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Planting Seeds of Numeracy: Supporting Quantitative Literacy in Young Children

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Abstract

This paper aims to present how quantitative literacy was made a focus in a preschool classroom of three- and four-year-old children. With a focus on examining two areas of quantitative literacy, number knowledge and counting (Jordan, Kaplan, and Locuniak 2007) we seek to explore how educators, within an early childhood setting, used a project approach (Katz, Chard, and Kogan, 2014) and inquiry-based practices to build and extend upon the emerging competencies of the children. Utilizing narrative inquiry (Clandinin & Connelly, 2000), we draw from planning meeting notes, lesson plans, and lesson artifacts to construct a story that chronicles the journey of these teachers and children, attending to the ways in which both took up early learning standards related to numeracy and infused them into the classroom projects. Furthermore, we examine noticings of the teachers with regards to how the children expanded upon their abilities related to number knowledge and counting throughout the project and school year. As we reflect upon the journey, we note how project work served as a vessel for this knowledge to develop, as well as the need for these elements to be examined and planned for during the early years so that young children can demonstrate their learning in the clearest way possible.

Keywords

early childhood, number, numeracy, counting

Cover Page Footnote

Jennifer Ward is an assistant professor at Kennesaw State University in Kennesaw, Georgia. She teaches mathematics methods courses in the Department of Elementary and Early Childhood. Her research focuses on preparing early childhood pre-service teachers to engage in using equity-based practices in teaching mathematics from birth to grade 2. Victoria Damjanovic completed her PhD in Early Childhood Education at the University of South Florida. She is currently the Director of the USF Preschool for Creative Learning and Affiliated Faculty in Early Childhood Education. Her research interests include inquiry-based teaching and learning with pre-service and in-service teachers, professional learning communities, Project Approach as a framework for children's inquiry, and documentation as a tool for teacher learning.

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Introduction

Rooted in using play and inquiry as a springboard for mathematics instruction, our school sought to build understanding of numeracy through explorations based on children's interests and integrated with other subjects. Our aim for this project was to show how children between the ages of three and five might engage in mathematics learning that builds from their own interests, thereby fostering a positive mathematics experience early on. Furthermore, we wanted to demonstrate how this process can be facilitated in young children's classrooms void of worksheets and direct instruction tasks. Rather, we demonstrate this learning can take place in a more constructivist form where children are actively involved in constructing new knowledge that builds on their experiences (Clements and Battista 2009). In order to demonstrate this learning experience, we share the story of one classroom of three- and four-year-old children and how they built competencies in numeracy. Examples of teacher documentation of children's early abilities in this area support this story alongside narratives of the instructional activities used in the classroom, with a closing glimpse of children's abilities following the project.

According to a joint position statement around instruction for early mathematical learning from the National Association for the Education of Young Children (NAEYC) and the National Council for Teachers of Mathematics (NCTM) (2002, mathematics teaching for children from birth through age five should be grounded in exploration, connected to children's own lived experiences and other subject areas. Through the use of project work, teachers plan for and young children are engaged in necessary areas involved in quantitative literacy, which Jordan et al. (2007) identify as number knowledge, counting skills and principles, non-verbal calculation, number combinations, and story problems. Specifically, within our space, children and teachers were focused on the first two of these core ideas: number knowledge and counting skills and principles, both essential within the mathematical work of three to five-year olds. Work in the area of number knowledge in the early years rests in exposure and experiences in written number representation, early counting and correspondence, joining and separating situations and magnitude of number (Maclellan 2012). Furthermore, counting skills and principles seeks to attach a counting name to an object being counted and responding to questions and inquiries regarding the quantity of items in a set.

These areas served as a focus for teachers working to prepare in-depth classroom learning experiences that connect both interests of children with relevant mathematics content. Through the careful attention to these areas of quantitative literacy, teachers were able to follow the lead of children, noting where they were in their development of related numeracy skills, and designing experiences which built from these points to further children's conceptions of number.

