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The green bean has to be longer than your thumb: An observational study of preschoolers' math and science experiences in a garden

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Abstract

School gardening has become increasingly popular as a context for learning in which children construct new knowledge, learn cultural and societal values related to ecological awareness, and develop and practice authentic or real - world skills (Blair, 2009; Bowker & Tearle, 2007). The present research was a longitudinal case study of children's gardening experiences at a Reggio -inspired preschool in the United States. Eleven children and their teacher were observed over nine days in various activities such as preparing the garden be ds, planting, and harvesting. Through sustained participation in a variety of gardening activities, preschoolers engaged in science - rich dialogue utilizing complex and abstract science process skills such as observing, predicting, evaluating, and comparin g. Discussion of number -related concepts, spatial orientation, and size estimation and comparison was also recurrent during gardening activities. In addition, analyses of social interactions and dialogue related to gardening knowledge and ecological awaren ess indicated that working in the garden was an authentic context for enjoying, learning about, and valuing the natural world. The results of this study support the conclusion that with appropriate teacher guidance, a preschool garden affords myriad opport unities for young children to develop mathematical and scientific thinking, ecological awareness and positive affective responses to the natural world.

Keywords: school gardens, Reggio Emilia, preschool, early childhood, mathematics, science

The present research was a longitudinal case study of children's interactions with a teacher in a garden at a Reggio - inspired preschool in the United States. The research utilized a social constructivist theoretical framework in which children's cognitive and social development is fostered through participation in meaningful social and cultural practices (Rogoff, 2003; Peterson, 2009). Everyday experiences that build knowledge and skills are critical for young children's early scientific and mathematical learning, two areas that have been understudied in preschool settings but are critical for subsequent school achievement (Duncan et al., 2007; Linder, Powers -Costello, & Stegelin, 2011; Peterson, 20 09). Reggio Emilia is a social constructivist early childhood approach with a holistic view of learning and development, in which children are viewed as active agents or "researchers" who construct their own knowledge and teachers serve as co -learners and guides who help to facilitate children's discovery and learning in ind oor and outdoor environments (Hewitt, 2001). The garden was selected as the research context for this observational study because growing, harvesting and eating the produce are authentic, engaging and meaningful experiences that provide numerous opportuni ties to practice and develop mathematical and scientific skills and reasoning, as well as to build ecological awareness and an affinity and respect for the natural world.

Early math and science experiences within a social constructivist perspective

Young children's developing knowledge and skills are constructed through participation in dynamic and reciprocal cultural practices and traditions (Kumpulainen & Renshaw, 2007; Rogoff, 1990; Vygotsky, 1978). Research on mathematics, for instance, has highlighted the diverse pathways through which authentic problems are solved in social situations in various cultural contexts, including the extensive measurement practices of the Kpelle in Liberia, arithmetic expertise of street vendors in Brazil and purchasing kno wledge of elementary school African American students in an urban neighborhood (Nasir, Hand & Taylor, 2008). Findings from cross -cultural studies confirm the premise that these culturally relevant, routine experiences across contexts "both shape and const itute our learning" (Nasir et al., 2008, p. 193).

Scholars have emphasized the importance of young children's early math and science learning in the course of everyday activities, but there is a dearth of research on how much, and under what conditions, children incorporate mathematical and scientific understandings into the course of daily activities (Tudge & Doucet, 2004). More research examining young children's use of math and science concepts in daily activities is needed, especially considering tha t mathematical knowledge at school entry has been found to be the strongest predictor of subsequent school achievement (Duncan et al., 2007).

In early childhood educational settings, a social constructive approach to teaching math and science includes a curriculum with a diversity of engaging, meaningful activities and an inquiry -based approach in which teachers ask children open -ended questions designed to facilitate problem -solving and reasoning (Gelman & Brenneman, 2004; Linder et al., 2011). Recent research suggests that children need repeated exposure and practice using relevant math and science language in the context of interconnected, meaningful activities (Gelman & Brenneman, 2004). According to Clements (2001), high quality preschool approaches should "invite children to experience mathematics as they play in, describe and think about their world" (p. 270). In his view, based on extensive research and practice, preschool teachers should plan activities that simultaneously involve cognitive, soc io -emotional and physical development, and build on children's informal knowledge and experiences. A holistic approach acknowledges and extends preschoolers' high levels of motivation and self -directed learning.

The Reggio Emilia Early Childhood Approach

Reggio Emilia is an internationally recognized holistic early childhood education approach, founded by Loris Malaguzzi after WWII as part of a post -war reconstruction effort in the Italian city of Reggio Emilia (Edwards, Gandini, & Forman, 2012). Researc hers have increasingly turned to Reggio Emilia as an exemplar of a high -quality social constructivist approach (e.g., Clements, 2001; Edwards et al., 2012; Edwards & Willis, 2000; Hewitt, 2001; Inan et al., 2010; Kim & Darling, 2009; Linder et al., 2011). In the United States and elsewhere in the world, the term "Reggio -inspired" has come to symbolize early childhood educational approaches that incorporate many of the central tenets but also adapt the pedagogies to their own unique cultural context.

Reggio -inspired pedagogies feature a child -centered approach in which children create meaning from daily life experiences through planning, coordination of ideas and abstraction (Gandini, 2012). The teacher's role is to facilitate learning through listening and knowing when to intervene. Through a process of documentation, teachers capture ongoing learning processes in photographs and detailed transcripts of the children's activities. Long -term projects based on children's enthusiasm are co -constructed between a dults and children (e.g., Ghirotto & Mazzoni, 2013). Foundational principles of Reggio Emilia include the following: the idea of multiple intelligences (known as *hundred languages* in Reggio Emilia); the importance of design and aesthetics in the physical environment; collaborative relationships between children and adults in the community; and attention to all aspects of diversity (Edwards et al., 2012).

