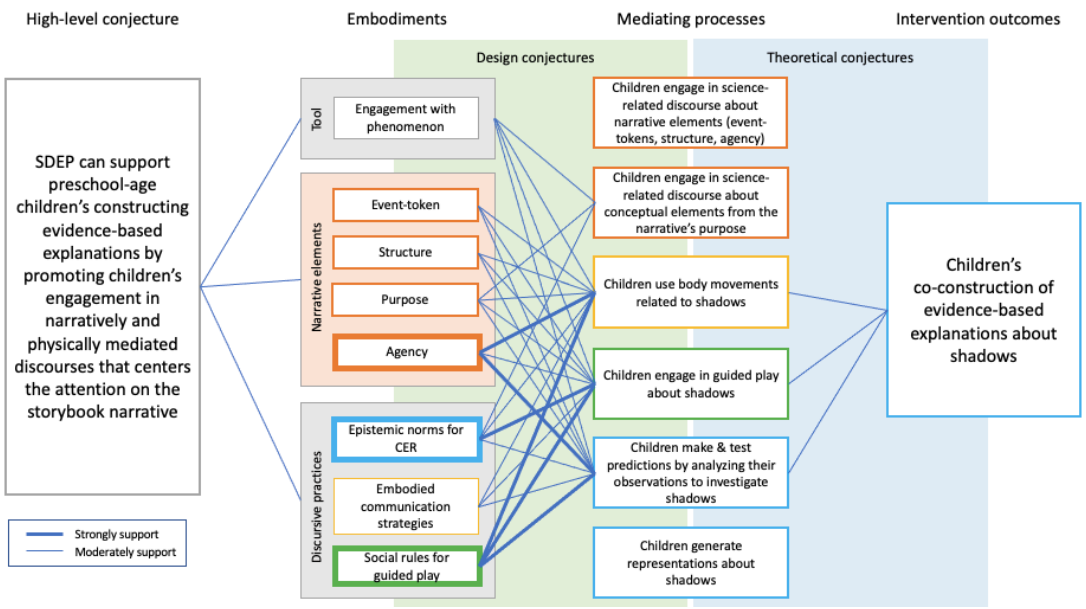

Figure **5-3**: An individual conjecture map of the investigation phase of the SDEP program

Theme 2: Theoretical conjectures

During the investigation phase, each of the three mediating processes—*children's body movements related to shadows, engagement in guided play about shadows*, and *making & testing predictions by analyzing their observations*—often led to children's co-construction of evidence-based explanations. These three mediating processes occurred as children engaged in the investigation of shadows. The following transcript illustrates the interaction of how these mediating processes worked together to support children's co-construction of evidence-based explanations. The transcript shows an instance of children's engagement in the investigation when they mirrored Moonbear's action from the narrative to make their own shadows and try not to scare the fish.

1 Jane: Okay, little Moonbears! Can I get you to make sure your shadow doesn't scare the fish?

2 Noah: [He moves his body to the right side of the pond until his shadow does not cover the fish].

3 Jane: Oh, move to the side? [pointing to his shadow that was cast on the pond.]

In this transcript, Jane asked a question to encourage children to make sure their shadow does not scare the fish. The occurrence of 'making shadows to try not to scare the fish' is the main event from *Moonbear's Shadow* book. This specific event experienced by the main character is considered an *event-token*. Noah, while observing his shadow, *moved his body* to the right side of the pond until his shadow did not cover the fish as a response to the educator's question. When Noah took action to make his shadow, he followed the event-token as Moonbear from the narrative. This playful learning environment was considered *engagement in guided play* as both the educator and the environment provided an opportunity to support children's investigation by prompting their discoveries of the concept related to playful moments. The three mediating processes—the use of body movements, making observations, and engagement in guided play—happened together and led to constructing evidence-based explanations.

Noah's claim was not verbalized, but his body movement represented his claim by responding to the educator's question. The evidence for his explanation was implicit while he was observing his shadows (the phenomenon). While observing his shadow, his body movement (moved his body to the right side of the pond) also provided evidence to support his claim about making a shadow not scare the fish. Thus, Noah co-constructed evidence-based explanation by using body movements, observing the phenomenon, engaging in guided play. In this way, the children were engaged in the three mediating processes that were embedded within each other to support their co-construction of evidence-based explanations; therefore, these three mediating

processes were simultaneously shaping the children's co-construction of evidence-based explanations.

Theme 2: Design conjectures

Mediating processes arose from a combination of a variety of the embodiments' elements from the learning environment. During the investigation phase, narrative elements (agency) and discursive practices (epistemic norms for CER and social rules for guided play) are salient features that led to three mediating processes (children's use of body movements, engagement in guided play, and making & testing predictions by analyzing their observations). In the following section, I present how the embodiments (design feature of the program) support the three mediating processes from the investigation conjecture map.

Narrative elements (agency) in the program design prompted children's use of body movements and engagement in guided play

I designed the SDEP program using specific narrative elements from the narrative from *Moobear's Shadow*. In particular, the narrative element of agency provides an imaginary role for children to pretend they are part of the scenario during guided play. By designing the program with a narrative agency, children are encouraged to actively engage in the phenomenon of the shadow by taking the same actions as the Moonbear from the book. In the transcript above, Noah made his shadow to try not to scare the fish during the investigation (line 2). When the educator provided the imaginary scenes using substitute objects from the picturebook narrative, the children engaged in this imaginary guided play and acted like the Moonbear using their body movements to try to make their shadows scare or not scare the fish. Therefore, the narrative element of agency is an important feature for children's engagement in the mediating processes of use of body movements and guided play in the investigation phase.

The educator's guidance for claim-evidence-reasoning (CER) in the program design prompted children's engagement in guided play

During the investigation phase, the educator's guidance for CER strongly led to children's engagement in guided play. The following transcript illustrates such an exchange that led to co-constructing evidence-based explanations in the investigation phase.

1	Jane:	[To everyone] Okay, little Moonbears! This is a chance to work together with somebody else at your pond. Can you make the biggest shadow together? Without falling into the pond.
2	Noah:	[He puts his hands up.]
3	Jane:	[She speaks to Josh who is next to Noah] How do we make the biggest shadow?
4	Josh:	[He puts his hands up.]
5	Jane:	[To Noah and Josh, she puts her hands up] Are you gonna make your body really big with hands-up? [She moves her body to get close to Noah and Josh and works together to make a big shadow. She points to their shadow on the wall.]

In this instance, Jane provided a question for children to make the biggest shadow. Noah did not verbalize his claim but still he represented his claim with his body movements (he put his hands up to make the biggest shadow) (line 2). Jane's follow-up questions kept supporting children's engagement in guided play (line 3). She also engaged in co-playing with Noah and Josh to make the biggest shadow together with guidance for them to observe their shadow on the wall. With the opportunity to observe the phenomenon, they had an opportunity to indicate evidence to support their claim. Their body movements represented the claims and the evidence was implicit while they looked at their shadows on the wall.

The educator's social rules for guided play in the program design prompted three mediating processes

During the investigation phase, the educator's social rules for guided play strongly led to three mediating processes (children's use of body movements, engagement in guided play, and

making & testing predictions by analyzing their observations). To understand social rules for guided play for this program, I indicate three central components of guided play: (a) commenting on children's discoveries; (b) asking open-ended questions; and (c) co-playing with the children (Gray, 2017; Rubin, 1983; Saracho & Spodek, 2003). During the investigation phase, Jane provided these three social rules for guide play. First, Jane asked an open-ended question for children to make the biggest shadow (line 1). When Jane asked this question, she referenced some specific components from the picturebook narrative, such as "Moonbear" and "the pond" (line 1). These narrative elements provided an imaginative scene drawn from the picturebook to encourage children to engage in playful moments. After Noah made his shadow with his hands up, she encouraged Josh (just next to Noah) to make his biggest shadow while putting her hands up and commenting on their actions (line 5). Then, she moved her body to Noah and Josh and co-played with them to make the biggest shadow together (line 5). The educator's employment of these three social rules for guided play promoted children to engage in guided play, use their body movements, and make observations of their shadows on the wall.

Theme 3: During the reflection phase, children's engagement in science-related discourse about conceptual elements from the narrative's purpose and children's generating representations about shadows happen together, often producing co-constructed evidence-based explanations.

The interaction between (a) children's engagement in science-related discourse about conceptual elements from the narrative's purpose, and (b) generating representation about shadows often occurred in the reflection phase of the SDEP program. These two mediating processes happened together and led to children's co-construction of evidence-based explanations. Theme 3 is a salient feature from the reflection phase. In the following section, I present the conjecture map of the reflection phase (see Figure **5-4**) and provide evidence for

theme 3 with specific transcripts focusing on the reflection phase of the program. After the investigation phase, children were given a sheet of paper with a bear printed on it on which they drew the location of the Sun and the bear's shadow. The educator first asked the children to draw the Sun and then draw the bear's shadow. These drawings supported children's development of claims using evidence drawn from their embodied play experience with the narrative from the book.

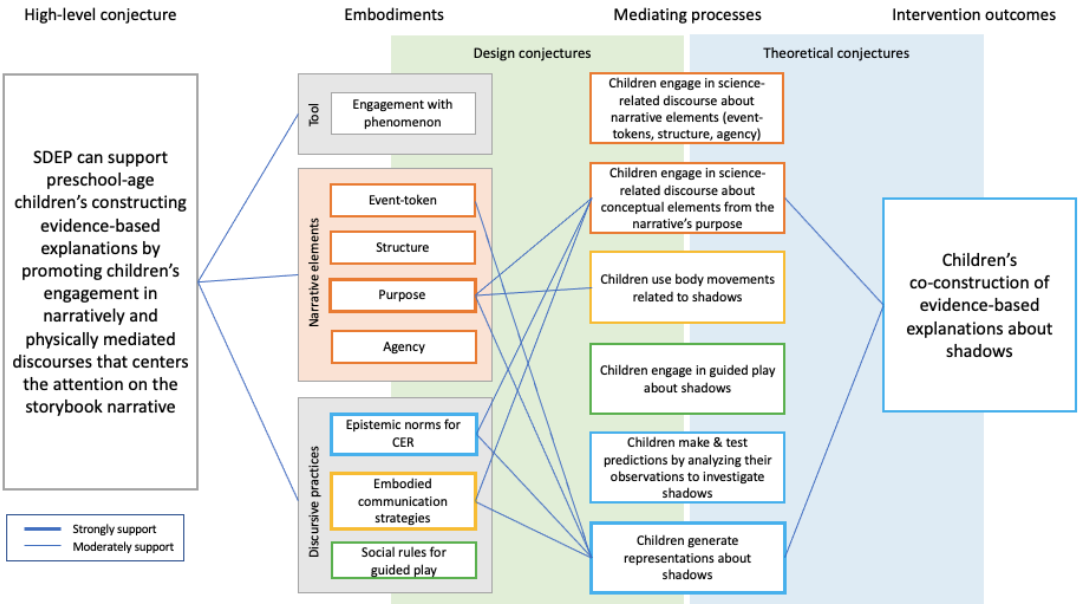

Figure **5-4**: An individual conjecture map of the reflection phase of the SDEP program

Theme 3: Theoretical conjectures

During the reflection phase, each of those two mediating processes—*discourse about conceptual elements from the narrative's purpose* and *generating representations*—often led to children's co-construction of evidence-based explanations. These two mediating processes happened together to encourage children's representations of the relationship between the Sun and the shadow. The following transcript illustrates the interaction between these two mediating processes and how these mediating processes worked together to promote children's co-

construction of evidence-based explanations during the reflection phase. The following instance shows the interactions between the conceptual discourse and the generating representation.

