Journal of Leadership, Equity, and Research

JLER
Vol 7, No 1
http://journals.sfu.ca/cvj/index.php/cvj/index

KNOWLEDGE IN USE: DESIGNING FOR PLAY IN KINDERGARTEN SCIENCE CONTEXTS

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ABSTRACT
Decades of research support integrating play in kindergarten to benefit young students' social, emotional, and cognitive development. As academic readiness becomes a focus, time for play has decreased. As a result, there has been a demand for integration of play with content. This study modifies a project-based science curriculum about how living things grow to include both child-initiated play and teacher-guided play to meet disciplinary learning goals. The curriculum was initially designed to address reform science standards based on knowledge-in-use. We explore how play invites all students to access and understand the phenomenon. The qualitative study involves 18 kindergarteners and their teacher in a Great Lakes state in the U.S. highlighting four lessons during the enactment that emphasized play. Data include observation, audio recording, transcription of interviews, children involved in play, classroom dialogue, and the examination of artifacts. Thematic coding and analysis of field notes, interviews, and dialogue suggest that child-initiated imaginary play and teacher-guided play can promote the science practice, science ideas, and crosscutting concept of patterns needed to explain the phenomenon.

Keywords*: science education, diversity, equity, kindergarten, play, phenomena, three-dimensional learning*

Introduction

There is international consensus that play is necessary for early childhood development (Al-Mansour et al., 2016). As the hours in kindergarten are increasingly squeezed due to concerns of academic readiness (Miller & Almon, 2009), scholarship moves to integrate play-based learning in kindergarten classrooms to support academic learning (Bassok et al., 2016; Wood, 2007). Teachers lack curriculum that can support the teacher introducing play for meeting learning goals in these settings (Weisberg et al., 2013), and the teachers cite lack of curriculum as one of the main reasons they do not incorporate play during social or academic learning. Although there is some literature on the use of play to meet learning goals, much of this work centers on integration for literacy development and social emotional development (Samuelsson & Fleer, 2008). There is a notable lack of research about how to go about integration of play with science in early childhood education (Andrée & Lager-Nyqvist, 2013).

Recently science education has shifted globally, and learning science has become practice-oriented presenting a new challenge, and opportunity, to integrate science with play. Understandings of science education and science learning processes have been reformed to promote a knowledge-in-use perspective (Pellegrino & Hilton, 2012). Knowledge-in-use describes science understanding commensurate with the doing of authentic science and solving problems with others, rather than knowing facts and procedures. The knowledge-in-use perspective describes students making sense of ideas in science by using them to understand a science phenomenon. Knowledge-in-use is the basis of international education policy documents in countries such as Germany, Finland, Thailand, and the U.S. (Finnish National Board of Education, 2016; Kulgemeyer & Schecker, 2014; NRC, 2013; OECD, 2016). This study examines the potential for integrating play as part of a four-week learning set in kindergarten to promote knowledge-in-use. The research question for our study is, “How can play be incorporated into science instructional materials to support kindergarten students in accessing, engaging with, and explaining phenomena?”

Theoretical Framework

We use the sociocultural theoretical frameworks of constructivism (Vygotsky, 1967). According to Vygotsky’s theory, children learn within social interactive contexts by reconciling what they already know with novel experiences. Constructivism entails the creation of a personalized developmental arc of learning tasks, that, according to Vygotsky, includes imaginative play for young children. Personalized learning, meaning that the individual is creating meaning and can meet demands based on prior knowledge, is further refined through the feedback from others. Vygotsky described play as critical to children's social and cognitive development: Play is the manifestation of students’ knowledge construction and their access to emergent understandings. We build on the theory of Knowledge-in-use (Pellegrino & Hilton, 2012, which is the foundation of the Framework for K-12 Science Education (NRC, 2012). Knowledge-in-use reflects contemporary views of learning that value understanding which can be applied: “Learners who understand, can use and apply novel ideas in diverse contexts, drawing connections among multiple representations of a given concept” (NRC, 2007, p.19). To achieve these goals, scholars have called for the development of science education learning environments that provide opportunities for students to grasp how the application of scientific knowledge and practices relate to everyday events.

Literature Review

Importance of play

Research overwhelmingly supports play as critical in the early grades to foster students’ interest in school and to help them develop coping and learning strategies needed for success in school (Miller & Almon, 2009; Nicolopoulou, 2010; Rogers, 2010). Research about play primarily focuses on free play, or imaginative play, which is spontaneous free improvisation. Free play contrasts with play integration—play that is structured by integrating teacher prompts—disciplinary events, ideas, or materials (Fink, 1976; Pyle et al., 2018). For example, in their ethnographic study, Stipek and colleagues found that children in classrooms where free play is regularly supported worry less in school, have a better view of their abilities in school, choose more difficult problems in math, and are self-motivated, rather than dependent on the teacher, to begin academic tasks (Stipek et al., 1995). This imaginative free play in early grades leads to cognitive, social, emotional, imaginative, and physical growth -- all aspects of the child's development (Hirsh-Pasek et al., 2009). Through free play, children explore their emotions (Singer & Singer, 1992) and learn to manage themselves and others. Integrated play is seen as an essential component for early language and literacy skills, especially as play incorporates print materials (Van Oers and Duijkers, 2013). Van Oers' and Duijkers' study (2013) describes a growth in student vocabulary development when the teacher directed attention to objects during play, or inserted contributions to the shared dialogue. Research supports that students involved in imaginative free play have more advanced language skills, social skills, and can understand what other people mean better than students who do not play (Darling-Hammond & Snyder, 1992; Wohlwend, 2015). Because make-believe play engages students in the rich back and forth dialogue needed to invent scenes and dialogues of characters, students have to negotiate parameters of the imaginary world with one another.

Play integration to support academic readiness

Recent attention to kindergarten education in the U.S. has been on the lack of priority of play in kindergarten because of policy decisions that focus on academic readiness (Moyles et al., 2002; Singer & Singer, 1992). Studies show that most hours spent in kindergarten are focused on early numeracy and literacy development, relegating time for play to 30 minutes a day at most (Howes et al., 2013). In many schools in the U.S., play does not occur at all in kindergarten (Miller & Almon, 2009). Although this is a common pattern among many schools, the lack of play integration in schooling is pronounced more significantly in school districts with low income and non-white student populations (Bassok et al., 2016). Play, therefore, becomes an opportunity for some students who have access to resources when play should be a right for all students. Opportunity gaps are often mistaken for achievement gaps and children in lower-income settings are denied the privilege of play. The argument is that more rigorous academic expectations will close the achievement gap between low-income/non-white students and higher-income/white students. White and higher income students have the advantage of receiving play in their curricula because there is no preconceived notion among teachers and leaders that remediation is needed (Souto-Manning, 2017). Even though this disparity is more pronounced in schools that serve more low-income and non-white students, there have still been substantial reductions to time in kindergarten spent on playing in general (Bassok et al., 2016).

One way to compensate for lack of hours is to use play to bridge learning in key areas. Although there is lack of consensus about how integration is instantiated, even when curriculum uses play as pedagogy (Synodi, 2010), there is increasing support for play integration to foster key literacy goals (Pyle et al., 2018). Thus, an integration of play with disciplinary learning goals has potential (Wood, 2017). Similarly, data suggest that teachers can support mathematics by guiding play using materials and contexts (Seo & Ginsburg, 2004).

There are few research articles that describe the integration of play to support science learning for young students. One study in kindergarten compared direct instruction with science taught through active participation with phenomenon. The researcher found that "playful-learning" (Bulunuz, 2013, p. 229) significantly improved development of science concepts when compared with didactic instruction, according to a rubric. In another study, Andrée and Lager-Nyqvist (2013) used the context of chemistry of food to explore spontaneous play with sixth-grade students in Sweden. These scholars counter the narrative of play as detrimental to the academic activity by describing spontaneous play as a productive vehicle for students to make sense of the social, conceptual, and historical meanings of science. Andrée and Lager-Nyqvist (2013) describe:

> Students' spontaneous play may allow them to interpret their experiences, dramatise, give life to and transform what they know into a lived narrative.
> Students' spontaneous informal play (is) part (of) ...the processes of learning science in school science practices. (p. 1737)

The authors rely on Vygotskian theory to define play as when a person or an object is imagined to be someone or something other than who/what it is. They collected video and audio recordings of group work across two classes, which enacted a Swedish science curriculum over 12 lessons. The data collected showed that almost half of the group work involved students initiating imaginary play. For example, one student imagined his group members were scientists and they played along, while another group pretended to be bakers. The authors suggest that play removes the barriers that students encounter socially and conceptually in science.