The Reggio Emilia approach encourages children to engage with math and science in the course of dail y events inside and outdoors. By engaging in inquiry, or the processes of observing, questioning, predicting and evaluating, children construct knowledge and learn to coordinate evidence and theory, particularly when guided and encouraged by adults (Bourn e, 2000; Inan, Trundle, & Kantor, 2010). In a qualitative study of natural sciences education in a Reggio -inspired preschool, Inan et al. (2010) found that children's inquiry was a high priority for the teachers because they believed it was the basis for c hildren's abilities to make sense of the world. Inquiry was fostered through a science - rich culture, and the use of science terms such as "theory," "hypothesis" and "prediction" were often observed in teachers' and preschoolers' language. Questioning, se arching, and investigating were valued and utilized rather than having teachers deliver facts (Inan et al., 2010). Thus, the emphasis was on science *process* skills utilized in the course of everyday experiences.

Another central theme of Reggio -inspired p reschools is that the natural environment is a third educator (Torquati & Ernst, 2013). Educational spaces are designed to be welcoming, aesthetically pleasing and supportive of multiple ways of learning. Reggio educators utilize a diversity of materials and experiences that afford different possibilities for actions on the environment (Edwards & Willis, 2000). While outdoors children can explore natural phenomena such as changing seasons, the habitat of animals, or growing food crops. Extant research sup ports the conclusion that outdoor environments can foster holistic and integrated learning, particularly when teachers believe in the benefits and provide educational opportunities and guidance (Ernst & Tournabene, 2012; Maynard & Waters, 2007). Reggio -in spired schools utilize outdoor spaces to increase children's awareness of the natural world as they participate in ongoing projects and play outside throughout the seasons. Gardens are a prominent feature, teaching children about topics such as taking care of land and growing fo od (Thornton & Brunton, 2009).

Gardens as a context for learning

School gardening has become increasingly popular as a context for learning in which children construct new knowledge, learn cultural and societal values related to e cological awareness, and develop and practice authentic or real -world skills (Blair, 2009; Bowker & Tearle, 2007). Extant research on school gardens has focused on food systems ecology and nutrition education, the benefits of positive experiences with the natural world and environmental stewardship, and learning outcomes related to math and science -education opportunities (Blair, 2009; Chawla, 2007; Miller, 2007). In an international project investigating children's experiences in school gardens, Bowker and Tearle (2007) found that children developed complex conceptual maps linking their gardening experiences and knowledge with ecological awareness. Children in all three countries also had strong positive affective responses to gardening. Miller (2007) fou nd that when participating in garden activities, young children developed important skills in a breadth of domains, including personal growth and academic learning. Research by Skelley and Bradley (2007) showed that third -grade students who participated i n gardening activities had positive attitudes towards science, and that teachers reported using gardens to instill positive environmental attitudes. Parmer et al. (2009) found that gardening was associated with positive influences on children's vegetable consumption and preferences, as well as increased fruit and vegetable knowledge.

In the United States, the number of school gardens has increased considerably in recent years (Lekies & Sheavly, 2007; Skelley & Bradley, 2007). However, t he majority of res earch on school gardening has been conducted in elementary school settings, and less is known about preschoolers' interactions in this context (Blair, 2009; Miller, 2007). In addition, little is known about how children's interests in gardening develop ov er time (Lekies & Sheavly, 2007). Preschool is an ideal time for learning about the environment, given children's interest in the natural environment and their developmental readiness for observation and hands -on learning (Witt & Kemple, 2007). Through the ir experiences in the natural world, children not only learn to enjoy their time outdoors but also prepare to become environmental stewards (Chawla & Cushing, 2007).

PURPOSE AND DESIGN O F THE STUDY

The present research was a longitudinal case study of children's interactions with a teacher in a garden at a Reggio -inspired preschool in the United States. The study was grounded in a social constructive, Reggio -inspired pedagogical approach. An observ ational design enabled the researchers to study naturally occurring behaviors and discourse as children and their teacher worked in the garden throughout the school year. Social relationships and communication are cornerstones of the Reggio approach, and analyzing discourse provides one way for researchers to understand the role of social interaction for children's learning processes (Kim & Darling, 2009).

The primary research questions were as follows: (1) W hat math and science experiences are afforded to young children while participating in gardening activities through out the year with their teacher ? (2) Does working in the school garden provide opportunities for preschoolers to develop gardening knowledge and ecological awareness? and (3) What were children's affective responses to gardening?

Method . The present study utilized a single - site case study design, with purposeful sampling of a Reggio - inspired preschool in the Southeastern United States that incor porates children's work and play in a garden into the regular curriculum throughout the year (Creswell, 2007). Children and the teacher's interactions in the garden were filmed by the second author as part of a study on outdoor contexts of learning at the participating preschool. She was a familiar but unobtrusive observer and the children were accustomed to her presence and to being recorded since she was related to one of the teachers, visited the school often and filmed throughout the year for several d ays each week. Additional sources of data included interviews with the children and the teacher. The research received approval by the University Institutional Review Board and parent permission was obtained for all participating children. All teacher and student names reported here are pseudonyms, and permission to include the photos was obtained from teachers and parents.

The Preschool . The preschool has mixed -age grouping with a total of 12 3 - and 4 -year -old children who attend the school for two or t hree years. The school is part -time with students attending four days a week from 8:30 a.m. until 1:30 p.m. In addition to a Reggio -inspired pedagogical approach, the preschool adopts a unique approach to outdoor education, with a seamless indoor -outdoor e nvironment in which children can move between spaces at will. The school's garden is connected to an extensive outdoor playground, and is maintained throughout the year by the children and teachers (see Figure 1).

Figure 1: Photo documentation in the preschool garden

Participants . The participants were 11 mixed -aged preschoolers (5 males, 6 females) ranging in age from 33 to 59 months at the beginning of the study. Six of the children were Caucasian, two were African -American, two were Asian, and one was Latino. Based on a demographic survey administered to parents, average reported family income was greater than the U.S. average. Although both of the teachers participated in the larger study, only one of them was the focus of this observational study . Sharon was a 43 -year -old Caucasian woman who had been a teacher at the school for six years. She developed and implemented all activities related to the garden.