1	Jane:	[Pointing to the Sun on David's paper] Is this your Sun?
2	David:	[Nodding his head.]
3	Jane:	Wow! [points to his Sun on paper] Is your Sun high in the sky, or is it low?
4	David:	[Drawing something on his paper.]
5	William:	This is the Sun.
6	Jane:	[Points to the Sun on William's paper] Is that the Sun up there?
7	William:	Yeah.
8	Jane:	Is it high [pointing to the Sun on his paper] in the sky or is it low?
9	William:	High.
10	Jane:	High. I can [pointing to the Sun on his paper] see it's really high in the sky.
11	Daniel:	I will draw mine super high.
12	Jane:	Super high? It's gonna be right in the middle of the day with high Sun?
13	Daniel:	[Draws the Sun on his paper.] There is the Sun [points to the Sun on his paper].
14	Jane:	[To everyone] And then, I want you to have your sun high in the sky or low in the sky, I'd love you to draw where you think your Moonbear's shadow would be.
15	Daniel:	[Drawing a Moonbear's shadow on the opposite side of the Sun on his paper.] Here.

In this reflection phase, the educator asked the children to draw the Sun first. She asked follow-up questions about the location of the Sun by using pointing gestures to indicate the Sun in children's drawings (line 1, 3, 6, 8). William and Daniel described their Sun's location using one word or one simple sentence (line 9, 11, 13). After the children drew their Sun on the paper, the educator asked the children to draw their Moonbear's shadow (line 14). Daniel drew his Moonbear's shadow that was cast on the opposite side of the Sun in response to the educator's

question (line 15). While drawing the Sun and Moonbear's shadow, children engaged in discourse about conceptual elements from the narrative's purpose. Daniel's drawing represented his understanding of the relationship of the Sun and shadows with a simple claim and by drawing on his paper. His explanation was simple as one word ("here"), but he engaged in constructing explanations through his drawing as evidence that show his understanding of shadows (line 15). Overall, these two mediating processes were deeply embedded within each other to support children's co-construction of evidence-based explanations.

Theme 3: Design conjectures

Narrative elements (purpose) in the program design prompted the two mediating processes

I designed the reflection phase of this program using the conceptual purpose of the narrative which was the location of the sun and the bear's shadow. In the reflection phase, children were given a sheet of paper with a bear printed on it on which they drew the location of the sun and the bear's shadow. These drawings supported children's development of a claim using evidence based on their previous experience. The reflection phase allowed children to engage with the same purpose of investigation as the narrative from the book.

1 Jane: If you have your sun up in the sky, I'm gonna want you to think about where would be Moonbear's shadow.

2 Noah: Right on the back of him [draws the shadow].

3 Jane: If your sun is up high in the sky, where would be Moonbear's shadow? If your sun is here [pointing to the Sun on his paper], this is pretty high in the sky, is it gonna be long [stretching her arm to represent 'long'] or short? [using her hands to represent 'short']

4 Noah: It's gonna be long [drawing the shadow].

In this instance, Jane provided questions and prompts to encourage children to think about the relationship between the location of the Sun and the shadow which mirrored the purpose of the picturebook's narrative (line 1, 3). Noah engaged in discourse about the conceptual understanding of the Sun and the shadow while drawing the Moonbear's shadow and the Sun on his paper; his drawing represented his evidence to support his simple claim (line 4) in response to the educator's question. Therefore, purpose from the narrative elements prompted discourse about conceptual elements and generating representation together.

The educator's discursive practices (educator's guidance for CER and embodied communication strategies) in the program design prompted the two mediating processes

During the reflection phase, the educator's guidance for CER and embodied communication strategies strongly led to two mediating processes, *discourse about conceptual elements from the narrative's purpose and generating representations*. In this transcript, Jane asked a question to encourage children to make their claims through their drawings about the location of the Sun and the bear's shadow (line 1, 3). Jane also used gestures to communicate the concept of long and short to help children describe their shadows (line 3). Jane's two discursive practices of guidance for CER and embodied communication strategies supported mediating processes together for children to construct explanations and communicate their ideas. Noah first drew his sun and then drew the bear's shadow when responding to the educator's question (line 2). He built his claim, "the bear's shadow is right on the back of him" when the Sun was in front of him. He partially verbalized his claim but his drawing represented his understanding and provided evidence for his claim. Overall, these two discursive practices by the educator supported children's engagement in discourse about conceptual elements and generating representations.

Chapter summary

In this chapter, the conjecture mapping analysis of the SDEP program answers the second research question guiding this study to explore *how story-driven embodied play supports preschool-age children and educators in co-constructing evidence-based explanations*. The master conjecture map presented in Figure **5-1** serves as the foundation for this analysis and conjectures across all the embodiments, mediating processes, and outcomes. This analysis helps us better understand how narrative, body movements, and play are used together as pedagogical functions in a program to support preschool-age children's science learning particularly co-construction of evidence-based explanations. The conjecture mapping analysis enables me to understand the relationships between theoretically-supported program designs and learning enactments during the program.

Each phase of the program—exploration, investigation, and reflection—supported children in co-constructing evidence-based explanations in different ways. First, in the exploration phase, discourse about conceptual elements, use of body movements, and making & testing predictions by analyzing their observations together supported children's construction of explanations. Body movements as a pedagogical function of embodied cognition played a central role to connect to other mediating processes such as discourse about conceptual elements and making & testing predictions by analyzing their observations. In this way, children verbalized their claims after they explored shadows using their bodies. Second, during the investigation phase, use of body movements, engagement in guided play, and making & testing predictions by analyzing their observations also supported children's construction of explanations. In this phase, however, children did not use as much verbal language as compared to the exploration phase. Perhaps this difference may be because body movements and guided play learning serve as a vehicle for children to go beyond the verbal expression in order to more completely show their

thinking. While making their shadows in response to the educator's questions, for example, the children did not need to describe the direction of their shadows; rather the resources of guided play (pond, fish, tree) enabled a fuller representation of their understanding of shadows. Therefore, narrative-based as pedagogical function of narrative theory, body movements as a pedagogical function of embodied cognition, and guided play as a pedagogical function of play theory coalesce into an essential role in generating an authentic learning environment for young children. Finally, in the reflection phase, children were able to combine their drawing with verbal descriptions of shadows. Not only did drawing provide children with opportunities to gather evidence from their experience, but children could also make observations and test predictions in multimodal ways. As demonstrated above, children were able to communicate their understanding of the Sun and shadows to the educator through both drawing and verbal description. This is notable because when explaining their drawings, children also employed narrative elements, such as the pond and fish. In this way, narrative elements are embedded in children's representations of their experiences with and understanding of science phenomena.

Significantly, this chapter demonstrates that all three pedagogical functions of narrative, body movements, and play are strongly linked in encouraging preschool-age children in co-construction of evidence-based explanations. Perhaps most notably, I see these three pedagogical functions working together during the investigation phase. As mentioned, during the investigation phase, the interplay between the three pedagogical functions of narrative, embodiment, and play is most obvious. In short, the setting of the narrative from *Moobear's Shadow* was recreated in a play-based learning environment as the children used their bodies and physical learning environments to act out imaginary scenes as the Moonbear character. The educator's questions and prompts also employed narrative elements, encouraging the children to respond with their bodies to generate observations as evidence for explanations during the guided play moment. Through their embodied interactions, the children communicated their ideas and understanding

with the educator. As a result, children and the educator were engaged in SDEP through intertwined narrative, embodiment, and play functions to co-construct evidence-based explanations.

What these findings illustrate is that the SDEP program moves beyond traditional play-based or narrative-based learning to engage children and educators in meaningful ways to teach and learn science phenomena. The emphasis of the SDEP program is the collaboration between the children and the educator through narrative, body movements, and play-oriented means. These pedagogical functions, then, can be integrated together into curriculum design for making sense of science phenomena. These pedagogical functions, as discussed, intertwine to impact children's relationships to learning, self-expression, self-representation, and articulation of evidence-based explanations. From this analysis, I recommend that science curriculum can be integrated with narrative, body movements, and play for young children as a framework for engaging their constructing of science explanations. I further discuss how these three pedagogical functions can be explained by three theoretical frameworks—narrative theory, embodied cognition, and play theory—together for preschool-age children's science learning in chapter 7. In the following chapter, I compare story-driven embodied play and embodied play to understand the affordances of adding a narrative component to an embodied play learning environment in children's construction of evidence-based explanations.

Chapter 6

Comparison of Story-Driven Embodied Play and Embodied Play

In this chapter, I offer a comparison of story-driven embodied play and embodied play learning environments to determine the role of narrative in embodied guided play for preschool-age children's co-construction of evidence-based explanations. To determine the role of narrative, I developed two learning conditions: story-driven embodied play (SDEP) and embodied play (EP). The SDEP learning environment was developed by combining three pedagogical functions––narrative, body movements, and play—to support children's co-construction of evidence-based explanations. The EP learning environment was developed by echoing the SDEP program structures as connecting only two pedagogical functions– body movements and play, without narrative in the program. The conditions of program design for both SDEP and EP enables me to identify and understand where and how narrative interacts with other pedagogical functions when SDEP is compared to EP, a similar design that lacks a narrative function. In this chapter, I begin with findings from comparison of the SDEP and EP programs using master conjecture maps. Then, I further illustrate potential differences between the SDEP and EP programs by investigating how and why they differently support children's constructing evidence-based explanations. Finally, I describe how narrative makes a difference in the SDEP program as comparison to the EP program. This chapter answers the following research question: *How do story-driven embodied play and embodied play environments compare in terms of how they support or constrain preschool-age children's constructing evidence-based explanations?*

Comparison of SDEP and EP master conjecture maps

I used conjecture mapping (Sandoval, 2014) to guide data analysis and identify the most salient features of the program design (embodiments) and children's learning enactment (mediating processes) in their construction of evidence-based explanations. First, I used initial conjecture map elements as codes, and these conjecture map elements were iteratively refined and revised when I coded the data. The conjectures were generated by identifying temporal overlap in coded instances. These conjectures are represented by lines on the conjecture map. The different strengths of lines represent the frequency of connections by counting the number of connections for each possible conjecture and then dividing that number by the total number of connections. Bold lines represent the top quartile of conjectures (most frequent connections), solid lines represent the second and third quartile of conjectures, and the dotted lines represent the bottom quartile of conjectures (least frequent connections). Based on this conjecture mapping analysis, I revised initial conjecture maps and generated the master conjecture maps for SDEP and EP programs, respectively. In the following section, I present these two conjecture maps to compare how SDEP and EP program designs support children's mediating processes that lead to constructing evidence-based explanations.