There is only one study that uses the Next Generation Science Standards (NGSS) (NRC, 2013) –the reform science standards in the U.S.—as the context for the integration of reform science using dramatic play. Lozon and Brooks (2019) designed a playful preschool curriculum with science and engineering. As the students were involved with self-motivated imaginary play using paint materials, the teachers inserted questions meant to leverage the crosscutting concepts in the NGSS. The students were tasked with creating a green monster and were given the opportunity to explore solutions and figure out how to make the color green out of primary colors. The teacher asked questions to leverage scientific thinking. For example, one question motivated thinking of energy and matter: "The sample seems to look different to me in different light. Does it to you?" (Lozon & Brooks, 2019, p. 92). The authors suggest that there is room during imaginary play to insert questions and problems related to science and, in particular, the crosscutting concepts, math and literacy; however, they argue that young students need repeated experiences to develop the ideas coherently.

Definitions of Play

There is not wide acceptance about what defines play (Pyle et al., 2018), and it can range from entirely student-guided and motivated (Singer & Singer, 1992) to play that is launched and guided by the teacher and through selected academic teaching materials (Weisberg et al., 2013). To respond to the question "what is play?," one interesting study from Hong Kong sought young students' perspectives in defining play (Wong et al., 2011). In this study, students in kindergarten through second grade were given cameras and asked to take pictures of students involved in play and in schoolwork. The students were then interviewed about what they selected to photograph. The researchers found that students had a consistent view of play—It should be fun, intense and focused, include materials that are used as something they are not, and have little direction from the teacher related to how the play unfolds. According to Darling-Hammond, a leading U.S. expert on early child education and teacher evaluation, these are the features essential for play to be taking place: Play is child motivated, intensely focused, and people and objects stand for something they are not (Darling-Hammond & Synder, 1992). Many authors add Vygotzky's perspective on play, which emphasizes the negotiation of rules. He theorized that play occurs when children engage in the negotiation and renegotiation of rules for imaginary worlds (Vygotsky, 1967). Definitions of play are concerned with the level of guidance, or structure, from adults that leverage "intentional make-believe play" (Bodrova & Leong, 2007) to enrich the academic learning experience (Bulunuz, 2013).

In this work, we apply more constrained definitions of play that include teacher-guided play, as well as child-initiated imaginary play within structured settings. We consider both integrated play and teacher-guided play. Hence, in this manuscript, we describe play as occurring at varying degrees of teacher guidance in classrooms, according to levels of teacher intervention. (Miller and Almon, 2009). In our study, we added to the definitions featured in the 2009 Alliance for Childhood (ibid.) to extend the two approaches to incorporating play in the units for science.

We extend their framework by including a representation of science as a playful activity that is child-centered, with guidance from the teacher toward the use of teacher-guided creative play to solicit clear science-related learning. We have developed definitions of play adapted from Miller and Almon (2009). The first is **Classroom Rich in Child-Initiated Play**, which we define as exploring the world through play with the active presence of teachers, and fostering student engagement in imaginative creative play through purposeful selection of materials that correspond to the science lesson and the phenomenon under study. The second definition of play is **Playful Classroom with Focused Learning,** which consists of teachers guiding learning with rich, experiential activities. Teachers guide the exploration of the phenomenon using creative play as a connection to the science and by using guiding questions to focus the learning.

There is a remarkable parallel between the teacher-guided and child-initiated play and the reform science and its knowledge-in-use, practice-based approach to science learning. The reform science curriculum supports a pedagogy of students creating and testing the rules of science collaboratively and dialogically. The teacher may guide the activity, provide materials, and scaffold the inquiry with questions and prompts. The teacher enables the students to figure out explanations and the relationships that lead to a science event themselves. We proposed a design for integration of play in science that promotes knowledge-in-use, and that there be both approaches toward play integration--child-initiated and teacher-guided play. Including child-initiated play and teacher-guided play in science instruction extends opportunities for young students to work on the social and self-regulatory skills needed for developing scientific practice, as well as clear learning goals for rigorous science.

Integration Design: child-initiated play and teacher-guided play. Child-centered play enables students to use imagination and rule creation to place themselves in the socially situated world of science (Nicolopoulou et al., 2009). Young students use child-centered play to work out ideas, roles, and rules, which is a separate activity, uninfluenced by the teacher. The rule orientation of the non-imaginary world implicitly belies the students' own rule making and their imaginations and spontaneity. There is some consensus that science carries urgency for students to work out the particulars of that science world, including aspects of positionality and identity. "Play offers opportunities for sensemaking…Play also offers students opportunities to create situations in the school science classroom that meet their needs and interests" (Andrée & Lager-Nyqvist, 2013, p. 1735). The benefits to guided play, however, contrast with child-centered play because play is teacher-initiated and directed toward predetermined outcomes. Guided play carries potential to marry motivation and interest with targeted learning goals. Although guided play is condemned by some as inauthentic (Singer & Singer, 1992), difficult content can be made accessible through guided play (Weisberg et al., 2013).

Methods

Case Study

We use Merriam's (1998) approach to case study design which highlights a case as a "bounded system" (p. 27), and further elaborates on the case as "a phenomenon of some sort occurring in a bounded context" (p. 33) where there is focus on the process for causal explanations of impact or outcomes. In this way, case study is a particularly suitable design. In this article, we explore how both child-initiated imaginative play and a playful classroom with focused learning can support science learning as described in the reform standards. Our field setting is a Young 5 kindergarten class in a suburban public school in a Great Lakes state in the U.S. The state adopted the reform science standards (NGSS) five years prior to the study. Young 5 is a state-endorsed early kindergarten program for children who turn five between September 1st and December 1st. The study began before school closings due to COVID-19. Data was to be collected from a kindergarten classroom and would have been coupled, but due to school shutdowns for COVID-19, the data remain unfinished. Ideally, using data from a kindergarten classroom would have strengthened the case of this argument as it would have taken into consideration the current curriculum pressures and time constraints facing kindergarten teachers. Young 5 teachers do not face the pressures kindergarten teachers do since Young 5 students are preparing for entrance to kindergarten the following year.

Context of the School Setting

The school that was chosen for this research is located in a middle-class neighborhood. Houses near the school that are for sale range from $89,000 to about $175,000. The parents of students who attend this school work in a wide range of professions or don't work at all. Some parents are engineers, pharmacists, mechanics, foundry workers, medical professionals, stay-at-home parents, and unemployed parents. The demographics in the vicinity of the school are as follows: white 82%, Asian 2%, Hispanic 9%, and Black 7%. The statistic describing 82% of the population as white does not take into consideration the Arab-Americans in the classroom. On census forms, Arab-Americans are racialized as white, however, they deal with many similar issues as other minorities, such discrimination and negative stereotyping (Suleiman, 2001). Several of the students in the class were English Language Learners.

Fifty-three percent (53%) of the students in this school receive free/reduced lunch. Fifty-six percent (56%) are English Language Learners. This site was chosen because of the flexibility in the Young 5 program. The class consists of 18 students (13 boys and 5 girls). This classroom, in particular, consisted of 7 white students, 7 Arab American, 1 Latinx, and 3 African American students. The teacher is female and has 20 years of teaching experience. The teacher is animated, entertaining, spirited, kind, loving, and empathetic towards her students.

Data Sources and Collection

Data for this study was collected in January after all students turned five years old. Another reason this particular classroom was chosen is because the teacher has a strong passion for play and science at the early childhood level. The teacher volunteered to be a part of this study. This teacher was followed over the course of two weeks. Within these two weeks, the class participated in three lessons that took four days to complete.

Young students can be very verbal, but easily distracted as they were challenged to describe their thinking and motivations for learning. Therefore, we relied on multiple data sources to triangulate interpretations of the data. The lead author collected audiotapes of semi-structured interviews with students during each of the four lessons and with the teacher after the lesson set was concluded. The interviews with the students consisted of questions like “Can you tell me about what you are doing?” and other related follow up questions. The questions for the teacher were “Tell me about what you noticed today?”; “What, if anything, surprised you?”; and “Can you tell me about how students were, or weren’t, learning today?”.

All four lessons were audiotaped, including small group work during the play and discussion. During the small group work, students used the practices of analyzing data and carrying out investigations. Subsequent discussions were transcribed. The author recorded conversations while the students were playing and asked the students the semi-structured interview questions during their moments of play. Field notes were also recorded during the observation. Each field note described what happened in each lesson and overall impressions related to play and science learning, events that were surprising, and how the students made use of the ideas presented in the lesson for making sense of the phenomena.

Data was collected over the course of two weeks, comprised of **two stages**:

Stage one: The lead author met with the teacher and observed her teaching a math lesson with her students. Information was collected on the classroom environment and the educator’s teaching style.

Stage two: The lead author attended four science class sessions and observed the lesson facilitation. The lead author collected observational data, audio recording, and interviews of the students. The author took pictures of student models and student play stations. At the end of each day, the lead author wrote memos (Birks et al., 2008) related to themes of play and science learning that emerged during the lesson enactment.