Defining Project Work

The project approach is a framework used to enact curriculum that utilizes an inquiry approach to teaching and learning. Using an inquiry model, children investigate the world around them through hands-on exploration. Projects are broken into three distinct phases (Katz et al. 2014), outlined in Figure 1 below. In Phase 1, children share existing knowledge and artifacts from home, and they discuss what they know on the topic of interest. Children might tell memory stories or do a memory drawing to share their experiences with the topic. Teachers and children create a web of this knowledge to identify what children already know and conceptions or misconceptions the children might have. Through classroom discussion the children come up with research questions which will expand their existing knowledge. In Phase 2, children begin to investigate and collect data to answer their research questions. The children use both primary sources and secondary sources to find the answers to their questions. They explore and investigate by touching, looking closely, visiting with a field expert, or whatever they might need to do to answer their questions. Teachers use this opportunity to incorporate additional content areas while children seek to answer their questions. As they conduct research on the topic, children begin to represent their understandings. For young children, multiple modalities help to unpack what they know. Some examples include both 2D and 3D models such as drawings, construction with blocks or tangible materials, clay, paint, and written representation. During Phase 3, children disseminate their work by sharing their knowledge. This too can take many different forms depending on what the children are studying. Classrooms might have a showcase sharing their work samples and creations. They might create a book, put on a show, unveil something they created, or go to other classrooms to teach others what they learned. No matter the topic of study, teachers are able to create opportunities for children to engage in math, science, social studies, and literacy in an authentic way.

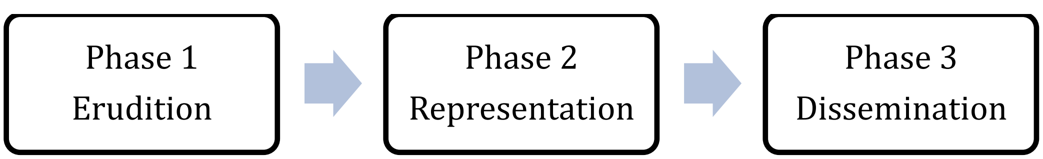

Figure 1. Phases and corresponding purpose

In exploring ways to connect outside numeracy with classroom practices highlighting counting, our foci rested on where these intersections existed, and how we might leverage outside-of-school experiences as springboards to learning in counting and cardinality. In doing so, we worked closely with both veteran and novice teachers to creatively embed counting practices into inquiry-based projects

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explored in the three- and four-year-old classrooms. Throughout collaborative planning sessions, we worked with teams to develop inquiry-based learning experiences where children counted objects, recorded counts, measured objects, and explored the ways in which numbers are represented in their world. The teachers meet weekly with the Director to brainstorm ideas for the project and select lessons for each content area. These meetings are collaborative spaces where teachers get to be creative and think outside the box. Afterward, discussion takes place about the materials and other practical considerations. The teachers and Director then go through the plans carefully to ensure all content areas (e.g., math, social studies, literacy, science, and art) are met.

Building Numeracy

When children enter school with backgrounds and experiences shaped by their home and community funds of knowledge (Moll et al. 1992), they bring with them theories and ideas about number and quantities. These ideas include the ways in which quantities are represented in both symbolic and abstract form, as well as ways of interacting with these quantities. The focus of this work was to document the methods in which young children were involved in representing and comprehending numerical quantities, an area of numeracy noted by Vacher (2014, 11) that draws from word sense 1, "skill with numbers and mathematics," and word sense 2, "ability to read, write and understand material that includes quantitative information such as graphs, tables, mathematical relations, and descriptive statistics." Operating under these ideas, we find numeracy to be strongly connected to the domain of counting that is a focus of early learning.

Counting can be considered the first and most basic algorithm for young mathematics learners, as it has connections to algebraic thinking later on (Clements and Sarama 2014). The Florida Early Learning Standards for three- and four-year-olds in our state also include big ideas related to number, including number meaning, relationships, and magnitude within this domain. With an instructional emphasis on number meaning, the focus of many early learning classrooms rests in the symbolic representation of numbers, cardinality, and answering questions related to quantity such as how many, how much, and what part of (Van DeWalle 2018). Within these early counting practices teachers also spend time engaging students in verbal counting, in which children work to connect counts of up to 25 objects.

Methods

Aiming to draw upon the lived experiences of the teachers, children, and researchers within the school, we used narrative inquiry as a method to examine our experiences in developing lessons linked to quantitative literacy for young children. Following a prior project, the teachers and researchers were interested in exploring how they might focus on the development of number more readily during their upcoming project. As we began to prepare for the project, including its planning and implementation, we sought to study and chronicle our journey into developing these connections. Following approval from the Institutional Review Board to study our work as occurring in a classroom setting, we began to document the project.