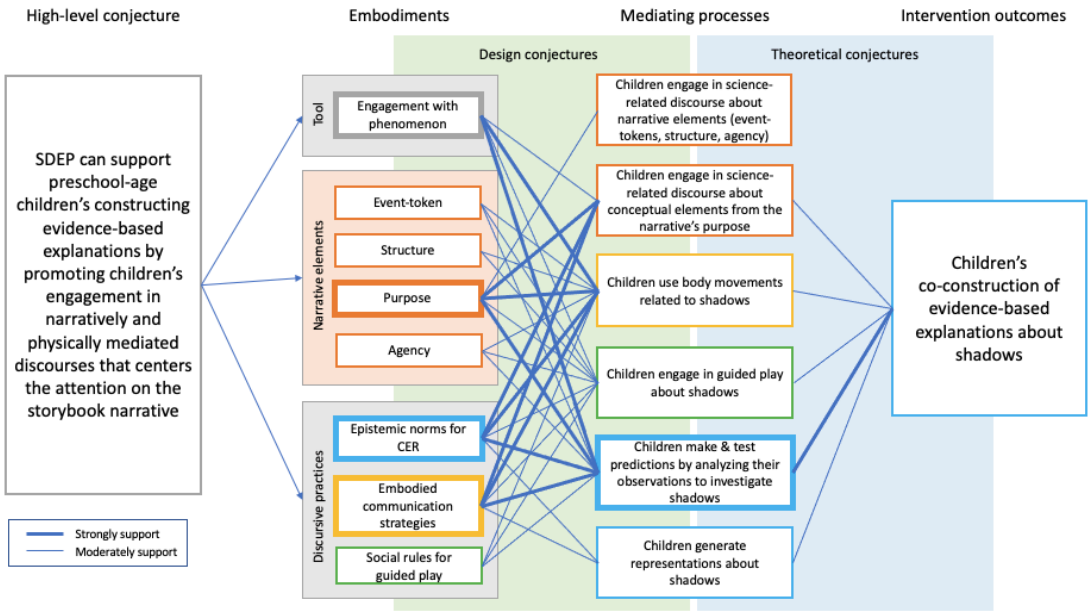

Figure **6-1**: The master conjecture map of the SDEP program

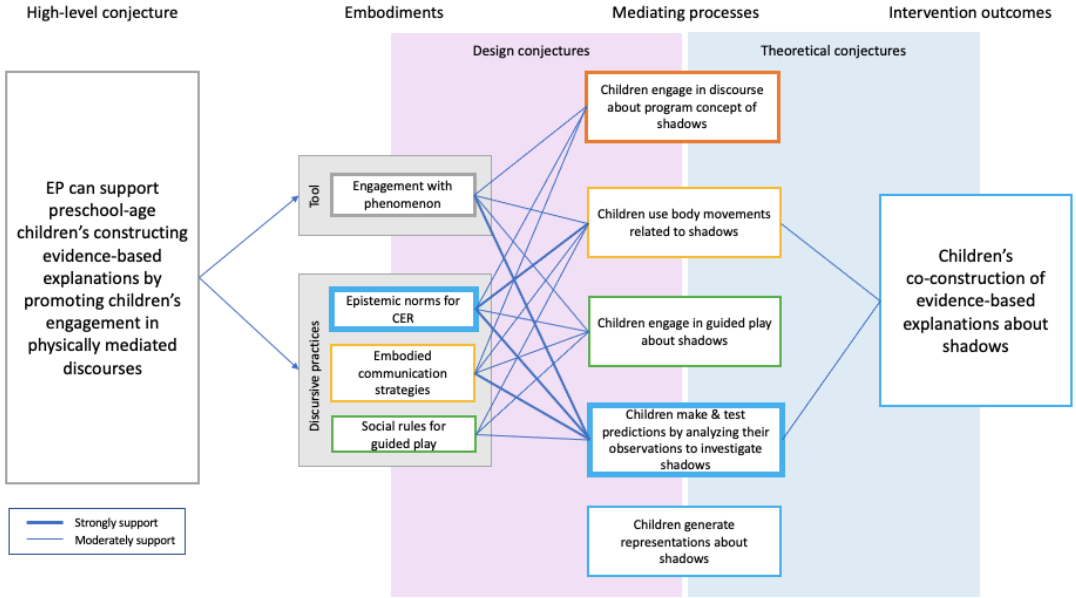

Figure **6-2**: The master conjecture map of the EP program

Overview of the SDEP and EP conjecture maps

Figure **6-1** and Figure **6-2** show respective master conjecture maps of the SDEP and EP programs. Both SDEP and EP programs were designed to support children's co-construction of evidence-based explanations, therefore the conjecture maps of SDEP and EP have the same desired outcomes. The SDEP and EP programs have similar high-level conjectures about how to support preschool-age children's construction of evidence-based explanations. The SDEP high-level conjecture articulates 'SDEP can support preschool-age children's constructing evidence-based explanations by promoting children's engagement in narratively and physically mediated discourses that centers the attention on the picturebook narrative' and EP high-level conjecture describes 'EP can support preschool-age children's constructing evidence-based explanations by promoting children's engagement in physically-mediated discourses.' These two high-level conjectures are quite similar except for narrative components and become reified in different ways through embodiments and mediating processes. In the EP program, there are no narrative elements in the embodiments because the narrative was not embedded in the program design nor are narrative features included in the two mediating processes about discourse. In the following section, I compare the design conjectures (Embodiments to Mediating Processes) and theoretical conjectures (Mediating Processes to Outcomes) of both the SDEP and EP master conjecture maps.

Design conjectures of the SDEP and EP programs

In the SDEP conjecture map, I found that narrative elements (*purpose*) and discursive practices (*epistemic norms for CER & embodied communication strategies*) are the most salient features in the embodiments to support the mediating processes that lead to co-construction of

evidence-based explanations. In the EP conjecture map, I found that epistemic norms for CER (discursive practices) is the most salient feature in the embodiments to support the same outcome. The strength of design conjectures in the SDEP and EP master conjecture maps, however, cannot be directly compared across the programs due to the differences in the nature of the program context. For example, the EP program has a smaller number of the embodiment features (tool, discursive practices) that affect the lines of different strengths in design conjectures.

Despite the differences in the nature of each program, epistemic norms for CER are the salient embodiment feature in both the SDEP and EP program. In both programs, this feature most strongly supports children's use of body movements and opportunities to make observations & testing predictions. In the SDEP program, epistemic norms for CER also strongly support discourse about conceptual elements from the narrative's purpose. Embodied communication strategies—the most salient feature in the SDEP and the second strongest feature in the EP—strongly support children making observations & testing predictions in both the SDEP and EP programs. These two salient features of the embodiments support various mediating processes. However, epistemic norms for CER and embodied communication strategies strongly supported children's engagement in discourse about conceptual elements in the SDEP program. In the EP program, epistemic norms for CER and embodied communication strategies moderately support children's engagement in discourse about conceptual elements. It seemed that the educator's questions for CER and her embodied strategies provided more opportunities for children to verbalize their thinking by engaging in discourse about the concept. Therefore, epistemic norms for CER are the most salient features in both the SDEP and EP programs that lead to mediating processes such as the use of body movements and making observations & testing predictions; but notably, epistemic norms for CER strongly supported children's engagement in discourse about conceptual elements only in the SDEP program.

Theoretical conjectures of the SDEP and EP programs

Diverse combinations of mediating processes facilitated children's co-construction of evidence-based explanations. Figure **6-1** (SDEP) shows six mediating processes of children's engagements in the program that were predicted to lead to children's co-construction of evidence-based explanations. Figure **6-1** indicates that the mediating process *children make observations and test predictions to investigate science phenomenon* strongly led to children's co-construction of evidence-based explanations. Four other mediating processes (*children engage in science-related discourse about conceptual elements from the narrative's purpose, children use body movements related to shadows, children engage in guided play about shadows,* and *children generate representations about shadows*) moderately led to the outcomes. The mediating process for *engagement in science-related discourse about narrative elements* rarely led to the outcomes. However, these six mediating processes should not be considered individually because they worked together in combination with one or more other mediating processes to support children's co-construction of evidence-based explanations. Although *making & testing predictions by analyzing their observations* have bold lines that strongly lead to the outcomes, other mediating processes were observed concurrently facilitating children's co-construction of evidence-based explanations.

Figure **6-2** (EP) shows five mediating processes of children's engagements in the program that were predicted to lead to children's co-construction of evidence-based explanations. Figure **6-2** indicates that *children use body movements related to shadows* and *children make & test predictions by analyzing their observations to investigate shadows* moderately led to children's co-construction of evidence-based explanations. Three other mediating processes (*children engage in discourse about program concept of shadows, children engage in guided play about shadows, and children generate representations about shadows*) rarely led to children's co-

construction of evidence-based explanations. However, these five theoretical conjectures (connecting mediating processes to the outcomes) should also not be considered individually as all five mediating processes happened together in combination with another one or more mediating processes. Although *the use of body movements* and *making & testing predictions by analyzing their observations* have solid lines that moderately lead to the outcomes, other mediating processes also have the lines that indicate their role in helping other mediating processes to support children's co-construction of evidence-based explanations.

To examine the interactions between the mediating processes, I analyzed video-data segments in *V-Note* vertically to identify when mediating processes were happening at the same time, supporting co-constructed evidence-based explanations. I analyzed the combinations of all mediating processes that led to the outcomes. Through this analysis, I generated three themes that explain how the mediating processes worked together in each phase (exploration, investigation, and reflection) from the SDEP and EP programs. The SDEP and EP programs have the same themes by representing combination of the mediating processes: (a) three mediating processes (children's engagement in science-related discourse about concept of shadows, use of body movements related to shadows, and making & testing predictions by analyzing their observations to investigate shadows) happened together, often producing co-constructed evidence-based explanations; (b) children's use of body movement, children's engagement in guided-play, and making & testing predictions by analyzing their observations happened together, often producing co-constructed evidence-based explanations; (c) children's engagement in science-related discourse about concept of shadows and children's generating representation about shadows happen together, often producing co-constructed evidence-based explanations.

Overall, the SDEP program conjecture map shows one salient mediating process (making & testing predictions by analyzing their observations) and the EP program conjecture map shows two salient mediating processes (use of body movement and making & testing predictions by

analyzing their observation*s*). This seemed to indicate that children's use of body movements played a more important role during the EP program in helping children's co-construction of evidence-based explanations. In the following section, I further elaborate on other potential differences between the SDEP and EP programs by focusing on the desired outcomes which in this study are co-constructing evidence-based explanations.

Potential differences between SDEP and EP programs

Both the SDEP and EP programs were designed to support preschool-age children's co-construction of evidence-based explanations. Figure **6-1** and Figure **6-2** show how the embodiments guide the mediating processes that lead to the desired outcomes represented by different strengths of lines. From the horizontal (over time) and vertical (at the same time) analyses of mediating processes, I examined which embodiments and mediating processes contributed the most to co-constructing explanations and how mediating processes worked together to support this outcome. In this section, I will delve into the desired outcomes to uncover potential differences in the SDEP and EP learning environments.

As children's opportunities to make claims and indicate evidence arise with the support of educator's CER questions, the educator's instructional strategies may be a central factor in program design that makes a difference in children's opportunities for constructing explanations. When the educator asked questions and provided prompts related to the science concepts, for example, children were encouraged to make claims and use evidence for constructing their explanations. When children constructed explanations, children often used their body movements in response to the educator's questions for CER because of the concept in spatial nature. Children's body movements are a way to externalize their thinking and communicate their ideas with others (Abrahamson & Lindgren, 2014); thus, it may be a central factor in children's

enactments to make a difference in children constructing explanations. Therefore, I investigated potential differences between the SDEP and EP programs by comparing educator's questions for CER (embodiment), children's use of body movements (mediating process), and evidence-based explanations (outcome).

Table **6-1** shows the average number of evidence-based explanations (both explicit and implicit), the educator's instances of using questions for CER, and the occurrences of explanations using body movements as a means to identify potential differences between the SDEP and EP programs. I calculated the average for each by counting explanations (explicit and implicit), use of epistemic norms for CER, and explanations in combination with children's use of body across all iterations then divided by the total number of times each program was offered (SDEP=3, EP=2).

Table **6-1**: The average number of explanations, educator's CER, explanations with use of body movements

	SDEP (3 iterations) M (SD)	EP (2 iterations) M (SD)
Evidence-based explanations	24.333 (4.497)	33 (8)
Explicit	14 (4.546)	13 (4)
Implicit	10.333 (3.999)	20 (4)
Educator's CER	41.333 (7.587)	54.5 (4.5)
The use of body movements	14.333 (4.784)	16.5 (4.5)

The number of explanations

Although the SDEP and EP programs show the same themes from their exploration, investigation, and reflection phases, I further investigate potential differences focusing on the

outcomes. Table **6-1** shows the average number of evidence-based explanations that children generated in the SDEP and EP programs. In the SDEP program, children engaged in co-constructing evidence-based explanations 24.333 times (SD=4.497) on average in each iteration; in the EP program, children engaged in co-constructing evidence-based explanations 33 times (SD=8) on average in each iteration. Therefore, the children in the EP program constructed more evidence-based explanations during the program on average, compared to the SDEP program.

The children gave two different kinds of explanations which were coded as explicit (claim with verbalized evidence) and implicit (claim with non-verbalized evidence). Young children's evidence may be *explicit* as they verbalize their evidence. Implicit explanations occurred when children used non-verbalized evidence. For example, during the investigation phase, the educator asked children to make their shadow scare the fish. The educator's question was coded as epistemic norms for CER. The children moved their bodies to make their shadow cover the fish while observing their shadow and the fish in the pond. When children made their shadow cover the fish, the children's body movements were coded as implicit explanations; that is, their body movements showed their claim in response to the educator's question as their evidence was not verbalized (implicit) but rather children were using observational evidence in the moment.

In the SDEP program, children constructed more explicit evidence-based explanations (M=14, SD=4.546) than implicit evidence-based explanations (M=10.333, SD=3.999) on average. In the EP program, children constructed more implicit evidence-based explanations (M=20, SD=4) than explicit evidence-based explanations (M=13, SD=4) on average. Perhaps the SDEP program did more to support explicit explanations than the EP program. In the following section, I further describe potential reasons for these differences in the number of explanations by focusing on the educator's epistemic norms for CER and children's use of body movements that lead to the explanations.