Data Collection . The video -recordings were made over nine days between September 2012 and April 2013. There were five observations in the fall and four in the spring totaling 444 minutes, ranging from 23 to 72 minutes per day (see Table 1). For most activities, small groups of children came in turns to work in the designated garden bed.

Table 1
Description of garden activities

Day	Total Duration (minutes)	Description of activities	Season
Day 1	23	Harvesting first green beans; snipping herbs	Early Fall
Day 2	29	Digging for potatoes	Early Fall
Day 3	68	Planting broccoli, brussel sprouts, greens	Early Fall
Day 4	56	Harvesting green beans	Mid Fall
Day 5	44	Weeding garden beds	Late Fall
Day 6	72	Planting potatoes	Early Spring
Day 7	23	Planting sugar snap peas	Early Spring
Day 8	60	Planting lettuce, strawberries	Mid Spring
Day 9	24	Drawing the garden	Late Spring
Total time	**444**		

As part of the normally scheduled activities, the teachers conducted interviews with all children in October, February and May. Three questions were added to these interviews for the purpose of this study including what the child liked to do, found hard to do, and did not like to do in the garden. Children's responses were audio - recorded and transcribed by the teachers as part of their normal documentation.

The participating teacher was interviewed in August and May using a semi -structured approach. She was asked about the role of outdoor environments and specifically about the garden as a context for preschoolers' development, and her role in supporting these experiences. The interviews were audio - recorded and transcribed verbatim.

Data coding and analysis . Recording of each day was continuous, and each video recording was transcribed verbatim. Coding was conducted by simultaneously watching the video recording and consulting the written transcript. Video -recordings were coded in entirety and independently for each coding scheme. Coding schemes were developed a priori based on extant research, and revised during subsequent coding sessions. Videos were watched multiple times, with carefu l scrutiny of the written transcripts and researchers' notes. Reliability was assessed in the development of each coding scheme and coders had to attain a minimum of 75% agreement on 20% of the sample. Using a constant comparative method, relevant comment s from the teacher and children's interviews were also included in the analyses (Flick, 2006).

Math experiences . Developmentally appropriate mathematical concepts were selected from *Big Math for Little Kids*, a mathematics program for pre -kindergarten and kindergarten children developed by Ginsburg and colleagues based on their extensive research in early childhood settings (Greenes, Ginsburg & Balfanz, 2004). There were five primary categories of mathematical discourse observed in the present study, inclu ding *number concepts* (number word labels, counting), *number operations* (addition and subtraction, fractions), *shape* , *size estimation and comparison* , and *spatial orientation* . Definitions and examples of each code are presented in Table 2. In the developmen t of the coding manual, codes that were ambiguous or not observed in the data were dropped. One utterance could be coded for multiple math concepts, as in the statement, "Those are the tall collards and then there is that spiral" which was coded for size e stimation (tall) and shape identification (a spiral). Math concepts were coded separately for usage by the teacher and the children. Each category was coded at the utterance level, and repeated comments were not double - coded unless the conversational partn ers changed (e.g., the teacher asked a different child the same question).

Table 2: *Math experiences* [1]

CONCEPTS	DEFINITION	EXAMPLES	FREQUENCY [2]
Number concepts : Number word labels 1-1 C orrespondence Counting	Using a number word to refer to quantity of objects; Matching each member of a set to one number when counting; saying one number for each object	"I found 3 green beans." "12, there's one for each kid." "How many did we get? 1, 2, 3, 4, 5, 6 …"	Teacher: 134 Children: 77
Number Operations : Addition & Subtraction Fractions	Understanding properties of groups of objects; Putting together and taking apart operations; Understanding parts of a whole	"We'll plant 3 and 3 and 3 to make 9." "Break it in half, like bending it in two."	Teacher: 20 Children: 4
Shape	Recognizing shapes and their properties	"That's a heart -shaped leaf."	Teacher: 16 Children: 5
Size Estimation and/or Comparison	Comparing the size and/or length of objects	"Oh look at that huge sunflower, it's bigger than the one over there."	Teacher: 236 Children: 105
Spatial Orientation	Relative location and size of objects, often in relation to self and others	"Bend it so the sea m is going up towards the sky."	Teacher: 336 Children: 38

[1] Based on Greenes et al. (2004).
[2] Total number of codes observed over nine activities for a total of 444 minutes in the garden.

Science experiences. This coding scheme was developed based on prior research on science education in early childhood settings with a focus on science process skills (French, 2004; Gelman & Brenneman, 2004; Gerde, et al., 2013; Inan et al., 2007). They included the following: observing and questioning, predicting and evaluating, comparing, and classifying. The observing and questioning code was applied only to children's comments but the remaining codes were applied to discourse by the children and the teacher. As with math concepts, each category was coded at the utterance level, and repeated comments were not double -coded unless the conversational partners ch anged (e.g., the teacher asked a different child the same question). Definitions and examples of each code are provided in Table 3.

Table 3
Science process skills

CONCEPTS	DEFINITION	EXAMPLES	FREQUENCY [1]
Observing & questioning	Noticing and wondering	"I see something on the ground." "What are those flowers called?"	Children: 148
Predicting & evaluating	Making a guess and using evidence to check	"It looks like there's been caterpillars on here 'cause there's little tiny holes on it." "Look at this picture, and tell me what you think is going to grow there?" "Why do you think so?"	Teacher: 69 Children Predicting: 68 Children Predicting & Evaluating: 22
Comparing	Pointing out similarities and differences between objects and events	"See that little tiny seed, it looks like the big seeds down at the creek." "This is thicker, like a broccoli stalk."	Teacher: 86 Children: 29
Classifying	Organizing information into categories or meaningful units	"So all these herbs we put in, oregano, thyme, parsley, and that might be a different kind of parsley."	Teacher: 14 Children: 3

[1] Total number of codes observed over nine activities for a total of 444 minutes in the garden.

