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UNIVERSITY OF MIAMI

PRESCHOOL TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE FOR SCIENCE

By

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the requirements for the degree of
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PRESCHOOL TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE FOR SCIENCE

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Preschool Teachers' Pedagogical Content
Knowledge for Science

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Preschool teachers and their interactions with children are the most important aspect of classroom quality (Gunn, et al., 2013). Therefore, it is important to understand what factors contribute to successful early educators. Pedagogical content knowledge (PCK) is a prime construct of interest that relates positively with child outcomes (Ball, 1988; Kanter & Konstantinopolous, 2010; McCray & Chen, 2012; Munck, 2007). Over the past decade, leaders in early educational research have identified science to be an "ideal domain for early childhood education" (Bowman, Donovan, & Burns, 2001, p. 209). However, there is currently no research examining the PCK for early science. It is crucial that we understand the PCK for early science to inform professional development and best prepare our teachers to be successful in engaging children in science experiences. The current study is the first to address this need. This project has developed a measure of PCK for early science and begins to unpack this complex yet powerful construct.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

High-quality early education supports positive development in multiple domains across an individual's life and sets the foundation for later academic achievement (Anderson, et al., 2003; Barnett & Frede, 2010; Gunn, J., et al., 2013). "Interactions between *teachers* and children are the most important aspect of quality in preschool education" (Gunn, et al., 2013, p.1). Therefore, it is of utmost importance that we understand the teacher- level factors that contribute to such meaningful interactions. Pedagogical content knowledge (PCK), the unique knowledge base for teaching, is one such factor that is a prime construct of interest, and has been shown to relate to child outcomes (Ball, 1988; Kanter & Konstantinopolous, 2010; McCray & Chen, 2012; Munck, 2007). The research on PCK for early childhood educators is severely limited. The few studies on PCK within preschool examine this construct in the domains of mathematics and literacy. PCK for early science, however, has not yet been investigated. This is concerning because there is a national call for improved science education (DeJarnette, 2012; National Center for Education Statistics, 2004; Obama, 2011) given the numerous benefits of science for young children (Bustamante, White & Greenfield, in review; Conezio & French, 2002; Fuccillo & Greenfield, 2015; Nayfeld, Fuccillo & Greenfield, 2013). The current study presents the first measure of preschool teachers' PCK for early science and is the first to examine this construct for early childhood educators.

Current Context of Science Education

Redefining science. In 2012, the National Research Council (NRC, 2012) outlined a new *Framework for K-12 Science Education*. The Framework was designed to help shift the nature of science education from the memorization of discreet, shallow facts to a more meaningful and effective approach to science education. This approach challenges teachers and students to engage in *doing* science within the context of a rich set of ideas that are consistent and connected across children's academic careers. The Framework organizes science education into three dimensions. The first pertains to the "*doing"* of science, Science Practices (e.g., planning and investigating, drawing conclusions, communicating information, etc.). The second dimension is Crosscutting Concepts (e.g., cause and effect, structure and function, patterns, etc.). This dimension encompasses a set of foundational concepts that is used to explain various scientific phenomena *and* connect understandings and concepts from various scientific disciplines. The third and final dimension is Disciplinary Core Ideas. The Disciplinary Core Ideas dimension serves to organize the content of science education across four disciplinary areas: Life Science, Physical Science, Earth and Space Science, and Engineering and Technology. Within each of these disciplines is a small set of concepts and ideas to explore in increasing complexity across the K-12 educational system. By organizing and focusing the content of science education, students can experience deeper, coherent learning across their academic careers, as opposed to the previous shallow and disconnected approach to science teaching and learning.

In addition to structuring and defining science education, the framework also introduces the concept of three-dimensional teaching and learning. Three-dimensional teaching and learning calls for the integration of all three dimensions. When children experience three-dimensional science, they are actively engaged (practices) in constructing understandings about the world (core ideas) in a coherent and comprehensive manner (crosscutting concepts). If taught in isolation, however, science education may experience a shift back towards ineffective and shallow forms of instruction (i.e., rote learning). Although this framework was designed for the K-12 system, current research finds that very young children are able to engage in concepts and behaviors across all three dimensions (Shillady, 2013).