Multiple Literacies in Project-based Learning (ML-PBL)

The study context includes the use of a widely used science curriculum that is aligned with the reform-based science standards in the U.S. called Multiple Literacies in Project-based Learning (ML-PBL) (Krajcik et al., 2015). ML-PBL is a science curriculum that is rooted in the following precepts:

- It has project-based learning and reform science at its core;
- the combination of project-based and reform science means that units have driving questions that are meaningful to students and promote the need to know;
- the units engage students in figuring out phenomenon and solving problems and they culminate in artifacts that are authentic to the community;
- there is an integration of literacy;
- the units are tested for eliciting interest and motivation from students; and
- the units and the lessons have a coherent design, meaning that each lesson builds meaningfully and strategically toward the lessons that follow them, and each unit builds on knowledge developed in the previous unit.

In this section, we first describe the modifications made to the design of the project-based learning science curriculum. Then we describe the context for the study.

The modifications to the unit involve the introduction of two different manifestations of play, supported in the literature:

1. As imaginary, self-motivated, creative play, where students build scenes and dialogue; and
2. Play that is guided by the teacher through questioning strategies related to three-dimensional learning.

ML-PBL does not have a theoretical approach to play. This project investigates play as a useful vehicle for young students figuring out the phenomenon and answering the driving question.

The lesson-level driving question that begins the NGSS-aligned unit is, "Why do some things start small and get bigger?" Using phenomena in the unit to drive instruction is important when considering how all students can access the science learning. More importantly, the phenomena selected for instructional materials should be strategically established in a way that meaningfully connects to students lives. This means that there is an observable event in the universe that students authentically want to make sense of. Keeping in mind that this unit was designed for five-year-olds, we looked to select a phenomenon that almost all of the students in the class have wondered about: growing up. Kindergarteners often imagine the things they will do when they get older. As students engage in these ideas and when used concurrently with the science, students are compelled to figure out how things, including themselves, get bigger.

The phenomenon, "Why do some things start small and get bigger?" would not be genuinely authentic from the students' perspective if students are not wondering about it first. Oftentimes, phenomena can be teacher-directed in units where teachers come up with the phenomena with which students will engage. The writers, therefore, designed the first lesson of the unit in a way that would inspire curiosity about the phenomenon. Students were asked to bring in baby pictures and look for how they have changed since they were young. All the students in the class have a firsthand and direct experience with the phenomenon. Doing this was a deliberate strategy to ensure that every student in the class could experience the phenomenon, ask questions, and wonder together with their peers without any student being excluded. All students can make connections to the phenomenon because they all have experienced it before. They can connect to their prior knowledge and their homes. Students begin to talk about what it was like being young. This is what we use to launch the learning so that all students can take part in the learning.

Later in the unit, students wonder, "What can stop some things from getting bigger and how can humans help?" The phenomenon that was to be explored in the unit was that some things, including animals and people, get bigger, and some things never get bigger. Students complete the first learning set of this unit where they build toward the following performance expectations:

- K-LS1-1. Use observations to describe patterns of what plants and animals (including humans) need to survive.
- K-ESS3-1. Use a model to represent the relationship between the needs of different plants and animals (including humans) and the places they live.

By the end of the first learning set, students develop understanding of what plants and animals (including humans) need to survive and a simple model of this idea. The second learning set allows students to continue to make sense of what plants and animals need in order to survive and in relation to the places they live. The second learning set will have students use the core ideas and patterns they figured out in learning set 1 about what it takes for a plant or animal to grow in order to plan how they can care for living things. Students will participate in firsthand and meaningful experiences to do so. The third learning set allows students to explore what happens when humans remove plant and animal resource needs from a system. The culminating final project asks students to communicate a solution to others about how people can reduce their impacts on water, land, and other living things.

The lead author drafted the four integrated lessons that would be used in the study. The lessons, worksheets, and PowerPoint slides were designed by the lead author. The materials were then gathered and organized by the author as well.

Play integration

Building on the literature, we identified four lessons that would be strengthened by imagination, creativity, or exploration which include features of child-initiated and student-motivated, or teacher-guided play. Each of the instances were part of the larger cohesive unit with a driving question ("Why do some things get bigger?"), science practices, core ideas in science, and crosscutting concepts. It is important to note that play does not take the place of scientific practices, but rather fosters the integration of the science performances in a relaxed and student-centered, highly focused, and socially situated environment. By integrating play into these science lessons, more students have the opportunity to connect to, relate, and share their access to the phenomena. This in turn, provides the teacher with another method of assessment. The teacher is able to observe the student making sense of ideas without the student having to say or write their thinking. Play provides another modality for students to share their thinking, which all children, especially young children, need. Children's interest and growing ideas become visible in children's actions as they play. Offering varied and alternative assessments is a key approach to achieving equity (Lee et al., 2010).

Data Analysis

We employed qualitative data analysis, using a philosophical position of critical realism (Maxwell, 2013). Our position brings together two perspectives often thought to conflict--critical realism and epistemological constructivism. According to Maxwell, we accept that there is a world that exists apart from our beliefs. At the same time, we hold that we construct and shape our understanding of the world. We seek to straddle the two perspectives to acknowledge the reality that exists while simultaneously acknowledging that what we portray represents a perspective. To further the study, we present triangulated data that consists of multiple data sources, observations, artifacts, and transcribed dialogue. Additionally, our perspectives are shaped by our cultural histories and by the system of injustice that sustains the society in which we live. We also recognize the contradiction between our goals for social justice as we participate in academia--an institution that perpetuates racist, classist, and ethnically biased practices. Because we rely on observational and interpretive stances, we feel it is appropriate to position ourselves.

The first author is an Arab American woman who taught for three years as a classroom teacher before becoming an elementary science resource teacher. She has been in this position for two and a half years and identifies as working class. This author recognizes that by law, she is considered white and is afforded some opportunities although denied others because she is a visibly Arab and Muslim woman. The second author is a white woman, who has been an elementary teacher for two decades and identifies as working class. Even as the author was dissuaded from academia because of her socioeconomic class, she recognizes that she has been afforded many opportunities that come from whiteness.

First, the observation data and audio recording to identify moments of play were analyzed.

Next, the authors looked across the transcripts, field notes, interviews, and memos for emerging themes that responded to our inquiry related to knowledge-in-use and play: "How can play provide support to help students access, engage, and explain phenomena?" The authors looked for evidence to reinforce emerging and anticipated themes, how they could be supported, and how some could be nested within others. Next, the authors re-read each field note, and generated separate analysis notes for the purpose of discussing with the other authors the evidence to support the themes. Two key themes related to learning in knowledge-in-use through play emerged across the different episodes of play (see table 2). Through close analysis, the researchers noticed that some of the developing themes were less well supported by evidence. For example, the anticipated themes, "play supports science language," and "play provides access to sensemaking" were not backed by strong evidence.

The authors arranged the data across the two approaches to play and organized data according to those themes that were supported across play contexts:

Table 1. ***Key Themes across Episodes of Play***

Themes	Child-initiated imaginative play	Teacher-guided play
Theme 1: Play bridges the figuring out of phenomena through making sense of patterns.	Data sources: Students used and described patterns of feeding and watering animals and plants during free play.	Data sources: Teacher prompts and questions when using the felt board support ideas about patterns.
Theme 2: Play supports knowledge-in-use through application of core ideas.	Data sources: Exploration of materials in free play resulted in modeling different relationships to getting bigger.	Data sources: Testing and sorting of materials with the teacher enabled the students to negotiate "rules" and make claims about organisms.

Throughout the research, moments recorded as play and used in the analysis met the following criteria:

- **Child-initiated play**: Opportunities where students are engaged in imaginative creative play through purposeful selection of materials that loosely correspond to the science lesson and the phenomenon under study (unstructured play).
- **Teacher-guided play**: Teachers guiding the exploration of the phenomenon using creative play as a connection to science ideas and focusing student learning with guiding questions (structured play).

The research question examines how play can be incorporated into science instructional materials to provide support to help students access, engage, and explain phenomena. To answer the question, the researchers used student dialogue during play and student models to identify whether students were able to access, engage, and explain the phenomenon, "Why do some things get bigger?" The researchers looked for moments where students were starting to explain the science ideas related to the performance expectations. Students were making sense of these ideas through teacher-guided play and child-initiated play. The results demonstrated that both types of play enabled the students to figure out the phenomenon and are commensurate with the literature on the academic potential of play. We found that child-initiated play motivated engagement and interest more than teacher-guided play.

The science ideas associated with the phenomenon that were used to determine whether the data could be accounted for as evidence are as follows:

1. All animals need food to live and grow.
2. Plants need water to live and grow.

The crosscutting concept that students apply during the lessons was patterns: Students used reasoning and modeling to describe aspects of these science ideas and build toward a full understanding of the performance expectations.