Gardening knowledge and ecological awareness . The coding scheme was based partially on research by Bowker and Tearle (2007) and modified for the context of the present research. Communications between the teacher and children were coded in the following categories: strategies for gardening; identif ication of plants and animals; the life cycle of plants; growing plants for food; use of gardening tools; protecting animals in the garden; climate and weather; composting and recycling. Only one code was assigned to each conversation about a particular c oncept, but dialogue ranged from one utterance to multiple exchanges between the teacher and children on the topic. Examples of each code are depicted in Table 4.

Table 4
Communications related to gardening knowledge and ecological awareness [1]

CONCEPT S	EXAMPLES	FREQUENCY [2]
Strategies for gardening	Navigating the garden beds (e.g., stepping where there are no plants and reaching through the trellis to pick beans); Estimating number and width of holes for planting	358
Identifying plants & animals	"There's an onion." "I see a cricket in the bucket." "Those are brussel sprouts and collard greens."	Children Plant ID: 36 Children Animal ID: 16 Teacher Plant ID: 130 Teacher Animal ID: 10
Life cycle of plants	Growing plants from seed; Leaving small beans on the vine to grow; Pulling out dead plants	119
Plants as a food source	Harvesting green beans and eating them; Distinguishing edible and inedible flowers	45
Knowledge and use of tools	Using spades for planting and larger shovels for digging; Mounding the dirt around the plants with hands	62
Protection of animals	Avoiding caterpillars when snipping parsley; Putting worms back in the dirt; Leaving a bee alone	18
Climate and weather	Knowing sun and rain are important for plant growth	13
Composting and recycling	Using leaves for compost; Using collected rainwater in garden	19

[1] Although the teacher most often provided guidance and information related to gardening knowledge and ecological awareness, occasionally children communicated these concepts with each as well. This was most frequently observed with plant and animal identification, as noted here.
[2] Total number of codes observed over nine activities for a total of 444 minutes in the garden.

Affective responses . Multiple viewin gs of each video segment afforded the opportunity to assess the affective responses of the children. Positive and negative affective statements were noted, and the overall tone of each day was assessed based on the predominant mood of the majority of chil dren. In addition, singing and playing were added to the coding scheme post -hoc. The frequency of these events was noted for each observation. In addition, children's interview comments reflected their affective responses to the garden and representative q uotes were included in the analyses to illustrate themes (Creswell, 2007).

RESULTS

Math experiences . The frequencies of math -related talk by mathematical category and speaker (teacher or child) are portrayed in Table 2. Analyses are presented with transcript examples below.

Spatial orientation, size estimation and comparison, and shape identification. Spatial orientation was the most frequent mathematical concept observed in the teacher's discourse across all the observations, with a total of 336 instances across 9 observation days. Teacher guidance for spatial orientation often occurred in the context of planting, as she talked about covering stems, pushing the dirt in pathways, and getting the plants to stand up by "carefully pushing the soil up around the stem of the plant to see if you can make it stand up tall," (see Figure 2). In the transcript example below, Sharon (the teacher) used extensive guidance for spatial orientation as she helped two children plant broccoli, brussel sprouts and lett uce.

Sharon : *So Brian, how about you do the hole right there? Anthony, you do the hole right here. See if you can spread them out enough. So the idea for planting is if you go straight down and kinda do like a corkscrew. Can I demonstrate once and then you guys can try it? I'll try it on this hole over here. So check it out Brian, if you go down, give it a little twist and then just take that dirt straight out, and put it on the soil.*
Anthony : *I can do that.*
Sharon : *That way you're going down and back out, instead of making a big wide hole you're making a straight -down hole. Wanna try it? How about right here Anthony so then we're on this sort of imaginary line we made? Can you come over here and dig?"*

In this exa mple, children were reminded about their own position in the garden and the spacing of the plants in rows ("this sort of imaginary line we made"). Connections between their actions and the physical space were also established, with instructions on how to "dig down" with tools to make "big wide" or "straight down" holes, and make the plant "stand up" by moving the dirt with their hands. During each gardening activity, Sharon provided numerous opportunities for children to consider the position of their own bodies relative to the garden spaces. For instance, she guided children's navigational skills as they maneuvered through an arched trellis to pick green beans, telling one young girl:

"There's some on this side, Olivia. Remember sometimes you can go on the outside of the tunnel. I think it would be okay to step into the bed right here (pointing). See where there's nothing growing on that dirt? So if you want to step in there you can."

Figure 2: Teacher guidance emphasized spatial orientation dur ing planting

Children initiated talk related to spatial orientation 38 times. Although their references to spatial positioning were less frequent and less complex than the teacher's, their talk reflected basic understandings of location and space.

For example, one child told Sharon as they planted corn seeds, “It’s deep in there. And it’s trapped in a big hole.” Repeated engagement in gardening experiences throughout the school year fostered opportunities for deeper understanding. In a late spring plan ting Sharon consulted with the children on where to plant lettuces and strawberries, and they helped her consider factors such as amount of sun, depth of planting and distance from each other: “We don’t want them so close that if they’re neighbors, they bu mp into each other.” Some of the more sophisticated references to spatial orientation were observed on the last day, as the children drew the garden. Sharon brought stools, a drawing pad and pens to the garden and asked the children to sketch “the way th e garden looks to you, right now.” She provided extensive guidance that encouraged children to consider different perspectives and symbolic representations in their drawings, asking what they noticed and pointing out features of the plants (e.g., “look at the way that stem is curved”). On this day she told one young child, “You navigated that space very well!” as she found a spot to draw next to her friend. In the excerpt below, another child noted his position relative to the garden beds he was drawing, and used size estimation and spatial orientation in describing his view to the teacher:

> *“Now I’m drawing those, those big yellow flowers in the bed diagonal to that bed there with those, just that tiny group of those flowers.”*

Size estimation was the next most frequent category of math talk, with 236 instances for the teacher and 105 initiated by children. The teacher and children referred often to the size of plants, the holes they were digging, and the tools they were using (e.g., big shovels versus small spades). Sharon often combined talk about size with spatial orientation in her guidance, as in the first example below where they were planting potatoes and in the second example when they were picking green beans. Each type of math code is identified in italics in parentheses, with *SO* signifying spatial orientation and *SE* size estimation.