Differences between epistemic norms for CER

Children generated their claims as they answered the educator's questions and prompts about the phenomenon. They were able to provide evidence to support their claims to explain why and how the phenomenon occurs. The SDEP and EP programs were designed to encourage the educator's use of discursive practices, particularly epistemic norms for CER, to support children's engaging in the phenomenon, and provide opportunities to carry out investigations in ways that integrated other embodiment elements such as narrative elements or body movements. Educator's questions and prompts encouraging children to carry out the investigation may elicit children's generating claims, making observations, and engaging in co-constructing evidence-based explanations. Therefore, the educator's questions and prompts for CER may be highly related to opportunities for children to participate in constructing explanations.

The educator provided questions and prompts for CER an average of 41.333 times (SD=7.587) in each SDEP iteration and an average of 54.5 times (SD=4.5) in each EP iteration. More educator questions and prompts may lead to children's construction of explanations due to the opportunities for children to generate their claims and indicate their evidence from the investigation. Therefore, the greater number of children's explanations in the EP program may be related to the greater number of questions and prompts for CER. I closely examined the data to investigate why the educator provided fewer questions and prompts during the SDEP program than the EP program. During the SDEP program, the educator provided more descriptive questions and prompts that integrated narrative elements such as event-token and agency. In doing so, children were more playfully engaged in the investigation by acting like the Moonbear following narrative elements from the story. For example, the children who participated in the SDEP program sometimes acted like a bear in a pretend play; sometimes they acted freely not in response to the educator's CER questions. Therefore, the educators and the children in the SDEP

program spent more of the 30 minutes engaging in play and investigating the phenomenon to generate explanations as compared to the educator and the children in the EP program.

Differences between the use of body movements

Table **6-1** shows children in the EP program used more body movements (M=16.5, SD=4.5) than the children in the SDEP program (M=14.333, SD=4.784) while constructing evidence-based explanations. In the EP program, children used their body movements to represent their understanding of the concepts and communicate their ideas to the educator. In the SDEP program, children's body movements represented their understanding of the concepts by integrating narrative elements such as event-token and agency. The SDEP children used narrative-embedded body movements an average of 5 times in each iteration. When the educator provided CER questions related to the narrative elements (i.e., "can you make a shadow to scare the fish?") children used their bodies to make their shadows not cast over the fish by following the narrative elements (event-token, structure, agency). Following the narrative, the children sometimes took more time to construct evidence-based explanations because they enjoyed play acting like Moonbear and exploring imaginary play environments (i.e., moved a pond to other ponds to make their shadows scare every fish). Because the SDEP program spent more time using narrative-embedded body movements, which resulted in longer time spent constructing each explanation and thus the EP program had more time to spend on explanations, with the narrative elements.

Differences in participant's age

Prior research on children doing science (McNeill, 2011; McNeill et al., 2017; Zembal-Saul et al., 2013) suggests that children can develop complex explanations and argumentations in their elementary years. A few studies on young children (three years old to second grade) provide evidence of young children's capacity to engage in explanations and/or argumentation (Manz, 2016; McNeill, 2011; Varelas et al., 2008; Plummer & Rickett, 2018). Because of science explanations and argumentation, children may be capable of developing more complex explanations as they grow older. Therefore, children's age may generate differences in explanations.

The participants in the SDEP program were an average age of 3.636 years (n=22) and the children in the EP program were an average age of 4.045 years (n=22); in short, the children in the EP program were slightly older than the children in the SDEP program. As mentioned above, this age difference may be related to the children's engagement with the phenomenon and how they generated explanations during the program: more explanations were co-constructed in the EP program, where children were older on average, than in the SDEP program.

Although age may be a factor in the differences in children's constructing explanations in this study, more research is needed to determine whether age or the use of narrative has a greater effect on the outcome of a program designed to support evidence-based explanations. The difference in age of participants between the SDEP and EP programs poses a potential research limitation which will be discussed further in Chapter 7.

Chapter summary

In this chapter, I answered the research question about the comparison of SDEP and EP programs. The conjecture maps of the SDEP and EP programs show the salient embodiments and mediating processes differently. The EP program had one salient embodiment feature (epistemic norms for CER), and the SDEP program had four salient embodiment features (purpose, epistemic norms for CER, and embodied communication strategies). However, all embodiment elements promoted the same mediating processes but with different strengths. Therefore, the embodiments of the SDEP and EP programs support children's mediating processes that lead to the desired outcomes in similar ways. The SDEP program conjecture map shows one salient mediating process (making observations & testing predictions) and the EP program conjecture map shows two salient mediating processes (the use of body movements, making & testing predictions by analyzing their observations). The use of body movements may have a more important role in the construction of explanations in the EP program. In effect, the two master conjecture maps for the SDEP and EP programs, respectively, represent varying strengths of design conjectures and theoretical conjectures. Despite these varying connection strengths, both programs presented the same interactions between the mediating processes to support children's co-constructing of evidence-based explanations.

There are potential differences between the SDEP and EP programs in how they support children's construction of evidence-based explanations. During the program, EP program children constructed more implicit evidence-based explanations than explicit evidence-based explanations; SDEP program children constructed more explicit evidence-based explanations than implicit evidence-based explanations. Given these results, I identified how the educator's use of epistemic norms for CER, children's use of body movements, and children's age are three potential factors that may be related to these differences in constructing evidence-based explanations.

First, the greater frequency of educator prompts and questions in the EP program might be related to children constructing more evidence-based explanations in the EP program. In the SDEP environment, the educator provided fewer questions and prompts because the children were more engaged in play and imaginary experience. The children acted like the Moonbear and in turn, the educator took more time between prompts and questions to allow the children this experience within the same allotted time of 30 minutes for each program. While the results may be compelling that children in the EP program generated more evidence-based explanations, we must consider that children in the SDEP program more engaged as meaningfully or fully in playful moments.

The difference in children's use of body movements in the respective programs is the second significant factor contributing to their making of explanations. The children in the EP program more often used their body movements while constructing evidence-based explanations than children in the SDEP program. The EP children often used their bodies to generate claims with evidence as they took actions to show their claims in response to the educator's guidance and recognized evidence through their in-the-moment experiences with phenomenon. When these results are compared to the children in the SDEP program, we see that the EP children were making more implicit explanations—that is, using non-verbalized evidence—when the SDEP children were making more explicit explanations using verbalized evidence. In the SDEP program, narrative elements (e.g., event-token, agency) were deeply embedded in the children's body movements to represent their understanding of the phenomenon because narrative was integral to the design of the program. This narrative-driven design coupled with the use of body movements in the SDEP program provided an agent for children to follow the picturebook's narrative and explore the nature of the shadow phenomenon. Although children in both the EP and SDEP program used body movements when making explanations, the SDEP children were

able to make explicit explanations through interanimation of their body movements with narrative elements.

Finally, the difference in age between the children in the EP and SDEP program poses a limitation to what we are able to interpret about children's construction of explanations. On average, the children in the EP program were older than the SDEP children. While research suggests young children's capacity for making complex explanations exists but increases with age, the difference in children's age between the EP and SDEP programs in this study might suggest that the EP children are more capable to make explanations because of their age. However, because the age of the participants in each program was different, we are not able to make such conclusions as the age of children as a factor in their making explanations does not also account for the different learning environments. In other words, because the focus of this study is to consider the effects of different learning designs on children's construction of explanations, children's age is a limiting factor in this research of what we can interpret as the children were not the same age in both EP and SDEP environments.

The most pronounced differences between the SDEP and EP programs were revealed through comparison of how and why children constructed evidence-based explanations. These differences between the SDEP and EP programs were best explained by the presence of narrative elements embedded in the SDEP program design. When I closely examined the data focusing on evidence-based explanations with direct factors (epistemic norms for CER and the use of body movements), the narrative in the SDEP program seemed to be an important factor that affects the occurrences of children's explanations, educator's CER questions, and children's body movements. Therefore, in chapter 7, I further investigate the role of narrative and how narrative intersects other key factors such as embodiment and play from various theoretical perspectives. Then, I suggest implications for instruction of the story-driven embodied play for preschool-age children.

Chapter 7

Discussion

The purpose of this study was to investigate how narrative, embodiment, and play intersect to support preschool-age children's co-construction of evidence-based explanations. This chapter will discuss how narrative theory, embodied cognition, and play theory do more to explain preschool-age children's science learning than what each theory can explain alone based on evidence from the results of studies of the SDEP and EP program presented in chapter 5 and chapter 6. I will expand on these results using narrative theory, embodied cognition, and play theory literature by emphasizing how these three theoretical perspectives might help explain preschool-age children's science learning by focusing on constructing evidence-based explanations. Further, I discuss implications for the fields of early childhood education and science education and future research work centered on narrative, embodiment, and play for other disciplinary areas.

The pedagogical functions of narrative, body movements, and play

In chapter 5, I investigated the pedagogical functions of narrative, body movements, and play that showed evidence of supporting children's co-construction of evidence-based explanations in the SDEP programs. In this section, first, I present the findings of the second research question by focusing on the second theme that represents how narrative, body movements, and play happened together in the learning environment to support children's construction of evidence-based explanations. There were three phases of the SDEP program: exploration, investigation, and reflection. In particular, the investigation phase was the only phase

that demonstrated how the three pedagogical functions interacted in the learning environment. I found that children's use of body movements, children's engagement in guided-play, and making observations & testing predictions to investigate a science phenomenon happened together, often producing co-constructed evidence-based explanations. Applying this result, I present how the three pedagogical functions interact with each other to support children's co-construction of evidence-based explanations by providing evidence with other theoretical literature.

In the SDEP program, the narrative was guiding children's learning moments—their use of body movements, engagement in guided play, and engagement in science practices—and supported children's constructing explanations. By following the narrative from the *Moonbear's Shadow*, children engaged in diverse learning processes in combining narrative elements. Children's body movements and guided play also reproduced narrative elements such as event-token and agency that encouraged children to engage in doing science in meaningful ways. Prior research on story-based learning indicates that stories can engage children with science by making concepts more meaningful and relatable (Avraamidou & Osborne, 2009; Murmann & Avraamidou 2014). In the SDEP program, children's narrative-based body movements (acting like Moonbear to solve shadow problems) and narrative-driven guided play (including narrative elements as learning resources) promoted children's engagement in science practices (observing and testing their shadow) and supported together children's learning science in relatable ways. Thus, narrative plays a critical pedagogical role in prompting and promoting how children physically engage (embody) with and in guided play about science phenomena which lead to investigations and sense-making.

Use of body movements was a central way for children to externalize thinking and communicate ideas in the SDEP program. During the guided play, children often used their bodies to make their shadows in response to the educator's questions inspired from the narrative ("can you make your shadow scare the fish?") without verbal language. Researchers in childhood

education argue that bodily actions play a central role in developing language and abstract thinking (Piaget, 1968; Vygotsky, 1962). The use of body movements in the guided play can be considered as a way of children's multimodality (Siry & Gorges, 2019; Siry et al., 2012). Therefore, body movements play an important pedagogical role in extending children's multimodality and their abstract thinking in narrative-driven guided play.

Guided play characterizes complex and dynamic learning moments that provide numerous opportunities for children to actively engage in doing science. In this study, the guided play driven by the narrative provided opportunities for children to discover the concept of shadow in a playful learning environment. The setting for guided play included narrative elements—a fish in the pond and tree—in combination with the educator's guidance which provided an authentic opportunity for children to experience narrative, body movement, and play together in doing science. With the educators' guidance, children explore the world with their natural curiosity and active engagement that lead to "sense-making processes" (Fisher et al., 2012). In other words, the educator's guidance provides scaffolding for children's natural curiosity to apply to investigating and making sense of science phenomena. Thus, the guided play learning environment in the SDEP program supported children's use of body movements to construct explanations while actively engaging in the phenomenon about the shadows.