Need for reform in science education. Bringing science to preschool has multiple benefits, one of which is to spur an improvement in science education in general. Improvement in science education in the United States is of utmost importance. As our society and industry progresses, so must the scientific and technological literacy of our citizens (U.S. Department of Commerce, 2012).

Despite the call for “more science”, we have yet to see a positive shift in our educational systems. Based on international reports from the 2012 Program for International Student Assessment (PISA; Fleischman, Hopstock, Pelczar, & Shelley, 2010), The National Assessment of Educational Progress Science Assessment (NAEP; National Center for Education Statistics, 2012), and the ACT College Readiness Benchmarks report (2012), the majority of students in the United States are not prepared to fulfill the global and national need for advanced scientific and technological literacy. Already by fourth grade, students in the U.S. lag behind their peers in other developed countries (TIMSS, 2011). It is imperative that we begin to shift science education in our schools, and even more important that we start early.

Preschool science. Like most domains of learning, exposing children to science early is important and helps foster later learning and potential interest in science as a career (National Science Teachers Association, 2014). Fortunately, science is already a part of preschool children's development. Children are naturally curious about their world and engage in observations, inquiry, and experiments on a daily basis. Research over the past two decades proves that science is not only engaging for young children, but also developmentally appropriate (Conezio & French, 2002; Greenfield et al., 2009). Science supports learning across multiple domains, including language development, mathematics, arts, approaches to learning and executive functioning skills (Bustamante, White & Greenfield, in review; Conezio & French, 2002; Nayfeld, Fuccillo & Greenfield, 2013).

Additionally, including science in preschool classrooms elicits greater quality of language modeling, high-quality feedback and use of open ended questions from teachers (Fuccillo & Greenfield, 2015), which are essential for encouraging higher-order thinking skills in children. Using the Instructional Support domain of the Classroom Assessment Scoring System (CLASS; Pianta, La Paro, & Hamre, 2008), Fuccillo and Greenfield found that when teachers are engaged in a science lesson, their ratings of instructional support are higher than when engaged in other small group lessons, like math. These findings suggest that engaging in science experiences with young children naturally provokes teachers' use of advanced language, open-ended questioning, problem solving, classifying and comparing, and other behavioral markers within the Instructional Support domain of the CLASS. When these interactions are of high quality, they predict higher academic outcomes in preschool as well as kindergarten (Mashburn et al., 2008).

Unfortunately, instructional support is generally low. The Office of Head Start has reported national grantee level scores on the CLASS Instructional Support domain that are consistently in the low range for the past three years (The Office of Head Start, 2012- 2014). If programs like Head Start are to effectively narrow the achievement gap and have lasting benefits for children, the quality of interactions between children and teachers, like those described above, need to be of high quality (Gunn et al., 2013). Current research suggests that science may be a means to achieving such high quality.

The knowledge that young children can and should engage in science experiences has gained support from both policy and practice. In 2000, Head Start released their Early Learning Framework with science as one of eight learning and development domains. Many states also have included science as part of their early learning standards. The 2005 review of these standards by Scott-Little, Kagan & Frelow revealed that 23 of 36 states include science as an early learning standard. Of the thirteen that did not, however, five of them cover science and scientific thinking within the umbrella term “Cognition and General Knowledge,” indicating a recognition of science and scientific thinking as a crucial skill to develop in preschool.

In an attempt to bring the benefits of science into preschool classrooms, a handful of science curriculums and materials for preschool science have emerged (e.g., Science Start!: French, Conezio, & Boynton, 2000; ECHOS: Brown & Greenfield 2011; Head Start on Science: Ritz, 2007; PrePS: Gelman & Brenneman, 2004; MESS: HHS/ACF/OHS, 2010; and STEMScopes: Bell et al., 2014). Preschool curriculums that are not focused on science, such as Creative Curriculum (used by more than 20% of Head Start preschools; Head Start Program Information Report (PRI), 2013) and High Scope (used by more than 10 % of Head Start preschools nationally; Head Start PIR, 2013), include science as a content area to be explored across the preschool day. Clearly, science has been accepted as a component of early childhood education.