> “And then put the potato down there, yeah, put it with the eyes facing up (*SO*). And then make a new, make that mound back again, so both of you guys put lots of dirt so it makes a nice big pile here (*SE*). ”

> “In this space there are green beans, however you must climb into the bed to find them (*SO*). Some of them are too little, like … look at these little things Olivia (showing small bean s on a plant hanging overhead). Find some nice big ones like those (*SE*). You just gotta go on a search, a hunt of sorts. Going in the green bean forest. … Keep going around this way you’ll find a bunch (*SO*).”

As they picked green beans, the children r eferred to the “skinny beans” that still needed to grow and the “big ones” that were ripe for picking. They navigated the locations of the beans, the trellis and their bodies as they reached up, around and through in order to pick the beans. They also dem onstrated understanding of size comparisons in their social interactions with each other. As they were harvesting gree n beans, one boy told his peer “Remember they have to be longer than a thumb” and held up his thumb to demonstrate (see Figure 3). Anothe r girl reminded a younger child of this same rule, telling her “Rachel, you need to have one as long as your thumb,” and showing her the long bean compared to her thumb. The teacher indicated that the older children were remembering this rule from a previo us harvest. Although the children discussed the size and appearance of the physical features in the garden, they rarely named specific shapes. Four of the five references to specific shapes occurred while children were drawing the garden (e.g., “I’m makin g a big circle”).

Figure 3: Two children demonstrate the rule that “the beans must be longer than your thumb” to be harvested

Number concepts and operations. The use of number concepts and operations was most prevalent during planting days. The most commonly observed number concept was use of number word labels, with 119 instances by the teacher and 56 by children. Children’s use of number words often indicated their developing knowledge number sense. In the following example, the use of a number wo rd implied that the child had counted as he snapped green beans, “I cut 3 pieces of green bean.” Use of number words also conveyed implicit understandings of quantity. One child estimated the large harvest as “maybe 175” beans. Although he didn’t count, he generated a high number as a guess.

The third day had the most frequent use of number words by the teacher (53), as she provided extensive scaffolding of children’s planting (e.g., “use your two hands to push the dirt like a bulldozer” or “put it in t he third row”). The example below demonstrates the integrated and connected nature of the math -related conversations. This transcript example includes number word labels (*NW*), counting (*C*), addition and subtraction (*A/S*), as well as predictions of the siz e and space needed for the plants as they grow (*SE* and *SO*).

Sharon : How can we figure out where nine plants could go in here? (*NW* ; *SO*)
Anthony : Like six, five, four, three, two. How, I know (counting on his fingers) 1, 2, 3, 4, 5, 6, 7, 8, 9, 10! (*C*)
Sharon : Nine altogether. Yeah, I noticed that they’re in these little rows (referring to the plastic containers the seedlings are in). So it goes, one, two, three. So we could do one, two, three and the second row, one, two, three could go in he re somewhere (showing them where plants could go in the garden bed). (*SE; C; NW; SO*)
Anthony : I’m I’m I’m counting my hand and see how much we could do! 1, 2, 3, 4, (counting on fingers) (*C*)
Sharon : Do you have enough fingers for it?
Anthony : 1, 2, 3, 4, 5, 6, 7, 8, 9 10. (*C*)
Sharon : So Brian what do you think? So three …
Anthony : (very excited) how ‘bout we how ‘bout we could dig a little … how ‘bout we could dig a *big* hole to put them in? (*SE*)
Sharon : So if we put them all in one hole I ’m worried that they would be too crowded because I think every plant can grow a big ol’ head of broccoli if it has enough space. So does that make sense to have three and three and three? Would that give us nine? (*NW* ; *SO; SE; A/S)*

Anthony : Oh man tha t's a lot!

As they planted the teacher noted "There's so much counting, so many numbers in gardening!"

Complex number operations like addition and subtraction and fractions were infrequent compared with talk about number concepts, possibly due to the difficulty of the concepts as well as the demand characteristics of the activities themselves. Math talk about fractions happened only on one occasion. After the green bean harvest, the children helped Sharon snap off the ends of the beans in preparation for cooking them for snack. She guided them to "snap it in half and drop them in the pan" and "snap in half, just go to the middle and snap." She and the children discussed the size of the beans and observed that they only needed to break the large beans in half; the tiny, skinny ones could go right in the pot.

Science experiences . The frequencies of use and guidance of science process skills are portrayed in Table 3. Children initiated 148 comments and questions. The high frequency of codes indicated children's curiosity and interest in their surroundings. Observations are the first step in the scientific process and serve as a foundation for more advanced conceptual thinking such as predicting and evaluating (Gerde et al., 2013). As noted by French (2004), the "cycle of inquiry begins with questions" (p. 143).

By adopting an inquiry style of guidance, the teacher encouraged children to make predictions about the natural world based on their observations. Responding to their observations and questions with "I wonder," or "What's your theory?" provided the impetus for the children to take their initial observations a step further and make a guess about what was happening or what they saw. Sharon also initiated children's predictions by pointing out interesting developments in the garden. For example, one day she showed children the developing onion bulbs on the plants and asked, "What do you think is happening inside of there?" The children took turns guessing, as in Daniel's prediction, "The onion is so strong it just pushes all the way up" and Olivia's hypothesis, "I think that the onion is coming from here all the way down here" (pointing to the stem). While digging for potatoes, Sharon offered the children a strategy for discerning the difference betw een the small hard potatoes and rocks, facilitating the science process skills of observing, predicting and evaluating, and comparing. She showed them how to tap each object against their rake in order to detect the differences in the sounds each made. A s they dug, they often asked her advice about whether they had found a potato or a rock. She replied with questions such as, "What do you think?" and "How could we tell?" before reminding them of the tapping strategy. Subsequently the children made predi ctions and tested them, and also compared the features of potatoes and rocks. This was challenging, as noted by Michael in his first interview in response to the question, "What's hard to do in the garden?" He replied, "Picking potatoes, because some lo ok like potatoes and some are really just rocks." Through these experiences, the children demonstrated emerging conceptual understandings of the value of using evidence to solve problems and the value of comparing features of different objects in order to identify them.