Findings

Below the authors first describe what occurred as the students interacted with the curriculum and engaged in child-initiated play and teacher-guided play. Next, the authors describe the affordances of child-initiated play and the themes related to this kind of play for figuring out phenomena and for knowledge-in-use. Next, we examine the affordances of teacher-guided play and the themes according to that kind of play integrated with science. Our research question, "How can play provide support to help students access, engage, and explain phenomena?" has two parts. First, the question is related to the integration of play in design, and secondly, we want to know how the integration serves as a vehicle for meeting expectations that students use practices, science ideas, and crosscutting concepts to explain phenomenon.

Description of classroom lessons

Day 1 On day 1, lesson 1.1 began with the teacher showing pictures of herself as a newborn and when she was five years old. She asked if anyone noticed any differences. The students noticed differences in outfits and hair color but did not pay much attention to size. The teacher prompted the students to pay attention to size asking, "What about my size has changed?" The students collectively answered saying their teacher got bigger. The students then sat in a circle holding their own baby pictures. They brought in pictures of themselves as newborns and themselves at 2 years old. Students took part in a gallery walk and looked at everyone's pictures. The students were then partnered up and asked to discuss the differences they saw in their baby photos compared to what they look like now.

After exploring, the students were brought together as a whole group to discuss some common differences that were noticed. Students readily acknowledged that their sizes had changed over time. Next, the phenomenon for the unit was presented to the class. The teacher said, "I wonder, do all things get bigger?" Students then discussed whether they thought so or not. They found they were not all in agreement and could not come to a consensus. The students then wrote their claim about whether they thought all things get bigger. They did this by writing their name on a post-it and placing it on an anchor chart. The anchor chart was titled, "Do all things get bigger?" Below the title was a t-chart. One side was labeled yes, and the other was labeled no. The students placed their post-its on the side of the t-chart that matched their claims.

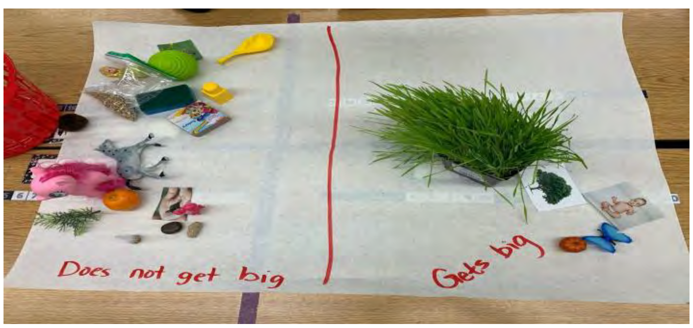
The discussion on day one set the stage for the phenomenon to be explored and answered through the science practices in upcoming lessons. The teacher found that students were unsure about whether they themselves actually grew, and if there was a way to definitely separate the things that get bigger from those that stay the same size. They also had a simple understanding that food is somehow connected to getting bigger. This lesson included no play, neither teacher-guided play nor child-initiated imaginary play.

Day 2 On day 2, lesson 1.2 began with a review of what the students did last time they met for science. Students remembered that they were discussing things that get big. Each student brought in an object for show and tell. Most students brought toys. The students sat in a circle and were asked what they brought from home and whether it could get bigger. Some described what would help it grow. For example, one boy brought a stuffed snake. When asked if the snake grows, he said if it were real, the snake would grow but because it was not real, he would not. Some students had trouble answering the question.

After show and tell, the teacher told the students that she brought in baskets of random objects. They were told to sort the objects into two piles, things that get bigger and things that do not. The students worked in groups discussing which things get bigger and which things do not. Students continued to move objects around even after they had finished sorting. Some students put pictures of animals and plants in the piles that did not get bigger. When asked why they placed them there, they said pictures do not get bigger. Other students thought that maybe if the animal were real and it ate something, it could get bigger.

At first, when students were prompted to explain why they had moved objects into certain piles, the students were hesitant to answer the questions. As students continued at the stations, they began to use reasoning to explain their placement of the objects. It took about five minutes into the activity before students started to go back and revise their thinking.

Figure 1. ***Students Sorting Objects***



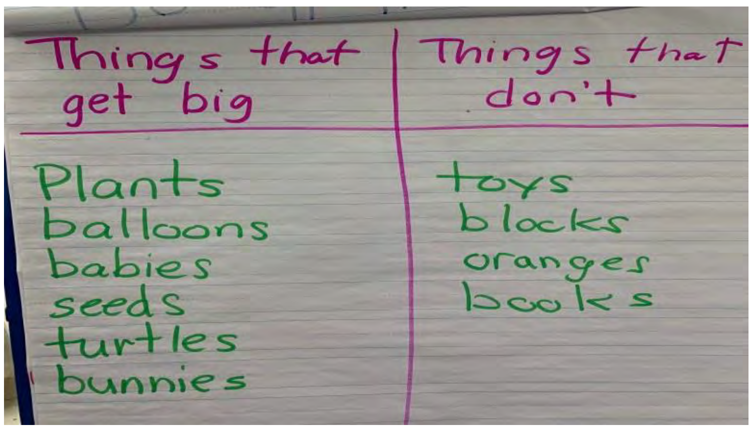
Afterwards, students sat at the carpet and the teacher projected a picture of how a group sorted their objects. The teacher asked the students if they agreed or disagreed with the way the group had sorted their objects and why. Students had trouble staying on task, so the teacher stopped the lesson.

This lesson used teacher-guided play, involving prompts and questions to support play. The play had explicit rules—the students sorted objects in two piles and they developed and explained a rule for how the objects should be sorted. At the same time, the activity involved some negotiation among the students of science-based rules. Some things stood for other objects (i.e., the pictures stood for real animals), which promoted children's imaginations (Nicolopoulou et al., 2009). There were two levels of rule negotiation, but it is important to note that the student motivation to determine the rules for the animals (pictures or real animals, for example, needed to be determined) was part of the engaging in the scientific practice and making sense of the phenomenon. Another rule related to the phenomenon, that needed to be determined by the students, was if blocks could stand for many blocks. There were students who felt that blocks should go in the "gets bigger" pile because they could be made big if there were many.

Day 3 Day 3 was a continuation of lesson 1.2 which started at the beginning of the following week. The teacher began with looking at a projected picture of how one group sorted the objects in the basket. The teacher asked the class if they agreed or disagreed with the placement of objects into their respective piles. The teacher then held up the objects from the basket and the class arrived at consensus deciding together which things get bigger and which do not. Students shared their thinking and their reasoning.

The teacher wrote the names of the objects on a t-chart. The students were then told to choose an object from the side labeled “Things that get big” on the t-chart and develop a model that showed how it gets bigger.

Figure 2. ***Things that Get Big***



This lesson provided the opportunity for the students to build on the experience of playing with the objects and interrogate some of the ideas that they brought from prior experiences. Play, discussion, and sorting enabled the students to dialogue about science “rules” to develop an understanding of what living animals and plants have in common.

Day 4 On day 4, lesson 1.3 began with the teacher reviewing the t-chart of things that get bigger and things that do not. The teacher told students that she brought some of the things from the chart so the students could play with them. Students rotated between six stations (two baby doll stations, two gardening stations, and two pet care stations) and were asked at each station, what they were doing and why they were doing it.

After students played with the toys at each station, they came back to the carpet for reflection and debriefing. The teacher mentioned to the students how she noticed similarities between what the students did at each station and what they said they did. She continued, “We gave plants and the horse water. Also, we gave the animals food and the babies food.” She asked the class to think about why they did those things. One student shouted, “to help them get big!” The teacher then made a t-chart. She explained that plants, animals, and people are all living things that need certain things to help them get big or grow. Then the class returned to the list of items of things that get big and reviewed the list. The teacher asked the students about the balloon they had placed on the side labeled “Things that get big.” She asked the class, is it a living thing? Students said no because it needs air to get big, not food. The teacher continued this questioning down the list asking students to identify whether the items were living or nonliving things and to give their reasoning for their thinking. Together, using a felt board, the class came up with a consensus model showing how plants, animals, and people need certain things in order to grow. Lastly, the teacher asked the students to choose a living thing and to model it growing. In this model, the students were to also include what it needed to grow.

Students at the end of this lesson knew some of the needs of plants, animals, and people, however, they still did not have a complete model. In the next learning set, students would explore seeds, plants, animals, and people to identify all the resources they need to grow. Students will come back to their models to revise and add the new ideas they learn. This lesson, specifically, included two kinds of play, teacher-guided play, with the felt board, and child-initiated imaginary play, using the stations. The child-initiated imaginary play was focused and rich with student language. Students were discussing what they needed to do to make sure the plants grew, and they found dog food (blocks) to feed the puppies so they could play. The teacher brought their attention to their prior knowledge to elicit thinking about patterns between organisms and how they grow.