Despite the recognition of science as an important learning domain for young children, very little science is actually happening in preschool classrooms. When it *is,* the quality of such experiences is often quite poor (Brenneman, Stevenson-Boyd, & Frede, 2009; Sackes, Trundle, Bell, & O'Connell, 2011). Using statewide school readiness data Greenfield et al. (2009) revealed that children attending Head Start programs grew the least in science development across the year, as compared to the seven other domains of development designated in the Head Start Outcomes Framework (approaches to learning, creative arts, early math, language and literacy, motor development, physical health, and social emotional).

A closer look at what is actually occurring in classrooms sadly supports these findings. Science centers, though present in many classrooms, are simply not used (Nayfeld, Brenneman, & Gelman, 2011), as teachers spend the majority of their time in the arts center (Tu & Hsiao, 2008). Research examining the factors that contribute to the lack of science and poor quality of science in preschools is scant.

Some studies suggest that teachers' negative attitudes toward science (Thompson & Shrigley, 1986), perhaps due to their own experiences of science learning and/or feeling incompetent and unprepared to teach this subject, (Goodrum, Cousins, & Kinnear, 1992; Hone, 1970; Tilgner, 1990; Wenner, 2001) may partially explain the absence of quality science in early childhood classrooms.

Another possible explanation for the limited focus on science in preschool classrooms is teachers' PCK for science; their pedagogical knowledge specific to the content area of science. If teachers do not understand how to scaffold children across various science practices and concepts, lack an understanding of how to plan for engaging and appropriate science experiences, or are limited in their own understanding of science content and practices in general, they will not be able to meaningfully engage children in deep science learning. Though existing literature on preschool science and established curriculums are beginning to outline *why* and *what* to do in preschool science (Conezio & French, 2002; Driver, Asoko, Leach, Mortimer, & Scott, 1994; French, 2004; Gelman & Brenneman, 2004; Hong & Diamond, 2012; Smith, 1987), it remains far less understood how to effectively engage *teachers* in utilizing this information in daily practice nor how to support the development of their PCK in this important subject area.

The current study begins to fill this gap, addressing first, a means to capture the PCK construct for early science. This paper presents a new measure of preschool teachers' PCK for early science, The Early Childhood Science Survey (ECSS), examines its psychometric properties, and is the first study to examine the variability and nature of preschool teachers' PCK for science.

Theoretical Framework

Vygotsky's sociocultural theory of development posits that child development is the result of interactions between children and their social environment (Vygotsky, 1978a, 1978b). In classroom settings, teachers are primary members of this social environment and therefore, directly influence children's growth and learning. The current study recognizes the critical role that teachers play and seeks to understand the mechanisms that drive quality teacher-child interactions, specifically within the science education.

Vygotsky also believed that the most effective learning happens when the new skills and knowledge are just on the edge of emergence, what he calls the “zone of proximal development”. For learning to occur within this zone, however, an expert is needed to bridge learned tasks with those that may be too difficult (Vygotsky, 1978a, 1978b). In classroom settings, teachers are often the experts interacting with children to support and challenge their thinking. Experts must draw on multiple competencies to effectively serve as a scaffold between current knowledge and new knowledge. Not only must one be skilled and knowledgeable of the content itself, but one must also know where the learner currently *is*, their actual knowledge and ability, where the learner should *go,* the potential knowledge and ability, and how to get them there. PCK subsumes all of the aforementioned competencies as outlined by sociocultural theory.

Pedagogical Content Knowledge

The construct of pedagogical content knowledge was coined in 1986 by educational researcher Lee Shulman. He described this as the “missing paradigm” during a time in educational research that shifted from a focus primarily on teacher’s content knowledge to a focus primarily on teacher pedagogy (classroom organization, structure of assignments and lesson planning). Both constructs provide a limited understanding on teacher knowledge if studied in isolation (Shulman, 1986). Pedagogical content knowledge (PCK), he argues, is a type of knowledge that “goes beyond knowledge of subject matter … to the dimensions of subject matter knowledge *for teaching”* (Shulman 1986, page 9). Shulman states that pedagogical content knowledge includes several dimensions of teaching including knowledge of how to represent and prepare subject matter so that it is comprehensible to learners, knowledge of the conceptions and misconceptions students bring with them, and knowledge of the strategies needed to effectively reroute those misconceptions.