Occasionally children developed hypotheses without prompting, especially as they gained experience in the garden. In an early spring observation when the children were planting potatoes, Anthony commented, "I hope the ants are much more cozy underground." Sharon agreed, "I haven't seen any ants on top of the ground since it's been cold." He hypothesized, "Maybe bugs don't like it when it's cold. Well, polar bears like it when it's really really cold!" The preschooler drew on his past experiences in the garden and realized that unlike in warmer conditions, the ants weren't on the surface and therefore he predicted they must be underground. He also contrasted this with the habitats of polar bears. This example illustrates the integrat ion of science process skills and the sophistication of scientific thinking that can be achieved by preschoolers in authentic activities.

As noted above, comparing was a science process skill encouraged frequently by the teacher. Throughout the year she prompted children to observe the changes in the garden, such comparing the features and size of the plants as they grew. In Sharon's final interview, she commented on the children's observations of changes in the garden throughout the year.

> *"I think through the year, and I think this year in particular just because we were just a lot more intentional about going to the garden and looking and looking for changes, I think they – as a group – got*

> *so much better at that than kids have in previous years ... Just their noticing and interest in wanting to know how are the onions different today. Or how much bigger is the corn, where's that one I planted. So … the scientist and looking for changes was … a lot more acute... And while they were there, t hen they would notice bugs or dewdrops or the way the dirt looked different or something. I think it kind of awakened them, having the plants as the catalyst to look for something different. It sort of made them more aware of everything in there."*

Sharon' s reflections included the importance of intentional planning and the children's sustained engagement in the gardening activities. On the last observation day, a particularly high number of teacher -initiated comparisons were observed. Children came to the garden in pairs to draw the garden, "as it looks to you right now." Sharon walked through the garden beds and pointed out how certain plants had changed. She talked about the different vegetables and how they looked and tasted, comparing the flavors (e. g., the chive flowers are "very oniony" and "a little like garlic") and shapes (e.g., "this one looks sort of like a heart"). As they drew, she helped the children construct symbolic representations of what they were seeing, as illustrated in the transcri pt example below. Emma was an older child with more experience in the garden and Rachel was in her first year at the school.

Sharon : Did you draw the way the potatoes are looking today?
Emma : Potatoes. I'm gonna draw potatoes. I'm only gonna draw on e potato.
Sharon : But can you see the actual potato that's stuck in the ground?
Emma : No.
Sharon : Yep, you just see that little green part. So you look at the leaf and figure out the way it's shaped and how you wanna draw it. How it looks on this day . What's next, Rachel?
Emma : I just did a big mountain.
Sharon : Yeah, cause they're each on their own little mountain (referring to the potato mounds).
Rachel: Right now leafs are on the mountain.
Sharon : I know, it's got leaves on mountains. See, it looks like a little seed the way it's got the stalk coming up and then the leaves are coming straight off of this? What's that part, Rachel? Hmm, yeah, it looks like a little straight line coming up and then the leaves go off of it.
Emma : One straight line coming up!

After Sharon urged another child to show "what was happening" in the garden as he drew, he told her, "But you can't show how fast they're growing!" She laughed and then wondered, "How could you try to show that?" The last day also yi elded the majority of classifications, as Sharon compared features across groups of plants while the children made their drawings. Although children rarely initiated comments in this category, they participated in joint conversations with the teacher and h er guidance provided opportunities for them to consider abstract concepts such as categorization into meaningful units.

Gardening knowledge and ecological awareness . Frequencies of codes related to gardening knowledge and ecological awareness are presented in Table 4. The teacher frequently offered strategies for gardening that enabled children to navigate and position their bodies as they worked, with careful attenti on to the plants and the garden beds. The transcript example below illustrates the extensive guidance provided during complex and challenging gardening activities, and the integrated nature of the teacher's communications about the life cycle of plants, pl ant and animal identification, the use of tools, and strategies for gardening. Sharon introduced the activity to a small group of children who then began digging for potatoes until it began to rain steadily. They went inside but soon came back wearing rai ncoats. The children had decided to don protective gear and keep working (see Figure 4).

Sharon : Come under the bridge … through the tunnel of sunflowers. Let's see, this is where the corn has grown also but it just went in too early. We had that funny early spring. It's too early for us to harvest them. Alright, so these plants are actually potat o plants and they're growing, I think, from the potatoes that we grew. So we planted potatoes, the plants grew up, they made more potatoes, and those potatoes have been there long enough to make more plants … We are just gonna start digging and see what w e find. Kind of like a treasure hunt. So Sophie you can come on through, and then you can just start digging anywhere in here (pointing in the bed). So whoever is ready can just put a shovel in there . . . it works pretty well if you push it down along the edge cause you know you don't want to end up chopping right through a potato. So Michelle if you go on the very edge and Olivia you can go there or at the end. Sophie you can go on the end. (*She then provided more detailed instruction on the availab le t ools and the children began digging with shovels* .)

Sharon : Anything yet? And then what you do with your hands or with your shovel, sort of poke some dirt … Shovels are good for the edges but forks may be good for the middle.

Michelle : (point ing to som ething in the dirt) See?

Sharon : Did you find something?

Michelle : A worm.

Sharon : A worm, I did see that.

Figure 4: Digging for potatoes in the rain

As illustrated in Figure 5, children were encouraged to establish a physical connection with nature by digging in the dirt with their hands as they found potatoes or planted seeds. In the final interview Sharon remarked on the progress of two children who were initially uncomfortable putting their hands into the dirt and encountering bugs.