While there is an extensive and rich body of scholarship that indicates potential beneficial relationships between narrative, body movements, and play in young children's science learning, little has been done to investigate the effects of integrating these three pedagogical strategies into developing learning resources and environments (Danish et al., 2015; Murmann & Avraamidou 2014). Overall, the results of the SDEP program provide promising evidence of narrative, body movements, and play as pedagogical elements that work together to support preschool-age children's science learning.

Comparing SDEP and EP: narrative as central integrated learning environment

To identify the role of narrative in embodied guided play environments and understand the importance of body movements and guided play, I compared the SDEP and EP programs through analyses of conjecture mapping and children's co-construction of evidence-based explanations. In presenting the differences and similarities between the SDEP and EP programs in this section, I illustrate how such a comparison reveals the role of narrative in learning environments and the importance of an integrated learning environment that connects and features body movements and guided play. From conjecture map analysis, the SDEP and EP program conjecture maps show different salient features in the embodiments and mediating processes. In the SDEP program, narrative elements of purpose, epistemic norms for claim-evidence-reasoning (CER), and embodied communication strategies were the most salient features in the embodiments. In the EP program, epistemic norms for CER were the most salient feature. These differences in the embodiments led to different patterns in mediating processes. However, the most salient feature of the mediating processes, making observations and testing predictions, was the same in both the SDEP and EP programs. As a result of comparing programs designed with and without narrative, I found that guided play combined with the opportunity to use body movements to investigate a science phenomenon will still provide opportunities for children to make sense of science concepts. Further, the conjecture map analysis did not provide notable evidence that adding narrative to the design produced differences in the processes leading to how children co-constructed evidence-based explanations.

I analyzed children's explanations in the SDEP and EP programs to investigate potential differences between these two learning environments. The results from the study show that children in the EP program constructed more evidence-based explanations than the children in the SDEP program. As the children's explanations were constructed in response to the educator's

questions and prompts, this finding suggests that the EP children may have constructed more evidence-based explanations because the educator asked more CER questions as compared to the instances in the SDEP program. Children engage in science practices, such as using evidence from observations, and explain why and how the science phenomena occur (McNeill, 2011) through constructing explanations by answering educator's questions and investigating science phenomena as "discourse-in-interactions" (Siry et al., 2012). In the SDEP program, the children constructed fewer evidence-based explanations during the program. Compared to the EP program, SDEP educator's questions and prompts were more descriptive and the children engaged in guided play like pretend and imaginary play such as acting like a bear and exploring narrative-based resources; as a result, the children and the educator took more time to co-construct evidence-based explanations while investigating the science phenomenon which resulted in fewer explanations during the same length program.

What this comparison of the SDEP and EP programs reveals is that although there are salient differences between the embodiments and mediating processes between the two programs, the two programs supported learning in similar ways by providing meaningful opportunities for body movements and guided play and limited differences could be teased out in respect to the role of narrative. As previously stated, the purpose of the comparison was to determine the effects of narrative on the learning outcomes. While there were limited differences in narrative's effect on children's construction of evidence-based explanations, in the SDEP program, narrative assumed an authentic role in that the children used narrative elements to reproduce the narrative in their learning moments. This "reproduced" narrative augmented children's engagement in the learning moment with "a greater degree of behavioral self-control in the play context" (Duncan & Tarulli, 2003, p. 277) —that is, children exhibited self-awareness (Fleer, 2011) in play through narrative when they tried "not to scare the fish" in their learning environment. Therefore,

narrative in the SDEP program played an essential role in encouraging children's best performance by managing their prolonged attention to and stimulating imaginary play context.

The comparison revealed that both SDEP and EP programs offer evidence that supports the importance of play with educator's guidance for young children's science learning and their construction of evidence-based explanations. This supports existing research arguing for the importance of facilitating and maximizing the advantage of play for preschoolers. Thus, we need to consider more specific ways educators can support the quality of play and elevate its primary role at the preschool age. The EP program was designed without narrative but still involved the educator's subtle guidance including questions and prompts to support preschoolers' constructing explanations in the play context. In addition, the opportunity for children to use their bodies to figure out the relationship between the light and shadow supported their understanding of the shadow. Therefore, embodiment and guided play are crucial in children's understanding of science phenomena; the integration of body movements with guided play appears critical for these outcomes in both SDEP and EP programs.

Preschoolers' science learning through three theoretical lenses: narrative theory, embodied cognition, and play theory

This dissertation study investigated three theoretical lenses of narrative theory, embodied cognition, and play theory to uncover how these three theories can be applied to explain young children's science learning in designed learning environments, the story-driven embodied play (SDEP) and embodied play (EP) programs. In this chapter, I answer my first research question: *How and to what extent does the combination of narrative theory, embodied cognition, and play theory do more to explain preschool-age children's science learning in ways that go beyond what each theory can explain on its own?* To answer this question, I use narrative theory (Bakhtin,

1986; Chatman, 1983; Norris et al., 2005), embodied cognition (Abrahamson & Lindgren, 2014; Alibali & Nathan, 2012; DeSutter & Stieff, 2017; Wilson, 2002) and play theory (Fisher et al., 2012; Vygotsky, 1987) together as a theoretical lens to investigate how these three theoretical perspectives can explain children's co-constructing evidence-based explanations by providing evidence from the story-driven embodied play learning environment.

Embodied cognition in the SDEP program: body-based in social interactions

Embodied cognition framework can explain children's learning as a body-based interaction (Abrahamson & Lindgren, 2014; Alibali & Nathan, 2012; DeSutter & Stieff, 2017; Wilson, 2002). From this perspective, students shape their understanding through gestures and body movement to make sense of the world (Abrahamson & Lindgren, 2016; Newcombe, 2016; Wilson, 2002). Embodied actions show students' ways of representing and shaping thinking by externalizing their thinking through gestures and body movements (Alibali & Nathan, 2012; DeSutter & Stieff, 2017). Embodied action becomes a mediator with which students interact with facilitated learning environments to develop their thinking (Abrahamson & Lindgren, 2016). This understanding of embodied cognition is a theoretical lens that undergirds this study to define children's learning while engaging in the SDEP program.

According to embodied cognition framework, use of gestures and body movements help children shape their understanding to make sense of shadows in their interactions with the environment (Abramson & Lindgren, 2016; Newcombe, 2016). In the SDEP program, the children used their bodies to externalize their understanding of the relationship between the Sun and shadows by investigating the phenomenon (Wilson 2002). These body-based learning opportunities may help children develop cognition and mental processes to represent and shape their thinking of the concept (Alibali & Nathan, 2012; DeSutter & Stieff, 2017). During the SDEP

program, children as well as the educator seemed to have taken advantage of using their bodily actions as a model in the learning environment to represent spatial information of the relationship between the location of the light and shadow (Wilson, 2002). An example of this was seen during the investigation phase when the educator asked the question, “can you make a shadow not scare the fish?” In response, the children moved their bodies while observing their shadows with the lamp to make their shadows not cast over the pond. The bodily actions helped children engage in science investigation through their bodies to figure out the relationship between the Sun and shadows.

The use of body movements helps children communicate their ideas through interaction within the learning environment (Abrahamson & Lindgren, 2016). During the SDEP program, the educator provided guiding questions for children to encourage them to use gestures (pointing and iconic) and body movements to make their shadows. Their body movements and gestures connoted spatial language—even though they were not verbalized—such as deictic terms (here, there), dimension (long, short), and spatial orientations (“in front of us”, “move this way”) (Ferrara et al., 2011). Therefore, the educator’s and children's use of body movements can be explained by embodied cognition framework that helps us understand how children learn through bodies in shaping and communicating their ideas within the resource-rich learning environment.

The resource-rich environment can support children’s learning through body movements. According to embodied cognition, students need guidance on how to use their bodies to interact with the learning environment and how to reflect their embodied thinking. “Students will often need guidance to take actions and move their bodies in ways that simulate the core mechanism and spatial relations” (Abrahamson & Lindgren, 2014, p. 7). The SDEP learning environment, which features story-driven guided play, is an advantageous learning environment for young children to use their bodily actions to learn spatial concepts in guided play. Children investigate learning resources through their bodies, narrative-based resources (tree, fish in the pond), and

educator's guidance referring to narrative and their agent. The educator provided embodied guidance on how to use their bodies to figure out the spatial phenomenon by asking spatial questions and co-playing with children using bodily actions. Therefore, children's learning engagement in the SDEP program can be explained by embodied cognition framework that helps us comprehend how children learn through their body movements and interact with learning resources using their bodies.

Play theory in the SDEP program: guided play in sociocultural perspective

In the field of early childhood education, researchers generally agree on the following principles of play: (a) play is self-directed; (b) play is exploratory and active; (c) play is social interactions or communication; (d) play is process-oriented; (e) play is guided by mental rules that leave room for creativity (Gray, 2017; Rubin, 1983; Saracho & Spodek, 2003). The playful learning in the SDEP program can be explained by these play principles. The SDEP program was designed to be children-centered by providing opportunities for children to actively engage in the science investigation through play. In the program, the children explored the concept of shadows with the educator's guidance in the play context. The educator and children had a shared goal during the play to figure out the shadow problems as Moonbear from the narrative; this shared goal was process-oriented and embedded in their discourse (Siry et al., 2012). The narrative-driven guided play in the SDEP program allowed children to engage in the science investigation and science-related discourse as well as provided opportunities for children to discover the phenomenon with their creativity in play context.

From sociocultural perspectives, play can be understood as "occurring within and influenced by, a child's social and cultural context" (Sliogeris & Almeida 2019, p. 1570). Vygotsky (1967) asserted that "the child moves forward essentially through play activity" (p. 16).

Because play allows children to engage in activities that draw on everyday experience, play can also provide opportunities for children to develop understandings of concepts that transfer from their everyday knowledge and experience, such as science concepts (Sliogeris & Almeida, 2017; Vygotsky, 1987). This study aligns with these sociocultural theoretical perspectives of play and is employed to interpret children's learning while they engage in the SDEP program. In the story-driven embodied play in the program, children brought their everyday knowledge of shadows from either their previous experience or *Moonbear's Shadow* book into the play context and easily transferred their knowledge to the science concept through the educator's guidance.

In essence, the SDEP program was designed to integrate a play-based environment—which considers play as socially and culturally relevant to children's learning—with guidance from the educator to cultivate guided play as a pedagogical approach. Guided play is a discovery-based learning approach intermediate between direct instruction and free play (Fisher et al. 2012; Weisberg et al., 2016). During guided play, children are free to choose the best way to carry out their capabilities and inquiries with adults' guidance. In the SDEP play-based learning environment, guided play enabled children to engage in play using narrative elements introduced by the *Moonbear's Shadow* book and reinforced by the educator (e.g., the character, a pond with fish, a tree, etc.). In this way, guided play cultivated opportunities for children's play actions and body movements to demonstrate an emerging understanding of science concepts. Children acted like Moonbear using narrative-based materials through interactions including body movements and discourse; and, their engagements in the play could not be transferred to science learning as constructing explanations without the educator's guidance such as asking questions and prompts and encouraging making observations during the playful investigation. In addition, the essential principles of play (self-directed, exploratory and active, social interactions, process-oriented, and creativity) cause intrinsic rather than extrinsic motivational characteristics in learning (Duncan & Tarulli, 2003; Fisher et al., 2012). Guided play in the SDEP program promoted children's creative

ways of investigating shadows with the educator's questions and prompts by maintaining child-centered learning. Thus, guided play is a useful lens to understand how children developed their conceptual understanding with motivation in play-based learning experience by the educator's guidance.

Narrative theory in the SDEP program: science explanations as narrative

The theoretical framework of narrative is outlined in this dissertation in two ways: narrow and broad views. A narrow view of narrative theory which is narrative elements (Norris et al., 2005) help us to identify features of narrative and how narrative elements support young children's co-construction of evidence-based explanations. A broader view of narrative theory, which is Chatman's narrative communication (1978) and Bakhtin's narrative responsivity (1986), provides a perspective on how narrative moves through discourse between children and the educator and how narrative is reproduced in the learning moments. I offer these three theories as the core narrative framework for this dissertation because these three theories can explain which narrative elements from the children's picturebook play an essential role in constructing explanations and how narrative promote children and the educator's engagement in the process of constructing explanations in science education.