Within the use of narrative inquiry, researchers are committed to understanding the lives and lived experiences of others as they are occurring (Clandinin and Caine 2012) and to later use these past experiences to construct meaning for the future (Connelly and Clandinin 2000). By collecting documentation of planning meeting notes, lesson plans, and teacher and child artifacts, we worked to track these experiences and present our journey using narrative writing (Hamilton et al. 2008) so that others might enter into our journey and consider ways in which their future work around number with young children may evolve.

It is through the following narrative of our classroom project that we capture the story of developing these lessons, a key benefit of narrative inquiry (Clandinin and Connelly 2000). As such, we layer in our own reflections related to how we pushed ideas of numeracy to the forefront of teacher planning in order to support children's development in these areas. As part of the narrative, emphasis is placed on providing contextual information related to the social phenomena occurring at the school during this time.

Our Setting

The USF Preschool for Creative Learning (PCL) at the University of South Florida (USF), is an NAEYC-accredited teacher educator lab school in partnership with the College of Education. Located on campus, the school serves families of USF students, faculty/staff, and the local community. The children enrolled range in age from two to five years old. The school is relatively small, with a total of five classrooms. The two five-year-old classrooms are part of Florida's Voluntary Prekindergarten (VPK) program. The PCL strives to exemplify an inquiry approach to teaching and learning, innovating, and improving early childhood education through teacher education, research, and community engagement. The mission of the school is to provide a site to demonstrate, observe, study, and teach exemplary practices in early childhood education.

Teachers at the PCL have degrees (undergraduate and/or graduate) in early childhood education. Through partnership with the early childhood program faculty on campus, faculty at the PCL engage in professional development related to the vision and mission of the school, as well as the needs of the children. This partnership has included a focus on enhancing mathematics instruction for young

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children through play, as well as ways of documenting children's learning in mathematics via anecdotal records, interviews, and work samples. For the children in this setting, project work served as the medium for a connection between mathematics and their own experiences and interests. Children and teachers at the school also used project work as a platform to foster mathematical practices such as problem solving, reasoning, communication, and construction of models or representations.

The 20-student three- and four-year-old classroom we chronicle in this project consisted of a lead teacher engaged in her doctoral work at the university and an undergraduate pre-service co-teacher. This particular teaching team co-planned on a weekly basis with the school's director and mathematics instructional faculty to ensure they were addressing the Florida Early Learning mathematics standards with the project. The teachers would come to a planning session with a fluid plan for the following week. They would discuss what took place during the current week (the time in which we were meeting), and areas in which they felt children might need to revisit specific standards based on collected assessment data. Once they shared their data and creative ideas for the following week with the director and mathematics faculty, the team formulated a plan to ensure that mathematics standards connected to counting and cardinality would be met.

Budding Abilities in Numeracy

In working with the teaching teams to determine steps for instruction and integration of mathematics across the project, we wanted to consider where the children were currently in their understanding of number. Consulting the statewide assessment they took for VPK was one route, but our teaching team critically examined the assessment and found problems with using an assessment geared toward procedural thinking. While children were subject to the assessment given by the state as a result of their attendance in a VPK program, many of the assessment items on the state assessment were written in ways that did not lend space for the children to engage with mathematics in developmentally appropriate ways (Ward and Vomvoridi-Ivanovic 2017). Problems included a lack of opportunities to use manipulatives or engage in discourse around mathematics. The assessment highlights three areas: numerical relations, counting, and arithmetic reasoning, with a total of 13 questions. These same 13 questions are administered two to three times per year, depending on a child's initial score. For the above reasons, the teachers sought a more authentic representation of what children could do in mathematics. We can report that on the initial assessment, given during the beginning of the school year, approximately 12 of the children scored greater than 10 out of 13 on the assessment, which put them above the 70% threshold the local school district considers mastery on assessments.