> *"I always called them the tool -lovers because they would always want a tool when they did stuff in the garden, and they got a lot – Daniel especially – got a lot mor e interested in just reaching in with his hand and just suddenly finding himself holding a potato and that was okay. Or moving something or moving the dirt with his hand or pushing it with his hand, which he wouldn't have done the previous year. So just ha ving all that experience and realizing what to expect from the dirt, realizing the bugs are not really that fast, knowing that you can get cleaned up. So having that practice in that space. There was a time where I saw him at (name of a neighborhood elemen tary school); we were putting down a whole bunch of compost and new dirt in the Peace Garden, which is this huge space, and he was in there just with his two bare hands, just pushing the dirt, massing the compost into the dirt. And he did it for half an ho ur, that's a really different boy. That repeated exposure. And the same thing, I think, for Matthew for bugs. He used to just always flinch at any sign of anything flying that wasn't a bird. So just being able to say, like when the carpenter bees came out this year, just saying "It's a bee. It wants to eat wood. It doesn't want me. You're right. Exactly right." All those things. And just feeling safe being in that place, "I've had that experience, it's happening again, I'm okay."*

Through their work in the garden children gained opportunities to value many aspects of the natural world. As Sharon's interview quote illustrates, children were encouraged to appreciate the value of insects in the garden through their ongoing experiences (e.g., "there's a bumble b ee on there and we're just kind of letting it do its thing"), and the value of re -using materials such as pouring collected rainwater onto the plants and creating and using compost for the garden. Sharon helped the children realize the fragile nature of y oung plants, for example as she handed a seedling to the child: "This stem, Brian, is so skinny that if it gets bent or pinched the whole plant might not survive. You have to be really careful with it. So let me put this in your hands… ready? And you'r e just gonna nestle it down into that little hole you made." The children also noticed when plants were dying and needed to be pulled out of the garden. These rich, personal experiences, guided by their teacher, facilitated children's understanding of th e complex nature of the life cycle of plants and their own interactions in the natural world.

Figure 5: Using her hands to dig for potatoes

In her first interview, Sharon described her beliefs about the importance of spending time in nature and facing the challenges afforded by spending time outdoors, as well as her role in supporting nature experiences at the preschool.

> *"… being in nature just helps improve your mood and your general wellbeing and outlook. I think just being outside with trees and nature and sky and breezes and being able to be out in the world … to have it as a place to learn and to discover and watch how changes come and go, and notice when new things are happening on the playground or in the gardens … all of that is just suc h a rich place to learn and be exposed and … open children's minds and imaginations to the possibility of how things are not just one way."*

> *" I'm technically the garden teacher so helping them to plant and water and weed and harvest in the garden and to ju st use that place as an outdoor classroom. There's so much that happens there for them to see from growing their own food that they get to eat to what the animals and the insects are doing out there, so using that as kind of a window on the outdoors a who le …. so much can happen in just that little space …and then just offering all kinds of play experiences outside for them that we offer inside as well so just kind of facilitating the outdoors as a place to work and play."*

Affective experiences**.** Many of th e transcript examples above illustrated children's excitement as they made discoveries and observations in the garden. Even when the weather presented challenges (e.g., in the pouring rain) the children chose to return to the garden rather than play insid e. They seemed to take pride in their work and despite ongoing physical challenges (e.g., digging in hard soil) their demeanor was almost always positive and enthusiastic. There were 29 overt statements expressing positive affect (e.g., "I love green bean s") and only 2 negative affective responses recorded during the observations (e.g., "I don't like spiders"). There were 31 instances of children singing and engaging in overtly playful behavior in the garden. For instance, on the day they harvested green beans, Michael began singing, "Hakuna metata, what a wonderful phrase!" and the children danced around the garden.

There were particularly high levels of excitement during the second green bean harvest in mid -fall; the vines were covered in beans, which the children enjoyed picking, and afterwards they helped Sharon prepare the beans for snack. In their interviews, children often cited this as their favorite part of the garden work. When asked, "What do you like to do in the garden?" in the fall intervi ew, Olivia noted, "I like picking green beans and then washing them and eating them!" Michael concurred with his statement, "Pick snap peas. 'Cause sometimes I like to pop some in my mouth and then put 'em in the bucket, pop in my mouth, put in bucket." The children often ate the raw beans as they picked and commented on how delicious they were. They were surprised and delighted with the knowledge that some flowers could be eaten, and most of them tried the edible flowers and reported liking them (see Fi gure 6). In her final interview, when asked if there was anything in particular she wanted to emphasize in the garden work, Sharon noted that she wanted the children "…to grow an appreciation of the food that they're growing and to be able to try them and taste them. From an idea that if they grow their own food, they're more likely to eat it."

Figure 6: Enjoying the edible flowers

In her mid -year interview, Emma affirmed her enjoyment of gardening in response to the question, "What do you not like about being in the garden?" with the reply "I don't not like anything about being in the garden. I really like the garden." Michael also gave an affirmative response to this question, " I just always like it" as did Daniel, "I like everything." However, in her third interview Olivia responded, "I don't like to be in the garden 'cause I don't like holding dirty, slimy slugs." When asked what was hard to do in the garden, children talked about digging and planting. Daniel expressed this sentiment in his third interview in May, "Like when you have to dig the hole to plant stuff, sometimes when there's hard soil it's hard." Maya summed it up, "Like digging. Like my hands get tired!" In the first interview Olivia commented, "Hard to do is find a green bean. They are hiding from me in the garden!" As these observations and quotes demonstrate, the garden provided a rich context for establ ishing physical, cognitive and socio - emotional connections to nature.