Affordances of child-initiated imaginary play

Students engaged in child-initiated imaginary play through purposeful selection of materials that loosely corresponded to the science lesson and the phenomenon under study (child-initiated play). As described in the classroom observations, during lesson 1.3 on day 4, students participated in child-initiated play. Students were placed into small groups of three and played at each toy station for 5-10 minutes. At the gardening stations, some students explicitly recognized that they were watering plants to help them grow or “get bigger.”

Transcript 1

Teacher: What are you holding?
Student 1: I don’t know what is
Student 2: A shower pot
Teacher: What does the shower pot do?
Student 1: You put on there and the water makes it big

Transcript 2

Teacher: Hey, what are you doing?
Student 1: Shoveling
Teacher: And what are you doing with the spray bottle?
Student 1: Watering it so it will grow
Student 2: We gotta water the flowers so it will grow

After students played at each station, the class met at the carpet for a class discussion. During the whole class discussion, students were able to connect what they learned from playing at the stations back to the phenomenon.

Transcript 3

Teacher: So last time we talked about things that get big and things that don’t. Today, you guys

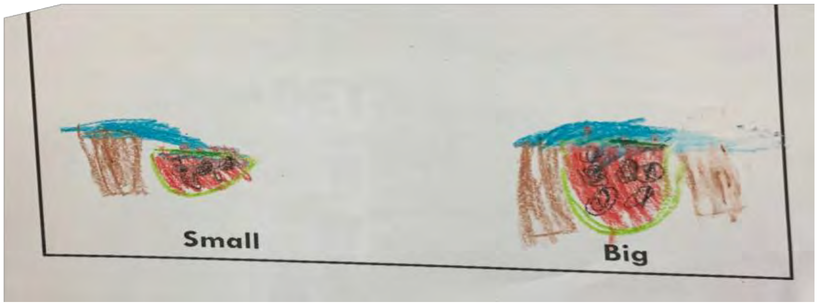
played at these different stations. What did you do while you were playing? If you played at the baby doll station, what did you do with the baby doll? What did you do there?
Student 1: We fed them so they ate food
Teacher: Why would you feed them?
Student 2: Because they are hungry
Student 3: So it can be happy
Student 4: So they don't cry
Student 5: Because they can be big
Student 6: So it can grow
Teacher: So how about the plant station? What did you do there? How did you play there?
Student 7: Put water in it
Teacher: And why did you do that?
Student 7: I put water in it so it could grow
….
Teacher: Let's look back at our list. We said balloons get bigger. Is a balloon a living thing? Think about that for a second.
Student 10: It is not a living thing
Teacher: Can you say why?
Student 10: Because it has air in it not food
Teacher: Do I have to feed a balloon so it can get bigger?
Students: NO (laughing)

This discussion indicated that the child-initiated play allowed students to capture and explain parts of the phenomenon. Students made connections between the imaginary games they invented while playing with the toys and what certain things need in order to grow. During the child-initiated play, students accessed prior knowledge and began imitating what they had either seen or experienced.

Students therefore used patterns to apply what occurs in the real world to the imaginary game they played at their stations. The child-initiated play was key in helping students combine their understanding of real-world applications and the scientific ideas that emerge in the unit. One specific example emerged from the only African American girl in the classroom who was also a selective mute. During this lesson, she began to speak as she played, asking the baby dolls or pets if they needed more food or water. This student felt comfortable to speak because of the opportunity to play.

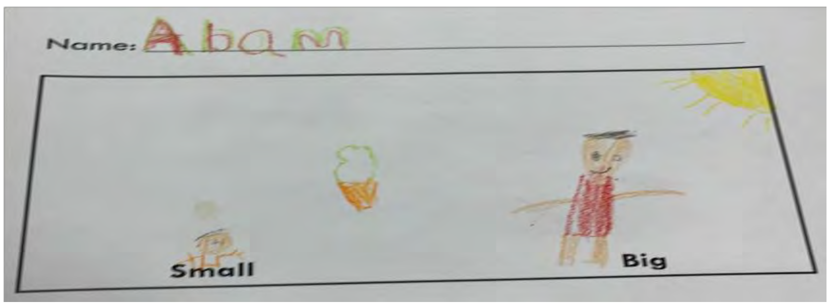
Further evidence to prove that students had acquired the science ideas after participating in child-initiated play can be seen in student models at the end of lesson 1.3 on day 4. Student models depict people, plants, and animals. Each model now also includes a pictorial representation of what each living thing needs in order to grow.

Figure 3. ***A Watermelon Growing***



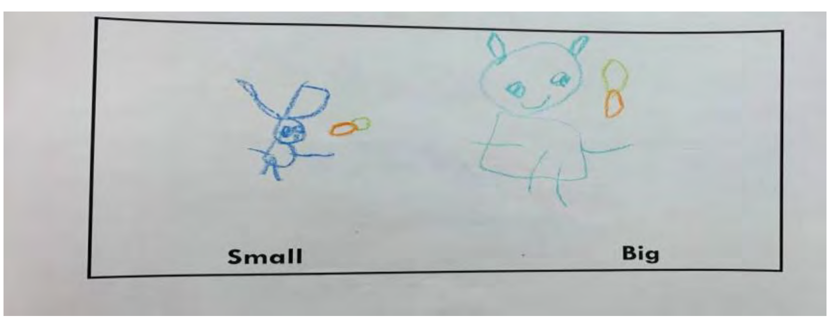
This student modeled a watermelon growing when it is watered.

Figure 4. ***A Child Growing into an Adult***



This student modeled a child growing into an adult when he eats carrots.

Figure 5. ***A Bunny Growing into a Rabbit***



This student modeled a bunny eating carrots and growing into a rabbit.

Each model is a clear representation that students were able to draw living things growing when one need is met. Later in the unit, students will add to this model as they make sense of more ideas and move closer to fully understanding performance expectations. Regardless of student race or socio-economic status, each student was able to play and engage in learning. Below we describe three themes that emerged during analysis.

Theme 1: Play supports the figuring out of phenomena through making sense of patterns.

During the child-initiated imaginary play, students negotiated the rules for the imaginary world that closely align with some of the rules in the non-imaginary world. In this way, they are using play as a safe, interesting, and child-initiated context to engage in sensemaking about the natural world and to make sense of the driving question, “Do all things get big?” This was depicted in transcript 3.

Theme 2: Play supports knowledge-in-use through application of core ideas.

Child-initiated, imaginary play supported the application of ideas. The students applied the core ideas about water and food and living and non-living things as topics of exploration during the play. The teacher preselected materials, such as animals and watering cans, which fostered agentive engagement in the core ideas.

In addition, the students were enabled through play to be the agent of the phenomenon. When they “watered” the plants, they imagined that the plants got bigger. The authors saw this depicted in transcripts 1 and 2 as well. Similarly, when they fed the puppies, they imagined that the puppies ate the food and grew.

During the child-initiated imaginary play, students made initial claims, one of the scientific practices that is necessary for students to figure out the scientific events in the real world.

The students used their imagination to change roles and become persons who take care of plants, and they acquired agency in the event. The students were considering the phenomenon from a new and active perspective. The core idea, living things have things in common, was being applied across the stations to figure out how they could cause things to grow in an imaginary world.

Theme 3: Alignment free play with the definition of child-initiated imaginary play.

The play featured in the lesson approximated, but did not entirely reach, the definition of child-initiated imaginary, or free play. Although the young students used the imaginary play to work out ideas, roles, and rules, the setting for the activity was designed by the teacher in terms of time, task, and materials. Also, the rules of the classroom remained salient. We suggest that the newness of the activity impeded the students’ ability to completely orient to the imaginary world, where turn taking and classroom norms for materials such as tables and social space remain intact. Hence, there were aspects of the imaginary play that overlapped with the teacher-guided play, particularly since the setting was intentionally designed by the teacher to promote children's self-initiated engagement with the toys.

Nevertheless, there were sufficient aspects to the play that existed squarely in the realm of child-initiated play. For example, many objects had imaginary uses, and there were some rules of interaction among the students (i.e., moving around the room, talking to objects and for objects, and inner focus) that align with the definition of child-initiated imaginary play. In addition, the interactions with the materials, even as they were chosen by the teacher, were entirely student-motivated. This discrepancy between intention of design for play, and student use of the setting as designed, may be a contradictory aspect to imaginary play in any context that is designed by an adult.

Affordances of teacher-guided play

There were three instances where teacher-guided play took place in the lessons. The first was the show and tell activity done on day 2 at the beginning of lesson 1.2. This form of play was guided by the teacher. Students brought an object from home and shared it with the class. To connect the play experience back to the phenomenon, the teacher asked students if the object the students brought from home could get bigger. All answers were accepted and students were not pressed to explain reasoning as this was an introductory activity and used as an assessment of their current understanding. Answers varied between yes and no.