Norris and colleagues (2005) suggest eight narrative elements: event-tokens, narrator, narrative appetite, past time, structure, agency, purpose, and readers. They argue that these elements have a hierarchy of importance and shape degrees of narrativity; the existence of event-tokens, past time, and agency is of primary importance and other elements (narrator, narrative appetite, structure, purpose, and reader) are of secondary importance in shaping degree of narrativity. In this dissertation, I take four of these eight narrative elements —event-token, structure, agency, and purpose—because I focus on how narrative elements are used in the

learning context rather than limited to written text of the picturebook. In the SDEP program, the children engaged in narrative-based guided play by using narrative elements (i.e., event-token, agency) in their verbal and non-verbal expression to communicate their understanding. The narrative elements that children used in the investigation were provided by *Moonbear's Shadow* book. Norris and colleagues (2005) believe that the existence of event-tokens, past time, and agency is of primary importance because these elements show "particular occurrences involving particular actors in the past and over time" (p. 544). In the investigation phase of the SDEP program, the children engaged in the narrative moments with particular occurrences (event-tokens) by acting like Moonbear (agency). This learning moment shows the primary importance of narrative elements (event-token and agency) as well as other narrative elements (structure and purpose) that increase the degree of narrativity and the purpose of the program.

In the program, children constructed evidence-based explanations using narrative elements in their explanations. For instance, the children developed a claim using their bodies to move close to the pond to make their shadow cast a fish on the pond in response to the educator's guiding question, "can you make a shadow scare the fish?" In this moment, children's body movements represented their claim about shadow cast on the fish and their observation of the shadow represented their evidence for their claim. These series of children's agents fully represented narrative explanations. Norris et al. (2005) describes that the characteristics of narrative explanations "explain an event by narrating the events leading up to its occurrence" (p.550). Because of children's age level, the explanations were simple (few words) or not fully spoken (sometimes their explanations combined with their body movements), but the process of constructing explanations included narrative events from the story that led to children's investigation of science phenomenon.

Narrative from the picturebook provides *narrative effect* in the SDEP program. The SDEP program was designed to use a children's picturebook about shadow. There is research on

genre of text in teaching and learning and several literatures argues that narrative text can generate *narrative effect*—which means to improve memory for content, enhance interest in learning, and increase comprehension compare to expository and argumentative prose (Graesser, 1981; Zabrucky & Mooer, 1999). There are some reasons why narrative effect is generated in learning context; expository and argumentative text, for example, tend to be more difficult than narrative texts because of greater vocabulary and less familiar structure. However, narrative usually includes aspects of human experience around us. In addition, narrative is the genre that is used fundamentally for teaching reading in literacy education because school students are familiar with how to interpret the genre compared to other genres (Bamford, Kristo, & Lyon, 2002; Grasser, Golding, & Long, 1991). In the SDEP program, children listened to the *Moonbear's Shadow* story during the read-aloud time, and its narrative genre was an entry point for the SDEP program. The narrative from the picturebook guided children's enactments and was used as a tool with which the educator encouraged children to engage in to investigate the phenomenon across the program. In the investigation of the SDEP program, narrative elements generated *narrative effect*—the comprehension and retention through narrative (Norris et al., 2005) —to improve children's understanding of the relationship between the location of the light and shadow, without greater vocabulary load, as well as improve their concentration for the program by following narrative.

Narrative theory from Chatman's (1978) perspective can explain how narrative moves around and is reproduced in learning contexts. The use of narrative in this dissertation aligns with Chatman's use of *story*, which he used to refer to story that included narrative elements. Narrative theory from Chatman's (1978) perspective is useful to explain how narrative moves around and is reproduced in learning contexts. In his narrative theory, Chatman considers narrative as functioning as a system comprised of stories and discourse. Within this system, a narrator (speaker/educator) and a narratee (listener/student) communicate in ways that go beyond the

individual elements of a narrative to negotiate meaning/understanding (Norris et al., 2005). Although I use the term "narrative" in the same way Chatman uses "story" to refer to the contents of the *Moonbear's Shadow* book, I use Chatman's narrative theory to explain how narrative (*Moonbear's Shadow*) transmits through discourses between the educator and children including verbal and non-verbal language to support children's science learning. Chatman (1978) developed a model of narrative communication to explain how narrative transmits from written text to real readers (in the top portion of Figure 6.1). The model illustrates a narrative text composed by the real author who produced the implied author in the narrative text. The implied author, generally, is a subset of the real author's capacities and is a version of the real author in the text. The implied author is more related to the text-based narrative. Chatman's model includes the narrator as the agent who delivers the narrative to the narrator. The narrative transmission in Chatman's model shows a one-way transmission between the author and reader.

In the SDEP program, the educator played the role of narrator who read *Moonbear's Shadow* picturebook during the read-aloud time. Then, as the narrator, the educator also used narrative (event-token and agency) to provide questions and encourage children's engagement in the investigation phase of the program. During the investigation phase, children reacted to narrative-based questions and prompts within the narrative-driven learning environment by taking their agency as Moobear who wants to figure out the shadow problem. While engaging in the narrative-based learning environment, the children reproduced the narrative through their language and/or body movements by interacting with the educators and narrative-based learning environment. Therefore, children have agency as narrators who generate narrative in this context. This narrative theory perspective characterizes a third theoretical lens in this study to interpret how narrative transfer between narrator and narratee in the SDEP program.

Based on these learning enactments, I revised Chatman (1978)'s six-part model of narrative communication (Figure **7-1**) by including another layer of the investigation phase of the

SDEP program (see the green box in the bottom portion of Figure **7-1**). The green box represents the read-aloud phase in which the educator reads *Moonbear's Shadow* picturebook to the children. The children acted as narratees in the read-aloud phase, but they were narratees (receive the questions based on event-token) who were also agents when they acted like Moonbear to figure out the problem drawn from the narrative. Therefore, Chatman's narrative theory explains the children's learning in the SDEP program in that the children and educator's science-related discourse interacts within the learning environment through use of narrative elements from the picturebook.

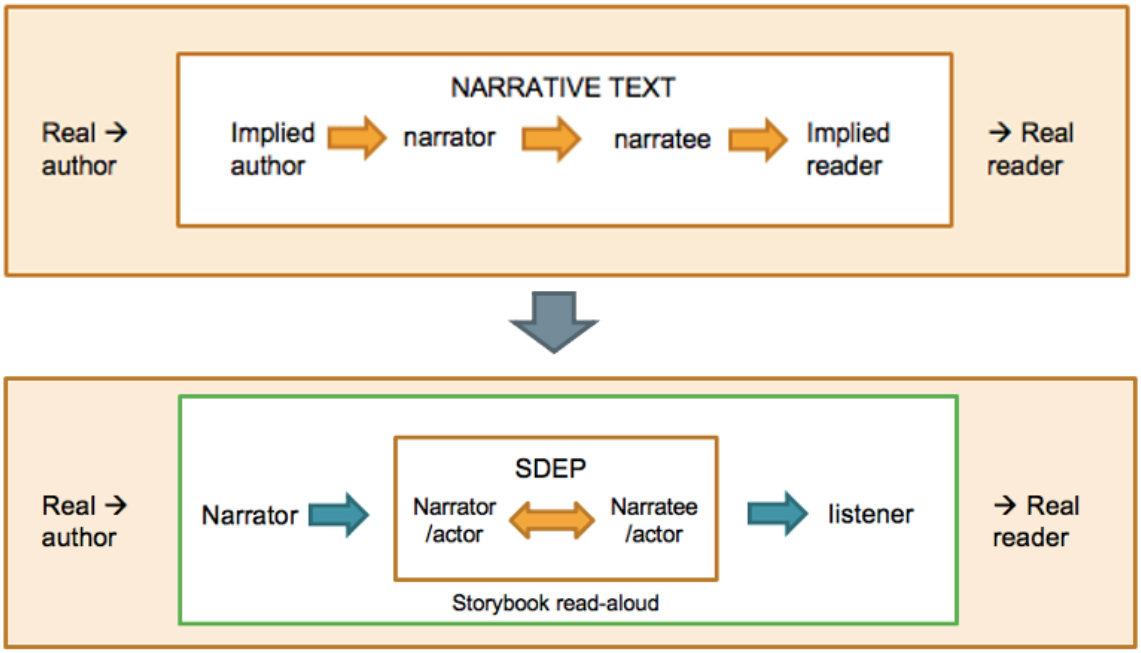

Figure **7-1**: Chatman's six-part model of narrative communication (top) and the revised Chatman's six-part model of narrative communication (bottom)

Bakhtin's concept of *responsivity* in narrative theory can also help to explain children's learning in the SDEP program. Bakhtin suggested the notion of "responsivity," which applies to both the educator and children; to understand each other, both speaker and listener must "perceive and understand each other's words" (Bakhtin, 1986, p. 68). In this SDEP program, the narrative from the book may enhance responsivity between the educator and children. The educator

introduced the activity and the setting to orient children to the guided play of acting like Moonbear from the picturebook. After that, children often engaged in the investigation without any questions about the context of the program. It may be that the narrative from the book became shared information of the concept of the shadow and knowledge of their environment to children and the educator; this shared and familiar information drawn from the picturebook may reinforce their science-related and goal-oriented discourse for both the educator and children (Bakhtin, 1986). Thus, the shared narrative from the picturebook enabled both the educator and children to engage in diverse mediating processes such as use of body movements like Moonbear to solve the shadow problem that supported co-constructing evidence-based explanations during the program.

Bringing together narrative theory, embodied cognition, and play theory to explain science learning

The discussion above points to evidence of how these three theories can be applied to explain preschool-age children's co-construction of explanations in the SDEP program. In this section, I turn attention to specifically how together these three theories explain preschool-age children's science learning in ways that go beyond what each theory can explain on its own. In other words, although these three theoretical perspectives individually shed light on specific parts of learning moments observed in the program, when these three theories are considered as integrated or working together, we can expand our understanding of preschoolers' science learning. For example, during the investigation phase of the SDEP program, children engaged in three mediating processes simultaneously: use of body movements, engagement in guided-play, and making observations & testing predictions to investigate a science phenomenon. What emerges from the simultaneity of these mediating processes is young children's co-construction

of evidence-based explanations that necessarily need to be understood through an integrated theoretical perspective of narrative theory, embodied cognition, and play theory. In this section, I describe how together these three theories can extend our understanding of preschoolers' construction of evidence-based explanations in science learning.

What is significant from this discussion is how the three theoretical underpinnings of children's science learning can come together and in doing so expand our views of young children's science learning in a specific learning environment design. When I analyzed the SDEP program through each theoretical perspective, it was clear that each theory can only explain a specific part of learning. Narrative theory explains how narrative integrated in science investigation and the learning environment affected children's engagement in science practices that led to construction of explanations; specifically, individual narrative elements (Norris et al., 2005) —event-token, agency, structure, and purpose—encouraged children's engagement in narrative-driven investigation. These narrative-driven experiences might generate narrative effects by sharing ideas easily and improve their comprehension without a heavy explanatory discourse. However, this perspective provides limited insight to how mental processes about shadows actually happened in children's minds that supported children's construction of explanations. Because narrative theory was not able to fully explain how children figured out the shadow problem as spatial in nature by using their body movements during the investigation, I use embodied cognition to understand how children shape their thinking and represent the concept of shadows. Embodied cognition, however, was not able to fully explain the motivation and driving forces of why children engaged in embodied actions in response to the educator's guidance. Children's body movements are tools to represent children's conceptual development as processes but without guidance, children might not purposefully use their body to develop conceptual understanding of shadows. Play theory explains children's active engagements in the program and how children were supported through play-based learning; however, play theory

does not extend to considering how children's mental processes were actually guided and encouraged in play-based learning for understanding science phenomenon and construction of evidence-based explanations. Therefore, we need embodied cognition to fully explain children's understanding and development of science phenomena in the play-based learning environment. I expanded Figure **2-1** by adding evidence of learning occurrences between two theories in the program. Figure **7-2** shows how three theoretical perspectives related to each other in the SDEP program and explains what I defined as preschooler's science learning using theoretical perspectives.