As teachers at the school engaged in the purposeful and systematic collection of work samples from the children, they collected documentation demonstrating the emerging understandings as connected to standards for counting. This documentation came from a combination of observations, children's work samples, teacher videos of children working, and photographs of children's work during the year. Throughout the school year, teachers collected informal data on children's work in counting collections and representing numbers. This data includes observations of children orally counting during the day. Instances of this oral counting typically occurred during morning meeting time, where children were involved in responding to categorical questions from the teachers, as well as during transitions and snacks/meals, where class members were counted aloud. We frequently noticed that children would correctly orally count up to 12, but would frequently produce errors during the teen numbers, specifically with the numbers 14, 15, and 17–19. Children would reverse 14 and 15 when orally counting and, at times, omit 16–18 altogether.

Beyond this, children used classroom materials, such as cubes or blocks, to count out sets of a given number. During these explorations, teachers reported that most students were approaching mastery to count out sets to ten, although some students needed additional time to develop one-to-one correspondence. The majority of the children were able to count out a set to five, but several began to produce errors in counting sets of six to ten. Specifically, children were unable to demonstrate components of cardinality, and would forget the number of items already represented in the set and continuously need to recount them. Although we recognized many of these behaviors as common according to the learning progressions proposed by Clements and Sarama (2014), we noted that we could use the abilities of the children, along with their interests to move their mathematics to deeper levels.

Growing the Project

One project centered around a garden being constructed outside of the children's classrooms, on green space adjacent to their playground. While the weather was warm enough to warrant planting sprouts and seedlings outside, the children were involved in planting seeds into a tower garden which was housed within their classroom. Children had taken to examining the seeds being planted within the garden and had been involved in a basic sorting of the seeds based on visual attributes including size, shape, and color. This daily occurrence was witnessed by the classroom teachers and other school-based personnel as they engaged with children on the playground, and in the classroom.

Teachers saw the children grabbing seeds from various packets which had been left out or left unburied in the emerging garden space. We saw these seeds being

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taken to picnic tables, then placed in small piles. Children continued to add to their collections during subsequent visits to the playground during the day. As we carefully listened in, dialogue emerged around what seed piles were being added to and why. Children started to explain their rationale for wanting to include a seed in one space or another, and some purposefully sought out new seeds to bring about new conversations and ideas. We saw this as an opportunity to introduce the idea of quantifying these sortings by counting, and later constructed graphical representations of these counts throughout all stages of the project. Through careful observations, work sample exploration, and collaborative planning, we supported a team of teachers in designing purposeful opportunities for mathematics engagement in their classrooms.

Phase 1

During the initial phase of the project, we worked with teachers to examine the standards related to number and brainstormed how they might tap into children's prior knowledge and experiences related to both seeds and counting. A first step to supporting children in developing their counting strategies rested in both determining how many objects to focus on when counting and using concrete objects to count. In determining how many objects to limit the counting exploration to, we guided teachers to look to both the standards at their particular age band (three- or four-year-old), but also the kindergarten standards for our state. Seeing as there was some overlap in the standards for four-year-olds and kindergarten-aged children, we decided to limit counts to 20 objects, with further modifications made to increase to 30 or decrease to 10 based on teacher observations of the children.

Research documents the use of concrete materials when counting as a beneficial practice for early counters (Clements 2000). Given that the scope of the project was gardening, children spent time examining the flowers and vegetables that were planted on the school grounds. Stemming from this interest, our instructional team decided to use actual seeds as counters. Beyond the exploration of the seeds in the playground and garden area at school, many of the children engaged in planting seeds for both flowers and vegetables at home with their families, so a connection to home experiences and learning was evident. Additionally, the idea of needing a certain number of seeds to plant in the garden provided a real-world context for our children, such that they saw how mathematical thinking was authentically connected to their world.

Teachers constructed opportunities for children to build from their earlier work counting collections by having children create groups of given numbers, beginning with 1–10 and later extending (Fig. 2).

Figure 2. Counting collections of seeds

This activity moved children toward creating collections with larger values, which ultimately was the standard being addressed. For children who needed support with one-to-one correspondence, teachers used foam to create "seed holes" in which the children could "plant" one seed per hole, orally counting as they progressed to 20.

Phase 2

Within the second phase of the project, as the oral counting of seeds progressed in the classroom, children became naturally curious as to the number of plants on the playground and around the school. Children could be seen traveling in groups during outdoor play orally counting these items on the playground and using their fingers as a representation for each one. Children problematized that they did not have a way to hold more than ten plants when counting and began to include more children in the group to utilize their fingers as a means of recording the counts. Several children began to note that this strategy was difficult, as when and if someone accidently put a finger up or down too soon, the count was lost. Quickly, children asked the teachers if they might be able to bring out clipboards, paper, and pencils to the playground, a common practice for children as they often engaged in observational drawing. They then used these tools to begin to record the number of plants outside via tally marks to represent each plant.