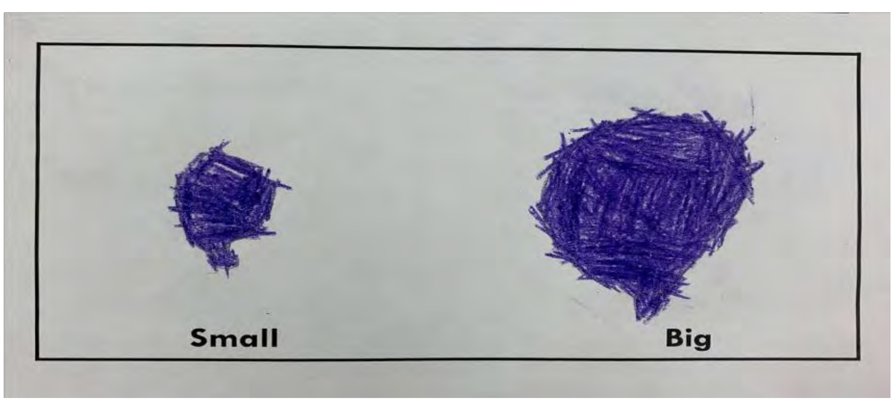
The second teacher-guided play activity also occurred on day 2 in lesson 1.2. Students were given baskets filled with random items. The students sorted the objects into two piles on a large piece of butcher paper. The students were asked to make two piles: things that got bigger and things that did not. The teacher walked around, circled the piles, labeled the piles, and commented on student identifications. The teacher was careful not to reveal whether the objects were placed incorrectly. Again, all student answers were accepted, however, the teacher did press for reasoning. The teacher asked open-ended questions to enhance student learning through the teacher-guided play. For example, students looked at a plastic spider toy and worked on trying to determine whether it could get bigger. Here is a portion of the students' conversation with the teacher:

Transcript 4

Teacher: How about this spider?
All students: No
Teacher: Ok
Student 1: Wait! Actually it does, it turns into a tarantula
Teacher: Do you agree with that? What does it do to get bigger?
Student 2: It eats webs
Student 3: and plants
Teacher: Which side do we put it on?
Students: Bigger!

Through this teacher-guided play item sorting activity, students recognize that the spider needs food in order to grow. Students recognized a pattern between the spider toy and the other animal objects in the basket that they had previously sorted into the "bigger" pile. Students then modeled to show how an object gets bigger. These models depict student thinking and whether students were able to recognize the difference between something growing and something just getting bigger.

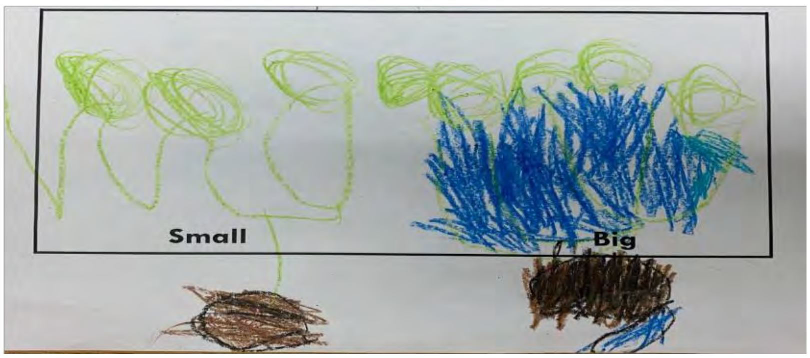
Figure 6. ***A Balloon Getting Bigger***



This student modeled a balloon getting bigger. He explained how but did not include this in his model. His explanation is quoted below.

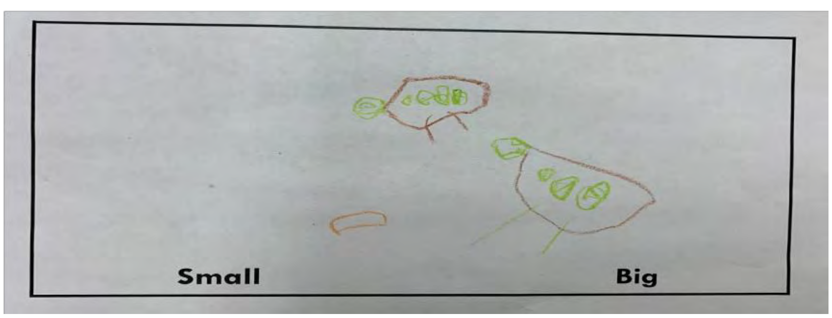
Transcript 5
Teacher: What did you draw?
Student: I drew a small balloon and a big balloon
Teacher: What makes the balloon get bigger?
Student: When air goes into it, it will get bigger

Figure 7. ***A Plant Getting Watered but Not Getting Bigger***



This student drew a plant getting watered but didn't necessarily draw it getting bigger. He only drew what the plant would need to grow. The model indicates that the student has some understanding that plants need water.

Figure 8. ***A Turtle Eating Food to Get Bigger***



This student drew a turtle eating food to get bigger. This model represents different scales that the student was able to describe as a small turtle who gets bigger after it has eaten food.

All three students listed in the examples demonstrated some understanding of the scientific ideas. However, at this point in the unit, the students are not yet able to fully explain that these living things need food and/or water in order to live and grow.

The third instance of teacher-guided play used in the lesson set was the felt board modeling activity. This activity was led during the end of lesson 1.3 on the fourth day of observation. The students worked with the teacher to come up with a consensus model describing how the three things students observed in play (animals, children, and plants) could get bigger. The teacher had food, water, animals, plants, and people cut out into felt pieces. The students were asked to come up to the felt board and to use the pieces to make their thinking visible and to serve the purpose of displaying to the whole class a summary of learning thus far.

Transcript 6

Teacher: Here is a little girl (holds little girl felt piece). What does the girl need to get big?
Students: Food!
Teacher: Ok, can she eat this carrot (holds up carrot felt piece)?
Students: Yes
Teacher: Let's put the carrot there… so she starts small and if she eats this carrot what will happen?
Students: She gets bigger!
Teacher: So is she a living or nonliving thing?
Students: Living thing
Teacher: Let's put her getting bigger on the board (adds an adult felt piece to the board). How about this bunny? What does the bunny need?
Students: Carrots!
Teacher: Oh people eat carrots too! And after the bunny eats the carrot what happens?
Students: It gets big!
Teacher: Can someone come and put these up for me?

Figure 9. ***Felt board of Living Things and Non-Living Things***

This process continued until the students finished discussing each different felt piece, where the felt piece should be placed on the board and why. The results of this guided modeling play activity indicated that students were able to display the needs of certain living things to grow. Students demonstrated their understanding of the scientific ideas and were beginning to develop an understanding of the phenomenon. Students were active in participating in the sensemaking experience. Student ideas came from the play investigations conducted during science time and from their own prior knowledge. Direction was not delivered by the teacher. Thus, all three instances of teacher- play supported students in accessing the science ideas that would be needed to fully explain the anchor phenomenon. Below, we return the themes found throughout the analysis of enactment.

Theme 1: Play bridges to the figuring out of phenomena through making sense of patterns.

Teacher-guided play enables the students to make sense of the implicit patterns that they were using during the activity. Considering the patterns between living and non-living objects that get bigger was the main objective of the teacher during the two instances of guided play, the playing with objects and sorting them, and the felt board. Students were interested and discussed the sorting of the objects prior to the teacher questioning.

The sorting was designed to elicit the negotiation of some of the core scientific rules of life science, which ultimately became a focused and guided game. The teacher prompts and questioning served to allow the students to make the rules explicit.

Transcript 7

All students: this one (points to bigger pile)
Student 3: This pumpkin gets bigger on Halloween
Teacher: What happens?
Student 2: If you water it, it will get bigger
Teacher: How about this spider?
All students: No
Teacher: Ok
Student 1: Wait, actually it does, it turns into a tarantula
Teacher: Do you agree with that? What does it do to get bigger?
Student 2: It eats webs
Student 3: and plants
Teacher: Which side do we put it on?
Students: Bigger!
Teacher: Do sponges get bigger?
Students: No

Theme 2: Play supports knowledge-in-use through application of core ideas.

The guided play with the sorting of objects and the felt board both resulted in the students enthusiastically modeling first that animals and plants that get bigger, and next what causes the scientific event. The guided play, through questioning and prompts, enabled the students who were troubled by the balloon and the blocks, both of which were in the bigger pile at different times, to come up with a difference between objects and living things. Without questioning by the teacher and the engaging context, this question may not have been resolved.

Figure 10. ***A Spider Getting Bigger***

The student drew a spider that can get bigger when it eats

Theme 3: Alignment of free play with the definition of teacher-guided play

The integration of teacher-guided play in a science curriculum was also not a seamless fit with our definition of teacher-guided play. There is a small but important discrepancy between our description of teacher-guided play and the classroom activities. The activities described as teacher-guided play include children sorting objects into two categories: "things that get bigger" and "things that do not get bigger," as well as a group discussion of living and non-living things while the teacher recorded students' answers by attaching pictures to a felt board. These activities (sorting and group discussion) are nearly aligned to the definition of teacher-guided play (Weisberg et al., 2013). Teacher-guided play means that adults design the setting and augment child-initiated play by asking open-ended questions and inserting definitions for concepts. There remains some question as to the extent that the play was instead teacher-guided and augmented by child-initiated play, rather than the reverse.