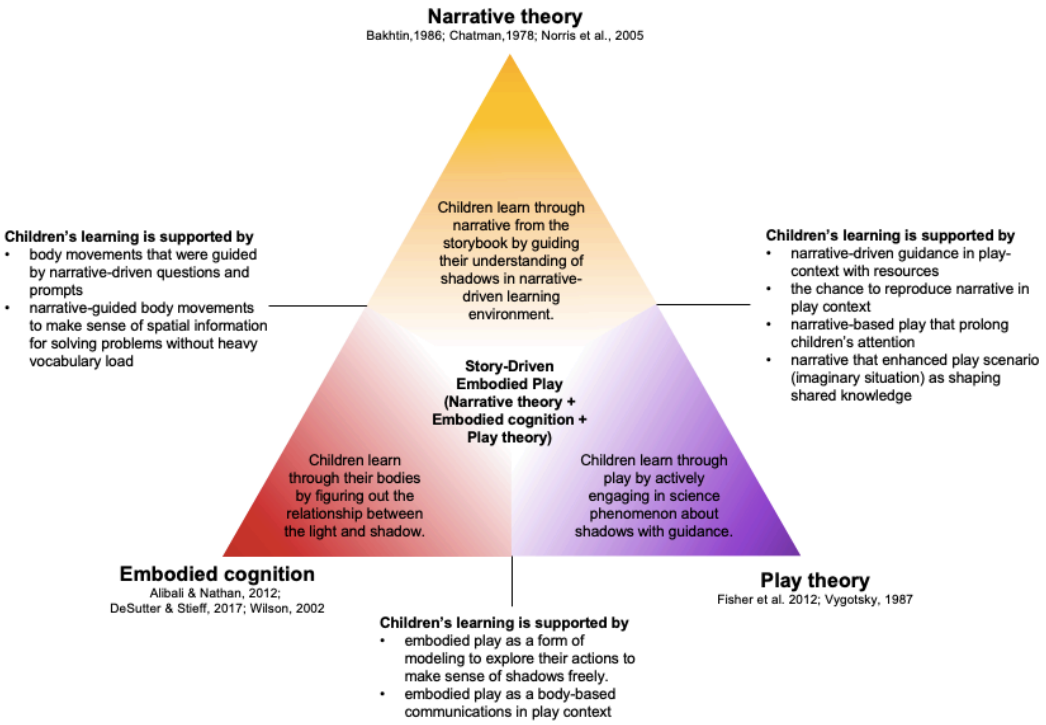

Figure **7-2**: The relationship between narrative theory, embodied cognition, and play theory in the SDEP program

In the investigation phase of the SDEP program, children engaged in story-driven embodied play in response to the educator's guiding questions drawn from the picturebook narrative. The children moved their bodies to figure out the relationship between the light and

their shadows by acting like Moonbear and engaging in the same challenge Moonbear experienced. Using narrative theory to understand this learning moment, I only understand the role of narrative in which narrative elements (event-token, agency, structure, and purpose) promoted children's engagements in science investigation. In addition, children adapted narrative from the picturebook and acted like Moonbear and reproduced the narrative by themselves. While sharing narrative context about *Moonbear' Shadow* story, the educator and children easily communicated their ideas and constructed explanations using their observations. When I add embodied cognition to understand this learning moment, I can further understand how children investigate the shadow by making observations and testing their predictions using their bodies to represent their spatial understanding of shadows. Based on their body-based investigation, children developed claims and indicated evidence to construct evidence-based explanations. Play theory adds a final dimension to develop a holistic view for story-driven embodied play learning that can explain how children were motivated and socially supported through play-based learning in constructing explanations. I recognized that the children and the educator in the SDEP program took more time to co-construct evidence-based explanations while joyfully investigating the science phenomenon through narrative-driven imaginary play which resulted in fewer explanations compared to the EP program. What this perspective offers—bringing narrative, embodiment, and play theories together—is an understanding that narrative is useful in guiding children's understanding of science phenomenon when it is purposefully integrated with and supported by guided play and embodied cognition in specifically designed learning environments.

By using the three theories together, I can explain young children's conceptual understanding of shadows through science investigation and also explain children's social-emotional development in terms of social interactions, agency, and motivation in learning (Bustamante, White, & Greenfield, 2018; Larimore, 2020). In domain-specific science learning, embodied cognition provided a theoretical understanding of how children figure out the

relationship between light and shadows using their bodies as models in the learning environment. Given the sociocultural aspects of science learning, play theory provided a theoretical understanding of how preschool-age children were guided and motivated in science learning through their embodied actions and embodied thinking. Narrative theory provided a perspective on how narrative is integrated in an embodied play environment as a catalyst for communication between the educator and children in the SDEP program. Therefore, the integration of three theoretical perspectives is significant in two ways: First, we can understand how learning environment designs that combine narrative, embodiment, and play contribute to children's meaningful engagements with science phenomena in their science learning. Second, this understanding points to opportunities for expanding our thinking about how young children experience science in ways that are bodily, social, and connected to their everyday experiences with the world and stories they hear about the world. Taken together, the theoretical discussion above offers a holistic view of how a program design using narrative, embodiment, and play together supports young children's meaningful experiences in science learning.

Implications

In this section, I discuss recommendations for early childhood educators in science based on the finding from this dissertation. From this study, I found that narrative, body movements, and play are essential pedagogies in young children's science learning: Narrative in children's literature promotes active engagements for children to act like the main characters; Embodiment supports multimodal interactions by providing opportunities to figure out science phenomenon using body movements; play, especially guided play, provides a play-based learning environment that can support science learning by including both joyful moments and the educator's guidance. These three pedagogical functions of narrative, embodiment, and play worked together to support

young children's constructing explanations in both the SDEP and EP programs. The EP program supported young children's active engagement in science learning by providing opportunities to use their bodies during the guided play even though the design did not include narrative. In the SDEP program, children reproduced narrative in their learning by using narrative elements which were learning opportunities that the EP children did not have in the program.

From these results, I first recommend that science educators in early childhood plan science instructions that use narrative, body movements, and guided play as essential pedagogical strategies to support children's maximal agency in investigating science phenomena. According to the dialectical relationship between structure and agency in learning (Sewell,1992; Siry & Max, 2012; Varelas et al., 2015), narrative, body movements, and guided play can enhance this relationship; in turn, guided play provides a structure that can mediate children's enactment in learning. In particular for constructing evidence-based explanations, the educator's CER questions are essential for children to generate claims and indicate evidence. The educators' guidance can be embedded in play (Fisher et al., 2010). Educators can also support children's active engagement by encouraging the use of body movements which will provide children with agency to engage in interactions in multimodal ways (Siry & Gorges, 2019). Narrative can also be used for instruction design. Narrative-based learning can provide a structure in which children can develop and employ self-awareness (Fleer, 2011) and self-control (Duncan & Tarulli, 2003) while engaging in narrative-based learning. Children's reproduction of narrative in the SDEP program for this dissertation study has implications for narrative-based learning designs to facilitate children's changing roles as both active narrators and engaged naratees. Therefore, a learning environment that integrates narrative, body movements, and play can support young children's co-constructing evidence-based explanations by supporting agency and structure in learning.

Second, I recommend that as part of an integrated learning design, educators can operationalize spatial language in their science instruction as my findings suggest that children's use of body movement includes engagement with and use of spatial language which affects their understanding of spatial concepts. In the SDEP and EP programs, children engaged with a science phenomenon about shadows, which is a spatial concept concerning a relationship between objects and the Sun. While interacting with the educators in the learning environment, children's body movements connoted spatial language—even though they were not verbalized—such as deictic terms (here, there), dimension (long, short), and spatial orientations ("in front of us", "move this way") (Ferrara et al., 2011). In addition, children already knew those spatial words from the picturebook because when read-aloud, the educator asked spatial questions and prompts with spatial gestures (pointing in the direction of a shadow and tracing the shadow) and spatial words. This support of children's understanding of science concepts is spatial in nature. Narrative, as a pedagogical strategy, can guide the use of spatial language with the educator's reference to a picturebook's narrative and illustrations. Therefore, narrative, body movements, and guided play together provide opportunities for children to fully explore and investigate spatial concepts.

Third, I recommend that researchers and educators in informal science education need to pay attention to body movements and gestures in combinations with young visitors' short phrases. It is important for informal science educators to understand where and how young visitors are learning at informal educational places such as museums, nature centers, or planetariums by the ways they watch and point to exhibitions to interpret their constructing explanations of how they do science. Because of the nature of informal educational places, the learning moments might be quick and short; therefore, gestures and body movement for interacting with exhibitions need to be considered a learning instance for further development of education programs in informal educational settings.

Limitations and future work

My dissertation expands science learning in early childhood literature by providing evidence of how an integrated narrative, embodiment, and play learning environment supports children's co-construction of evidence-based explanation. However, a few limitations call attention to directions for future research in this area. In this section, I will discuss some of the possible limitations of this study and necessary future work.

In this study, the programs focused on the concept of shadows which is spatial in nature. During the programs, children had opportunities to use their bodies to investigate the relationship between the Sun and shadows by interacting with the learning environment. Children's body movements represented their spatial understanding and externalized spatial language. Therefore, the nature of science phenomena that was already concerned with spatiality may have affected the program structure and the investigation of concepts. In the SDEP program, I found that children's use of body movements in combination with other mediating processes during the exploration and investigation phases strongly supported children's co-construction of evidence-based explanations. Especially, narrative elements were also integrated in body movements during the investigation phase while children acted like Moonbear to make their shadows not scare/scare fish in the pond during guided play. Given that the narrative already included spatial elements (dimension and direction of shadows), this may have led children to engage more in the use of body movements. The study's findings, then, must be understood accordingly given that the study was limited to analysis of children's engagement in spatial concepts through a SDEP learning environment design that already featured spatial concepts.

Future work examining and exploring the intersection of narrative, embodiment, and play might study the effectiveness of the SDEP environment by focusing on other science phenomena besides spatial relationships; for example, plants and magnetics. Vygotsky (1978) suggested that

gestures can work together with the learning environment to construct abstract thinking. Although my study was limited by the SDEP focus on spatial topics, future work might build from these significant findings and implications to consider how children's use of metaphoric gestures in combination with narrative elements may extend our thinking about children's use of gestures. In particular, metaphoric gestures working together with narrative elements may provide children with an imaginary environment (i.e., dramatic play) that can affect their understanding of other natural science phenomena.

There are also methodological limitations of this study in gathering video data. The video data was limited to two cameras in a classroom. These two cameras could not and did not fully capture all individual children's drawings, actions, and voices for analysis. In addition, children in this study worked in small groups. For future analysis, capturing every child's engagement and every small group work would be more useful in recording through more diverse camera angles and individual microphones. In early childhood education, children constantly move around the classroom, which makes it difficult to capture each individual child's actions and voice. And, because they are always moving, some children might visually block other children behind them given limited camera angles. Sometimes, their voices may overlap which obscures others' voices in recordings and makes it hard to discern who is speaking and what they are saying. These overlaps of voice and body make it difficult to fully recognize the meanings of children's body movements and their language together. To fully capture how children engage in the integrated learning environment, clear recordings from individual microphones and multiple and diverse camera angles might be helpful to understand the intersection of narrative, body movement, and play in children's social and physical interactions during the program.

Another possible limitation to this study was that the EP program was too similar in structure, design, and content to the SDEP program to be a useful comparison Two essential pedagogical functions (embodiment and guided play) were integrated in both the SDEP and EP

programs, and even though EP did not include narrative, EP provided similar opportunities for children's enactment (i.e., making observations & testing predictions, use of body movements) that led to children's co-construction of evidence-based explanations. Perhaps this limitation suggests other learning environment designs might be better suited for comparison with SDEP, such as story-driven guided play (without embodiment) or story-driven embodiment (without play), in order to more explicitly identify the role of narrative, embodiment, and play and how they interact with each other in a learning environment.

During the SDEP program, I found that children engaged in more playful moments with narrative elements (i.e., event-token, agency). As suggested by research on the relationship between emotion and play, children may be less stressed in guide play as compared to their experiences with direct instruction (Hirsh-Pasek, Hyson, & Rescorla, 1990). Thus, children's emotional effects should also be considered in future work to better understand the differences between the SDEP and EP learning environments.