Seeing this, we knew the next logical step was to focus on a more efficient way for children to track and record their counts using numerical representation. Baroody (2004) recognized that children between the ages of three and six begin to transition to using written numerals to represent quantities. Within this transition to numeral representation, knowledge of number form and knowledge of number function are emphasized. The first, knowledge of number form, rests on children's construction of a symbolic version of the number, which can be attached to a mental image. The latter, focuses on knowledge related to the meaning of a number, including how it connects to elements of cardinality, counting, and measurement.

Representing numbers was not a new idea within the classroom setting. Prior to the onset of this work, teachers spent time in collaboration with families to ensure that ways of representing numbers consistent with cultural backgrounds of students were used in the classroom. For example, posters and books depicting the written and symbolic representation for numerals in various language groups, such as

Arabic, Chinese, English and Hebrew were located in classrooms. At times, students would use these representations in their writing or the labeling of pages, but these were not seen on the counts coming from the playground.

Figure 3. One-to-one correspondence with seeds

Similarly, we wanted children to begin to recognize sets of objects or subitize, which would also help the cardinality issues we saw within our early informal data. Four-year-old children, for example, are commonly able to instantly recognize counts of up to four objects (Clements and Sarama 2014) and extend on the counting sequence from there. Our children were counting plants beyond four on the playground, so having them see a connection between the symbolic representation of a number and the physical quantity was important. In order to build this understanding, we began to connect the use of the actual seeds as a math tool to counting out collections of seeds corresponding with numeric representation. To provide scaffolding for children who were still working to develop one-to-one correspondence, numbers were recorded along with black dots on which children could place their seeds (Fig. 3).

Some children were given dice to roll, then instructed to locate the corresponding number, placing seeds on the dots in a representation which matched that of the dice. Other students were given an image of a flower with a number on it and asked to add the corresponding number of seeds or petals. Finally, another subset of children was asked to roll dice to determine the number of petals or seeds they would need (Figs. 4 and 5). After rolling, children would represent the number in tally marks, then count out the objects (paper strips) needed before adding them to their flower. In this way children focused on switching between numeric and concrete representations of number.

With many of the seeds on the playground sprouting, children became naturally curious about the heights of several of the plants they had been nurturing. As this fascination emerged, they started to inquire about how they might begin to track the heights of the plants. Discussions centered around whether the plants had in fact grown, and how the children could tell. Questions began to flow from the children asking teachers to contribute ideas about how the heights of the plants could be quantified. The teachers responded by asking the children to think about how they have experienced the idea of height and measurement in their own lives. As children contemplated about how this had happened they realized that they had experienced this idea of measurement before, such as finding clothes no longer fit and being measured at a doctor's office or health clinic during a check-up.

Figure 4. Rolling dice to determine the number of petals

Figure 5. Counting petals to place on the flower stem

Taking this idea into account, the teachers began to plan opportunities in which the children might engage with tools for measuring, using both nonstandard and standard units, so that they could connect counting and numbers to measurement. In one classroom, a small group lesson was planned for children to use different manipulatives to measure the heights of plants on the playground and within their classroom. As children used various items—such as stackable counters, their own hands, markers snapped together, and snap cubes—they discovered that the number of items used differed for the same plant. Along with an introduction to a simple number line, this discovery served as a springboard into how they might use one common item to measure an object. Children took to using the number line to measure the plants, standing it up vertically to determine what number it reached. The children then explored what would happen if the number line were stretched horizontally, connecting to the use of a ruler as a tool for measurement. Children used the background knowledge they had constructed to engage in questioning gardeners about the tools they used for measurement during interviews and field visits, referencing their own use of "rulers."

Phase 3

As the final phase of the project commenced, the sprouts were to be transferred outside to the butterfly garden. At this point, children produced final measurements of the plants and compared them to the average height denoted on the seed packet (Fig. 6).

Figure 6. Measuring plants

The children then determined which plants were closest to their maximum height and which ones had more growing to do. This information led to planning where plants needed to be located within the garden and sorting them according to their type and size.