Regardless of this small discrepancy, the teacher supported play by offering guidance through prompts and open-ended questions. The setting extended permission for the engagement and motivation of children's imagination adequately for the activity to fall under the definition of teacher-guided play. Although there was negotiation for driving the activity between students and the teacher, there was sufficient self-motivation and creative play, where students built scenes and dialogue. The newness of the activity, especially within the science classroom, was the probable cause for the tension between student and teacher motivation. It makes sense that there would be a transition, due to an unfamiliarity for teachers and students to disciplinary play.

Discussion

In this paper, we explore how guided play can be used to promote science learning, and we add to a small set of research articles that support the integration of play in academic contexts. There is a particular affordance for play to supplement, even enrich, the practices in science as students have the time to adopt agency in imaginary contexts and engage in conversation with one another about rules for events in science, as well as explore ideas about the world that they understand intuitively, such as patterns, but need teacher support to express.

Play is a necessary activity for emotional, intellectual, and social development for young students. To refer back to our theoretical framework, we know that children learn within social interactive contexts by reconciling what they already know with novel experiences. This includes imaginative play for young children. We have expanded this vision of knowledge-in-use when finding that students were motivated to engage in science learning because of play.

As a result, we suggest an innovative solution to the problem of decreasing time for play in school due to emphasis on academic readiness. When both child-initiated and teacher-guided play are integrated in science contexts there are affordances, which are aligned with knowledge-in-use. Using a Young 5 classroom makes it more feasible than a kindergarten classroom to insert play-based curriculum. However, integrating play into kindergarten science curriculum could support the effort to ensure more students have time for play during traditional instructional time in school. All students should have the right to high quality instructional materials. The goal is to complete this science unit and provide it openly to all teachers. The unit will be developed to include science as the base of access to literacy and play at the kindergarten level.

Which type of play was more engaging?

Engagement in play was measured by the discussions students had and how long students continued to stay on task. The richer discussions between peers or the student and teacher were coded as more engaging; and the richer the discussion, the more engaging the play was. Both types of play revealed evidence to support that students were engaged and gained access to the phenomenon through play. Both types of play allowed for rich discussions between the teacher and the students. However, students were more engaged during the child-initiated play than the teacher-guided play. This is possibly due to the fact that students were playing with new toys and were excited to have time to explore. Using child-initiated play does not necessarily mean there needs to be specific manipulatives for the lesson. Leaving open-ended manipulatives and materials for the students to interact with could drive more open-ended conversations and questions than this lesson allowed. For instance, giving the students gardening toys, dolls, and pet toys limited students to just role playing their prior knowledge. Although this did bring out student experiences, we acknowledge that not all classrooms can afford these materials.

Using the same dialogue that occurred after the teacher-guided play activity, it is evident that students were able to follow along with the teacher during the discussion and come up with conclusions together. After the teacher-guided play where students had to sort objects from the basket, students had a hard time staying on task.

Transcript 8

Teacher: What did you want to say about the sponge? He put the sponge on the side that does not get bigger. Who else did that? Raise your hand if you put the sponge on the side that does not get bigger. Why doesn't the sponge get bigger?
Student 8: Because it get bigger?
Teacher: It does?
Student 8: Yes
Teacher: Does a sponge get bigger?
Student 9: No
Teacher: Why not?
Student 9: Because it's a sponge
Student 10: Like spongebob
Student 11: Why did you open my shoe?
Teacher: Do we notice anything about the things that get bigger? We just said a sponge is a sponge… it will not get bigger?

Students murmuring
Student 12: We forgot that...
Student 13: If it got a baby
Teacher: I think we have exhausted them

All three lessons were coherent and relied on one another to help students access the phenomenon. By incorporating both types of play, the students were able to use imaginary instances to make connections with their prior knowledge about the needs of living things. Teacher-guided play and child-initiated play both provided students with opportunities to gain deeper understandings of concepts needed to acquire the phenomenon. Through each version of play, students recognized patterns between the objects and occurrences in the real world to make sense of the phenomenon. It was evident to the teacher which students had more background knowledge on certain ideas based on how they answered the teacher's questions. Some students, for example, knew plants also needed light as well as water to grow. Others were unable to relate light to the needs of plants. These ideas were exposed as students were playing. The teacher questioned student thinking and asked for reasoning as they played. Based on this assessment, the second learning set will begin with guiding students through a plant observation and question what exactly plants need in order to live and grow.

Child-initiated and teacher-initiated play helped students learn from others around them and access vocabulary words. We started the unit asking the class if objects get bigger. Then, students began to distinguish between things getting bigger and things growing. This language was brought to the surface as students participated in play. Students began attaching words like "grow," "living things," and "nonliving things" to concepts after students had experienced them.

Implications of play for further study

The potential for teachers to use play as a learning and assessment opportunity has implications for improving equity in schools—schools that offer widely disparate opportunities for students. Thus, in schools where hours are a commodity, the integration of play with content may be necessary to respond to students' emotional and cognitive needs (Dickey et al., 2016). As, in well-resourced schools, young students are often given more time to play than in schools influenced by poverty, both imaginary play and guided play, we see a viable solution to disparities between wealthy schools and those affected by poverty. Instead of a singular focus that results in didactic teaching, where students suffer from the push for academic readiness, play and disciplinary integration offer social, developmental, and academic benefits. Souto-Manning (2017) from Teachers College asks if it is ethical that play be a privilege, rather than a right for all students. This practice reflects the ability to prioritize what students need and should be available to students attending lesser-resourced schools.

In this example, young students learned core science ideas, practices, and cross-cutting concepts through play, and the teacher was able to 'see into the students' scientific minds'. Building on play for assessment has rich potential to evaluate learning goals with informal and formative assessment practices, a critical lever for equity (Lee et al., 2010). Further research is needed to understand how assessment and play can be utilized in classrooms, particularly with diverse students, English Language learning, and as culturally responsive pedagogy.

Lastly, the authors acknowledge that true child-initiated play did not happen in these lessons. Pure play in the classroom could be possible with the incorporation of more open-ended activities that the students could explore. For instance, if students were to play in a sandbox or at a water table, lessons could be designed around what students are doing and how they interact with sand or water. In this way, a phenomenon from the students' perspective could arise and be explored.

More research about how to accomplish this integration and prepare teachers is needed. Aspects of play and the role of play that need to be further researched include:

- Play in science and language acquisition (language development fostered through play)
- Play in science as a bridge to the three dimensions of learning
- Can play help improve student sensemaking and reasoning?
- How can curriculum be designed to help support teachers in using less structured play in their classrooms?
- Play as an assessment opportunity for disciplinary and cross-disciplinary learning goals

Conclusion

As a case study of a Kindergarten unit that places play within the discipline of science, this study makes several contributions to our understanding of science teaching and learning. Our inquiry describes initial patterns of play that engage young students in an interdisciplinary context. Young students were able to immerse themselves in imaginative and teacher-structured play while also accessing and applying rigorous science ideas. The results of this study suggest that three-dimensional learning of science and engineering need not be siloed in objective, empirical, and non-imaginative spaces. While playing, students develop understanding of core ideas, scientific practices such as modeling and data analysis, and cross cutting concepts. Young students can interact with their world socially and imaginatively and at the same time develop understanding along the evidence-base trajectory required of the NGSS and other science reform initiatives. This finding supports the idea that play fosters the carrying out, testing, using and evaluation of ideas– including disciplinary ideas--that young students encounter in the world around them. Knowledge-in-use presents a vision of science learning that positions students as the users of science ideas, and places them in situations where deep knowledge is required to solve a problem and explain a phenomenon. We offer the field a new question to consider: How can we better understand knowledge-in-use in imaginative spaces, and spaces for play?

The results of this study can inform and improve science access, participation and outcomes for students who are underserved in science education. Contrary to initiatives that remove play from the school day, suggesting that play is not academically crucial, play is the impetus for motivating children of all backgrounds and critical for their emotional and social development. Much of the discussion around equity in science education has been centered on test scores, academic achievement, and other markers found in upper grade levels. We suggest a new framing: one that focuses on equity and rich opportunity for play within educational contexts. This framing for equity merits the ubiquity that test scores have attained. With this study we hope to open the door to deepen discussion around justice, and we propose justice might look something like integration of creative play within the contexts of science. We see equity as an important and unique discussion with respect to younger students. This framing moves knowledge-in-use to be about applying science ideas during play, and other essential aspects to develop social and emotional learning. The integration of play with content can be one direction to afford younger students, including students from underserved demographic groups, the opportunity to develop into fully actualized people, who can harness their science knowledge, social experiences, and creativity toward access, participation and opportunity.