DISCUSSION

This was a case study of a Reggio -inspired preschool that incorporated children's work and play in a garden into the regular curriculum throughout the year. The results su ggest that children were afforded a diversity of engaging math and science experiences over the course of a year of working in their preschool garden. Through sustained participation in a wide variety of gardening activities with a teacher, preschoolers en gaged in science -rich dialogue utilizing complex and abstract science process skills such as observing, predicting and evaluating, and comparing. In accordance with a Reggio - inspired pedagogy, the teacher often employed an inquiry -based style of guidance characterized by questioning, hypothesizing and enthusiastically supporting children's interests. Researchers have suggested that children's scientific thinking and reasoning skills develop within real -world contexts as they participate in meaningful, goal -directed activities (Anderson & Gold, 2006; Gauvain, 1993; Lindner et al., 2011; Saxe & Posner, 1983), and the results of this study indicate that sustained participation in gardening activities with their teacher fostered numerous opportunities for presch ool children's to practice these skills.

Participating in a diversity of gardening activities throughout the year also enabled children to encounter a variety of math concepts in relation to the work they were doing. Spatial orientation was the most prevalent category of math talk employed by the teacher, as she guided children's placement of the plants and their own bodies with respect to the physical features of the environment. The observations of teacher guidance for spatial orientation support prior research by Franzén (2014), who found that teachers emphasized young children's bodily learning in the context of mathematical activities. In this study, the teacher supported children's learning through frequent reminders about the connections between their bodies, their actions and the physical e nvironment, fostering their awareness of space and spatial surroundings within a small but well -provisioned outdoor environment. Size estimation and comparison were also frequently mentioned concepts by both children and the teacher as they worked in the g arden. These experiences and the teacher's guidance contribute to young children's developing awareness that size, position and direction are relative to one's own point of view (Greenes et al., 2004). During early childhood, children develop number sen se or an awareness ranging from a basic understanding of the meaning of numbers to more complex and abstract number operations (Skwarchuk, 2008). Some basic elements of number sense include comparing number quantities and magnitudes, estimating and counti ng. In the garden, children often used number words as they communicated their work in progress. Comments such as "I found three!" indicated their developing sense of the use of numbers in real - world contexts. Children also counted spontaneously as they planted or harvested crops, occasionally using their fingers to reach higher numbers. The teacher offered contextual opportunities to develop complex understanding of numbers, such as asking children to problem- solve how many holes were needed for three r ows of three plants or how to fit three plants to a row.
In accordance with a Reggio - inspired pedagogy, the teacher's approach was holistic and integrated, in that she provided support for the preschoolers' physical, cognitive and social development durin g the gardening activities. In the garden, learning was embedded in meaningful activities and the observed social interactions between children and the teacher conveyed a shared sense of purpose, excitement and curiosity. There were common goals and shared meaning in each activity, ranging from preparing the garden beds to planting and eventually harvesting and eating the vegetables.

Supporting prior research by Bowker and Tearle (2007), findings from the observations and interviews confirmed that childre n had a developing sense of "eco -literacy" or conceptual knowledge of gardening and heightened ecological awareness, and also that they overwhelmingly showed enthusiasm for gardening activities. The children exhibited joyful behavior such as singing and la ughing, and rarely complained about the work. Even when the tasks were physically challenging, such as digging for potatoes in the hard dirt, children embraced the challenge and celebrated their work. No overtly negative interactions were observed through out the nine days and only a few negative comments by a child in response to a particular feature of the environment were recorded. For example, one child was dismayed to find an insect in her bucket while picking green beans, and the teacher elicited the help of a peer to move it to another spot in the garden. This response was indicative of the atmosphere of respect for the natural environment that was cultivated as children spent time outdoors. Throughout the year children were reminded to return worm s to the dirt or leave the bees alone as they landed on flowers in the garden. Thus, the affective context on each observation day was positive, and an atmosphere of respect and dedication to the ongoing work was prevalent. The findings also corroborated those of Parmer et al. (2009), who conducted an experimental study with second - graders and found that a nutrition education and gardening program positively influenced children's vegetable consumption. Children in this study were particularly excited abou t opportunities to eat their harvest, often consuming the vegetables and herbs as they picked them and helping prepare them for snack. Humberstone and Stan (2012) emphasized the importance of authenticity for children's learning in outdoor environments in the context of participating in daily routines with adult guidance. Authentic nature experiences are believed to shape life -long values, attitudes and behavior patterns toward the natural environment, and foster environmental stewardship (Chawla, 2007; Sob el, 1995; Wilson, 1996). Preschool gardens offer children the opportunity to participate in the authentic experience of growing their own food, and to develop an appreciation and respect for the natural world.

The research design was an observational stu dy of a small group of preschoolers and their teacher, and all of the interactions and discourse observed occurred naturally in the context of working in a school garden. Given the descriptive nature of this research, no causal explanations for the finding s can be drawn. In addition, the preschool adopts a unique pedagogical approach in which children are free to move indoors and outdoors throughout each day, and the school's mission includes a strong emphasis on the importance of outdoor experiences for ch ildren's well -being and development. Thus, it cannot be considered a representative early childhood educational setting in the United States. Despite the limited generalizability, however, the results have implications for early childhood educators.

Th e findings suggest the potential of a richly provisioned garden as an environment in which learning can be fostered through a holistic and integrated approach. For preschool teachers with adequate resources, planning a garden in which children can work th roughout the year affords diverse learning opportunities. Regardless of resources, all early childhood teachers can utilize guidance strategies supporting early math and science learning in the context of sustained, meaningful activities with a shared sens e of purpose and enjoyment (Gelman & Brenneman, 2004; Ginsburg & Golbeck, 2004). Further research with diverse populations and a variety of engaging activities in everyday contexts of learning is needed, and particularly in outdoor environments which offer a multitude of opportunities for holistic and integrated learning. Within a social constructivist framework, preschool teachers should work to provide rich experiences that offer authentic opportunities for development of the whole child, or in the words of Reggio Emilia, the *hundred languages* (Edwards et al., 2012; Gerde et al, 2013). The results of this study support the conclusion that with appropriate teacher guidance, a preschool garden affords myriad opportunities for young children to develop mathem atical and scientific thinking, ecological awareness and positive affective responses to the natural world.

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