This study is also limited given that the SDEP and EP programs were conducted with participants who were primarily Caucasian children in small towns in the Northeastern United States. In particular, three local preschools were in low-resource areas. The participants' demographic information varies in SES and may have affected the children's engagement in the SDEP and EP programs due to their prior knowledge and language skills. The relationship between SES and spatial language development has been found that although low- and-high SES (socioeconomic status) children start out with the same language level at 30 months of age, the capacity of spatial words in low SES children developed slower when compared to middle- and high-SES children (Pruden, Levine, & Huttenlocher, 2011). In this study, children's language skills may be closely related to their engagement in discourse and understanding the educator's questions and prompt from the narrative. To further understand the role of the SDEP program for young children's constructing explanations, future work may study the SDEP learning

environment implemented with multiple SES groups of children by considering their language skills.

Finally, this study only investigated a single program in one museum and three local preschools. There was no follow-up program to the outcomes of this study. Providing a series of quality programs is important in order to identify how children develop and construct their ideas throughout the programs over a period of time. However, as mentioned before, the purpose of this program should not be thought of as a curriculum in a certain period of time. This study, rather, demonstrates that preschool-age children show a capacity for construction of evidence-based explanation, even during a one-time program, which suggests that researchers and educators can further develop a series of programs and discussion as a science curriculum.

Final conclusion

Narrative, embodiment, and play have been shown to be important pedagogical functions of science learning in the field of early childhood (Ferrara et al., 2011; Fisher et al., 2012; Murmann & Avraamidou, 2014; Plummer & Rickett, 2018). Limited work exists, however, that explores how these essential pedagogical functions can be integrated in a learning environment to support young children's science learning (Danish et al., 2015; Plummer & Cho, 2020). Young children have been referred to as "science-in-waiting" because of their ability for scientific reasoning (Gelman et al., 2009). There is a growing body of literature on young children "doing science" as a way of engaging in science practices (Siry et al., 2012; Siry & Max., 2013); however, I found limited research on the design of the learning environment to better support preschool-age children's constructing evidence-based explanations. The goal of this study was to contribute to filling this scholarship gap by understanding how a designed learning environment of story-driven embodied play can support preschool-age children's constructing explanations.

The second goal of this study was to show how three theories, narrative theory, embodied cognition, and play theory, can be intertwined to explain preschool-age children's science learning.

I found that story-driven embodied play (SDEP) supported children's co-constructing evidence-based explanations by encouraging children's use of body movement and engagement in guided play. While engaging in guided play, children acted like Moonbear through narrative agency and event-tokens to investigate their shadows using their body movements. Their body movements represented their understanding of the relationship between the Sun and shadows, and demonstrated their agency and alignment with narrative purpose and structure. In comparison, the embodied play (EP) also supported children's co-constructing evidence-based explanations by promoting children's use of body movements and engagement in guided play. Although the two similarly structured programs supported children's co-construction of evidence explanations, children engaged in more playful learning moments to explore narrative elements (i.e., event-token, agency) in the SDEP program.

Perhaps most significantly, this study reveals and advocates for the integration of narrative theory, embodied cognition, and play theory in learning environments, which intersect and explain young children's science learning in the SDEP and EP programs. The dialectical relationship between agency and structure (Sewell, 1992; Siry & Max, 2013; Siry & Gorges, 2019) serves as shared common ground between these three theories that can be used to understand children's active engagements (agency) with learning environment (structure) that lead to their science learning in the SDEP and EP environments. These results and implications offer opportunities for future research directions on science learning for early childhood education concerning how we can support young children's constructing explanations by promoting opportunities for children's agency and meaningful interaction with their environments.

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Appendix A: Glossary

Term	Definition
Agency	I used two different forms of agency in this dissertation: (a) Agency is actors or characters who cause and experience events in narratives and have responsibility for their actions (Norris et al., 2005); (b) Agency is the capacity to act, which is mediated by structures in interaction (Sewell, 1992).
Body movements	The term body movements includes iconic & pointing gestures, and whole-body movements (such as sitting down to make small shadows). I focus on science concept-related body movements that connote spatial information of shadows. I considered science concept-related body movements as non-verbal language. I used body movements and embodiment interchangeably in this dissertation.
Conjecture mapping	Conjecture mapping is a tool used by researchers in learning science to illustrate a relationship between theoretically-supported learning environment designs and learning outcomes (Sandoval, 2014).
Discourse	I used the term discourse to refer to meaning-making through the use of verbal (spoken) and nonverbal (gestures and body movements) expressions when children are engaged in a learning environment (Siry et al, 2012). More specifically, the science-related discourse in interaction emerges from a science goal-oriented interaction during the program (Siry et al., 2012).
Embodiment	I refer to embodiment as a pedagogical function drawn from embodied cognition theory. Embodiment means children or educators use their gestures and/or their whole-body movements to shape, represent, and communicate their ideas about concepts.
Implied author	Implied author, generally, is a subset of the real author's capacity and is a version of the real author in the text. The implied author is more related to the text-based narrative than verbal-based narrative (e.g., storytelling) (Chatman, 1978).
Informational book	An informational text is a type of nonfiction work. Expository work, as a sub-genre of nonfiction, characterizes informational text as its purpose is to "explain, describe, give information, and relay fact to readers" (Heard, 2013, p.9). I used an informational book, *Guess Whose Shadow* for the EP program design.

Narrative	I used narrative and story interchangeably in this dissertation. Narrative specifically refers to the *Moonbear's Shadow* story that includes essential narrative elements (e.g., event-token, structure, agency, and purpose) (Norris et al., 2005).
Pedagogical functions	I used the term pedoagical functions to refer to teaching strategies drawn from theoretical perspectives that can be expected to lead students' learning outcomes in a specific learning environment. There are three pedagogical functions in this research study: narrative, embodiment, and play.
Picturebook	Picturebook includes stories that have settings, plots, and characters' actions told in combination with pictures (Van Kraayeonoord & Paris, 1996). In picturebooks, stories carry messages from an author and elicit cognitive and emotional responses in readers. I used a picturebook, *Moobear's Shadow* by Frank Asch in this research study.
Play	The term play is drawn from sociocultural perspectives that understand play as "learning through interactions." The term also necessarily involves the following aspects of play: (a) play is self-directed; (b) play is exploratory and active; (c) play is social interactions or communication tool; (d) play is process-oriented; (e) play is guided by mental rules that leave room for creativity (Gray, 2017; Rubin, 1983; Saracho & Spodek, 2003).
Real author	Real author is the person who devised the story to communicate through text form (Chatman, 1978).
Young children	Preschool age children (3 to 5 years).

Appendix B: Science practice, embodiments, mediating codebook

Category	Codes	Description	Sub-codes
Science practices	Evidence-based explanations - Full	Child *makes a claim* that answers a question or response to a goal statement about a science phenomenon using their observations of that science phenomenon and provides reasoning to make sense of how the evidence supports the claim. ● Though evidence is required, this may be implicit (e.g. claim is in close proximity to making a key observation).	The evidence is implicit for the educator and the children. The children who participated in the testing collected the data and sorted into the piles. Their observations with the magnets which led to the specific pile they sorted into (magnetic or not) is the data for the claim. So, the evidence is here, just not verbalized – more implicit, in the experience of the children and the activity.
	Evidence-based explanations – Emerging	Child provides a claim and evidence, but not reasoning. ● Evidence may be implicit.	<u>Explicit evidence</u> Children verbalize their evidence and it may be combined with their gestural expression. It should include a reference. <u>Implicit evidence</u> Children may not verbalize, but if they are engaged with evidence from phenomena directly (such as directly making observations of the phenomenon) or have just finished an investigation of the phenomenon.

Category	Codes	Description	Sub-codes
Narrative elements	Event-tokens (something happened)	**Educator** references a particular occurrence from the storybook narrative. Place and time refer to a particular moment in the storybook.	
	Structure	In the activity, **children** engage in the same or similar structure of events from the storybook. Note: Does not need to reference storybook but activities should be similar to broad set of events in storybook.	
	Agency	Children either engage in same actions as storybook characters or model those actions with external objects.	Internal: In the activity, **children** act like the main characters from the storybook and engage in the same event from the storybook. External: In the activity, children have choices with external objects (e.g., model, figurine) that match what the characters are doing.
	Purpose	In the activity, **children** engage in the same science phenomenon as the storybook as a way to help them better understand the natural world.	

Tool	Engagement with phenomenon	In the activity, children engage in the science phenomenon with materials and/or narrative from the storybook.	
Discursive practices	Epistemic norms for CER	Educator uses questions and prompts to encourage children to make claims, use evidence, **or** provide reasoning.	
	Embodied communication strategies	Educator uses her own body to convey instruction or ask children to represent **concepts** through their body.	
	Social rules for guided play	Educator provides a level of guidance helping children to follow the rule of guided play.	Co-playing: Educator enhances children's explorations and learning by co-playing along with the children. Commenting on children's discoveries: Educator enhances children's exploration and learning by commenting on their discoveries or learning process. Asking open-ended questions: Educator enhances children's explorations and learning by asking open-ended questions about what children are finding or exploring the materials in ways that children might not have thought.
Mediating processes	Discourse about narrative elements	Children engage in narrative-mediated discourse as guided by educators' prompts and questions that reference a particular event-token, structure, and/or agency from the storybook narrative.	

	Discourse about concept	Children engage in conceptually-mediated discourse as guided by educators' prompts and questions, as drawn from conceptual elements with the same purpose as the storybook narrative.	
	Children's body movements	Children's body movements include both gestures and whole-body movements. Children use their bodies to represent/externalize their understanding of concepts. Sometimes their gestures and body movement include narrative elements.	Concept-centered: children use their body and gestures to represent their understanding of concept. Narrative-centered: children use their body and gestures with narrative elements
	Making observation and testing prediction to investigate science phenomenon	Children make predictions, test their predictions, make observations, and/or analyze their observations of science phenomena.	Making predictions: children make predictions about the phenomenon. Testing predictions: children engage in phenomenon to test their prediction. Making observation: children observe phenomenon by involving investigation of phenomenon (e.g., making shadow and observing together). Analyzing data: when children describe their observations with their conceptual understanding using some concept related science words and/or gestures.
	Engagement in guided play	Children engage in playful moments in response to educator's prompts and guidance.	

	Children's representations	Children draw their understanding of concepts on a paper.	

Kyungjin Cho

kuc64@psu.edu | kjcho430@gmail.com

EDUCATION

Ph. D., Curriculum and Instruction, The Pennsylvania State University, USA, 2021
M.A., Early Childhood Education, Duksung Women's University, South Korea, 2013
B.A., Early Childhood Education, Duksung Women's University, South Korea, 2010

RESEARCH EXPERIENCE

Research Assistant, The Pennsylvania State University, 2016-21
Teaching Assistant, The Pennsylvania State University, Spring 2020

TEACHING EXPERIENCE

Instructor, Introduction to Astronomy for Educators, Spring 2020
Guest Lecturer, Introduction to Astronomy for Educators, Spring 2019
Kindergarten Teacher, Duksung Women's University Affiliated Kindergarten, 2013-15

HONORS AND AWARDS

Top Student Admission Scholarship, Graduate School, Duksung Women's University, 2010
Top Student Scholarship, Duksung Women's University, 2007

PROFESSIONAL PRESENTATIONS AND PUBLICATIONS

Plummer, J.D., **Cho, K**., & Botch, M. (2021). The use of narrative in the development of spatial sensemaking practices. In proceedings of the 15th International Conference of the Learning Sciences (ICLS), Bochum, Germany.

Cho, K., Botch, M., & Plummer, J.D. (2021). Developing Preschool-Age Children's Spatial Sensemaking Practices through a Story-Driven Investigation. A presentation will be performed at the NARST: A Worldwide Organization for Improving Science Teaching and Learning through Research annual conference, Virtual Conference, April 7-10, 2021.

Cho, K., Botch, M., & Plummer, J.D. (2020). Support for Spatial Thinking through Children's Use of Spatial Sensemaking Practices. LSGS Conference, Virtual Conference, November 13-15, 2020.

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