REFERENCES

Al-Mansour, M., Sevimli-Celik, S., & Johnson, J. E. (2016). Transcultural study of play: Turkish and Saudi mothers' beliefs about play. In M. M. Patte & J. A. Sutterby (Eds.), *Celebrating 40 years of play research: Connecting our past, present, and future* (p. 149). Hamilton Books.

Andrée, M., & Lager-Nyqvist, L. (2013). Spontaneous play and imagination in everyday science classroom practice. *Research in Science Education, 43*(5), 1735–1750. https://doi.org/10.1007/s11165-012-9333-y

Bassok, D., Latham, S., & Rorem, A. (2016). Is kindergarten the new first grade?. *AERA Open*,. https://doi.org/10.1177/2332858415616358

Birks, M., Chapman, Y., & Francis, K. (2008). Memoing in qualitative research. *Journal of Research in Nursing*, *13*(1), 68–75. https://doi.org/10.1177/1744987107081254

Bodrova, E., & Leong, D. J. (2007). Play and early literacy: A Vygotskian approach. In J. F. Christie & K. A. Roskos (Eds.), *Play and literacy in early childhood: Research from multiple perspectives* (2nd ed., pp. 185–200). Routledge.

Bulunuz, M. (2013). Teaching science through play in kindergarten: Does integrated play and science instruction build understanding? *European Early Childhood Education Research Journal*, *21*(2), 226–249. https://doi.org/10.1080/1350293x.2013.789195

Darling-Hammond, L., & Snyder, J. (1992). Curriculum studies and the traditions of inquiry: The scientific tradition. In P. W. Jackson (Ed.), *Handbook of research on curriculum: A project of the American Educational Research Association* (pp. 41–78). Macmillan Library Reference.

Dickey, K., Castle, K., & Pryor, K. (2016). Reclaiming play in schools. *Childhood Education*, *92*(2), 111–117. https://doi.org/10.1080/00094056.2016.1150742

Fink, R. S. (1976). Role of imaginative play in cognitive development. *Psychological Reports*, *39*(3), 895–906. https://doi.org/10.2466/pr0.1976.39.3.895

Finnish National Board of Education. (2016). *National core curriculum for basic education 2014*. Finnish National Board of Education.

Hirsh-Pasek, K., Golinkoff, M. R., Berk, L. E., & Singer, D. (2009). *A mandate for playful learning in preschool: Applying the scientific evidence* (1st ed.). Oxford University Press.

Howes, C., Fuligni, A. S., Hong, S. S., Huang, Y. D., & Lara-Cinisomo, S. (2013). The preschool instructional context and child–teacher relationships. *Early Education & Development*, *24*(3), 273-291. https://doi.org/10.1080/10409289.2011.649664

Krajcik, J. S., Palincsar, A., & Miller, E. (2015). Multiple literacy in project-based learning. *Michigan State University, East Lansing MI*. Lucas Education Research, a division of the George Lucas Educational Foundation, San Rafael, CA.

Kulgemeyer, C., & Schecker, H. (2014). Research on educational standards in German science education–Towards a model of student competences. *EURASIA Journal of Mathematics, Science and Technology Education*, *10*(4), 257-269. https://doi.org/10.12973/eurasia.2014.1081a

Lee, O., Buxton, C. A., & Banks, J. A. (2010). *Diversity and equity in science education: Research, policy, and practice (multicultural education series)* (1st ed.). Teachers College Press.

Lozon, C., & Brooks, J. G. (2019). The potential of purposeful play: Using the lens and language of crosscutting concepts to enhance the science and engineering practices of play. *International Journal of the Whole Child*, *4*(2), 88-94. https://161.45.205.92/index.php/ijwc/article/download/1602/1127

Maxwell, J. A. (2013). *Qualitative research design: An interactive approach (Applied social research methods)* (3rd ed., Vol. 41). SAGE Publications, Inc.

Merriam, S. B. (1998). Qualitative Research and Case Study Applications in Education. Revised and Expanded from" Case Study Research in Education.". Jossey-Bass Publishers, 350 Sansome St, San Francisco, CA 94104.

Miller, E., & Almon, J. (2009). *Crisis in the kindergarten: Why children need to play in school*. Alliance for Childhood.

Moyles, J. R., Adams, S., & Musgrove, A. (2002). *SPEEL: Study of pedagogical effectiveness in early learning*. DfES. http://www.dfes.gov.uk/research/

National Research Council. (2013). *Monitoring progress toward successful K-12 STEM education: A nation advancing?*. The National Academies Press.

Nicolopoulou, A. (2010). The alarming disappearance of play from early childhood education. *Human Development*, *53*(1), 1–4. https://doi.org/10.1159/000268135

Nicolopoulou, A., Barbosa de Sa, A., Ilgaz, H., & Brockmeyer, C. (2009). Using the transformative power of play to educate hearts and minds: From Vygotsky to Vivian Paley and beyond. *Mind, culture, and activity*, *17*(1), 42-58. https://doi.org/10.1080/10749030903312512

OECD. (2016). *PISA 2015 Results (Volume I). Excellence and Equity in Education*. Paris: OECD Publishing. Retrieved December 11, 2016. http://dx.doi.org/10.1787/9789264266490-en

Pellegrino, J. W., & Hilton, M. L. (Eds.). (2012). *Education for life and work: Developing transferable knowledge and skills in the 21st century*. The National Academies Press, Washington, DC. https://www.nap.edu/read/13398/chapter/1

Pyle, A., Poliszczuk, D., & Danniels, E. (2018). The challenges of promoting literacy integration within a play-based learning kindergarten program: Teacher perspectives and implementation. *Journal of Research in Childhood Education*, *32*(2), 219–233. https://doi.org/10.1080/02568543.2017.1416006

Rogers, S. (2010). *Rethinking play and pedagogy in early childhood education: Concepts, contexts and cultures*. Routledge.

Samuelsson, I. P., & Fleer, M. (2008). *Play and learning in early childhood settings: International perspectives* (Vol. 1). Springer.

Seo, K. H., & Ginsburg, H. P. (2004). What is developmentally appropriate in early childhood mathematics education? Lessons from new research. In D. Clements, J. Sarama, & A. diBiase (Eds.), *Engaging young children in mathematics: Standards for early childhood mathematics education* (pp. 91-104). = Erlbaum.

Singer, D. G., & Singer, J. J. (1992). *The house of make-believe: Children's play and the developing imagination*. Harvard University Press.

Souto-Manning, M. (2017). Is play a privilege or a right? And what's our responsibility? On the role of play for equity in early childhood education. *Early Child Development and Care*, *187*(5–6), 785–787. https://doi.org/10.1080/03004430.2016.1266588

Stipek, D., Feiler, R., Daniels, D., & Milburn, S. (1995). Effects of different instructional approaches on young children's achievement and motivation. *Child Development*, *66*(1), 209. https://doi.org/10.2307/113120

Suleiman , M.F. (2001). Image making of Arab Americans: Implications for teachers in diverse settings . Paper presented annual meeting of the California Association for Bilingual Education, January 31–February 1 (Eric Document Reproduction Service No. Ed 452310), in Los Angeles, CA.

Synodi, E. (2010). Play in the kindergarten: The case of Norway, Sweden, New Zealand and Japan. *International Journal of Early Years Education*, *18*(3), 185–200. https://doi.org/10.1080/09669760.2010.521299

Van Oers, B., & Duijkers, D. (2013). Teaching in a play-based curriculum: Theory, practice and evidence of developmental education for young children. *Journal of Curriculum Studies*, *45*(4), 511-534. https://doi.org/10.1080/00220272.2011.63718 2

Vygotsky, L. S. (1967). Play and its role in the mental development of the child. *Soviet Psychology*, *5*(3), 6–18. https://doi.org/10.2753/rpo1061-040505036

Weisberg, D. S., Hirsh-Pasek, K., & Golinkoff, R. M. (2013). Guided play: Where curricular goals meet a playful pedagogy. *Mind, Brain, and Education*, *7*(2), 104–112. https://doi.org/10.1111/mbe.12015

Wohlwend, K. E. (2015). One screen, many fingers: Young children's collaborative literacy play with digital puppetry apps and touchscreen technologies. *Theory Into Practice*, *54*(2), 154–162. https://doi.org/10.1080/00405841.2015.1010837

Wong, S., Wang, Z., & Cheng, D. (2011). A play-based curriculum: Hong Kong children's perception of play and non-play. *The International Journal of Learning: Annual Review*, *17*(10), 165–180. https://doi.org/10.18848/1447-9494/cgp/v17i10/47298

Wood, E. (2007). New directions in play: Consensus or collision? *Education 3-13*, *35*(4), 309–320. https://doi.org/10.1080/03004270701602426

Wood, J. (2017). *Supporting early literacy learning through play. What works? Research into Practice.*