Following planting, children at the school created signage for the garden to indicate which plants were represented in the space. They used the measuring tools constructed during Phase 2 to make sure the height of the plant marker was taller than the plant itself in order to be seen from the classroom window and porch area. After labeling the locations within the garden, the children applied the visual layout of the garden to a map, denoting the location of each type or plant. This information was then used to construct various representations of their experience in the project. One group decided to create a PowerPoint presentation to demonstrate their experiences measuring and interacting with the plants throughout the duration of the project. In doing so, the teachers worked with the children to use ordinal numbers in the PowerPoint, describing the steps and phases in the project.

Another group produced a book chronicling the garden project. They described the process of counting and planting seeds, as well as measuring the plants as they were growing. It was through this demonstration we witnessed the children engage in the dissemination of their knowledge around numeracy. These samples also served as a final evaluation piece for teachers to document children’s attainment of standards for counting and measuring.

Ensuing Abilities in Numeracy

The application of the skills the children refined during the project demonstrated their growth and development as doers of mathematics. They were able to transfer learning to new contexts and worked to find more efficient and accurate ways to work with numbers in their world. The VPK assessment was given again following this project, due to the time of year, and children who had not previously mastered counting and numerical relations questions were able to successfully answer them. We cannot be certain that the project resulted in this growth, as the same questions were asked in multiple iterations of the assessment, so we looked to more anecdotal evidence from work samples and documentation to show children's growth.

At the conclusion of the project, we noticed that that children in this class were more readily able to orally count to 20, and in some instances up to 30. Children still occasionally made reversals of 14 and 15, but these reversals were far less frequent and often self-corrected quickly. Furthermore, the failure to acknowledge numbers 16–19 were scarce, with only one of the numbers in this sequence omitted, rather than the complete series. Moreover, we noticed children instantly noting written and dot representations of numbers in context during the day. As the children moved about the school and larger campus, they quickly and accurately called out numbers they could see. Families echoed our findings, sharing stories of how their children were more adept at noticing numbers in settings outside of school, such a grocery stores, markets, and restaurants.

Additionally, we saw children applying our foci in the project to other activities embedded throughout the day. For example, as children engaged in conversations around the sand table, they began to count and record with written numerals the number of small cups needed to fill a large bucket. Once they had determined this quantity, they began to fill other objects with sand and transfer them to the bucket, comparing the quantities to see which would be the most efficient tool.

Another example of this transference came when the children reconstructed their outdoor play area. Children were charged with thinking about what structures they wanted in their play area, and one of the students identified a stage for outdoor performances. The children determined how big the stage would need to be, using the size and layout of their garden to determine the stage size. They discussed how many children should be on the stage at once, how wide they were, and added additional space to accommodate movement. As a result, they obtained a measurement of the proposed stage's width and took this to the teachers to help determine how many blocks were needed to form the stage. From there, the children counted out the needed number of blocks.

Summary and Conclusions

Operating from the lead of the children, teachers and staff within this setting were able to address a vast number of standards for mathematics content with young children. This included addressing standards related to demonstrating one-to-one correspondence, constructing sets, reading and writing numbers, measuring objects with both non-standard and standard tools, and representing and analyzing data. Children saw numbers being used in a multitude of ways, from symbolic and written representations to more abstract representations via graphs or expressions, in English or another language. This idea countered the notion of the universality of mathematics and gives insight into the ways in which mathematics is used and demonstrated in other cultures.

Additionally, many habits of effective mathematical practice were interwoven with the lesson plans of the teachers to present real world mathematics content and connected the learning and experiences of the young children. First and foremost, children saw mathematics as connected to a context, in this case gardening. Questions posed by the teachers strategically centered mathematical thinking as a means to address problems, such as determining the number of plants on the playground, recording and representing these counts, and measuring the plants. Young children operated from a constructivist perspective, themselves uncovering conceptual ideas within mathematics, such as why standard units of measure are needed. This served to support an understanding of the "why" behind how they saw mathematics being used in their world.

We conclude that early childhood classrooms, attending to the areas of quantitative literacy, including number knowledge and counting, are of critical importance. Using project work may serve as a vehicle for this learning to occur, but more importantly children working through lessons which strategically merge ideas of number with content can mathematize their learning about number.

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