Shulman's discussion of PCK sparked much attention from researchers across multiple domains of learning and teaching. The work on PCK for science, however, is limited and focuses solely on elementary and upper grades. Nonetheless, the findings from these studies empirically relate teachers' PCK for science, to student science achievement, calling for more focus on PCK for science in teacher training programs and professional development (Kanter & Konstantinopolous, 2010; Munck, 2007).

PCK and student achievement. Many studies have examined elements of PCK and their relation to child outcomes. However, all studies of PCK for science have been conducted with children and teachers in upper elementary, middle, and high school. The following section will review a few key studies of science PCK and proceed to discuss PCK in preschool within other subject areas.

In 1993, William Carlsen examined high school teachers' science knowledge, a discreet facet of PCK, as it related to their classroom pedagogy. Carlsen found that teachers' knowledge of the subject matter was positively correlated with general pedagogy. For example, teachers lectured less, asked more questions, and asked more cognitively demanding questions when teaching a science topic where they were knowledgeable as opposed to a subject wherein they lacked a solid understanding of the content.

Similarly, work done by Munck (2007) also measured facets of PCK, including attitudes and the degree of "teacher-directedness." Students' science achievement was measured in two different ways; a measure of content knowledge and a measure of students' inquiry. Teacher attitudes related positively *only* with student content knowledge. Teacher directedness, related negatively to students' inquiry such that less teacher directedness predicted greater student inquiry. Here, it is clear that pedagogy is related to child outcomes. As Shulman stated, however, pedagogy alone is only a part of what constitutes an effective educator.

Kanton and Konstantinopolous (2009) were able to capture the PCK construct more fully and found positive relationships between teachers' science PCK and child outcomes. The study took place in the context of an intensive science intervention wherein teachers participated in professional development in the form of a for-credit graduate-level course in the M.S.Ed. program. Teachers attended class for 3 hours each week over a 10 week period. As the measure of PCK, teachers reflected in essay form on videos of themselves teaching. They were asked to write about students' questions, how they facilitated student learning, and on the depth and content of students' understanding. Teacher's science content knowledge was also assessed using a direct assessment of science content that was the focus of the intended lesson. Teachers' knowledge (both content and pedagogical) in science predicted student science achievement. This study clearly illustrates the effect of high-quality and intensive professional development as a means of improving teacher PCK and child outcomes.

PCK in Preschool. Jennifer McCray is one of the pioneers in examining PCK in preschool. In her 2008 dissertation, McCray used a series of vignettes depicting children interacting in a preschool setting to provide the context for a semi structured interview. In the interview, teachers read the vignettes and were then asked to talk about the math that they saw and how they could support children in deepening the math they were naturally engaged in. Additionally, McCray measured the frequency of teacher math-related language in the classroom as a proxy for good teaching (Ehrlich, 2007; Klibanoff, Levine, Huttenlocher, Vasilyeva, & Hedges, 2006). She found that PCK related strongly to teacher math-related language *and* child math achievement. Her work has highlighted PCK as an important construct in early education, predicting both positive teaching practices *and* child outcomes.

Measuring PCK

Although PCK is lauded as a pivotal construct in research on teaching and learning (Van Driel, Verloop, and De Vos, 1998), the field is limited in its ability to measure PCK. This is due to the complexity, ambiguity, and highly contextualized nature of the construct (Kagan, 1990). Researchers seeking to capture PCK may include factors related to a teacher's thoughts during instruction, lesson planning, beliefs about students, classrooms, and learning in general (Calderhead, 1989; Clark & Peterson, 1986; Kagan, 1988). Furthermore, what is and isn't considered PCK is not always clear (Loughran, Gunstone, Berry, Milroy, & Mulhall, 2000) and often varies by the contextual bounds of a school's culture and the educational system in general (Jimoyiannis, 2010; Siorenta & Jimoyiannis, 2008).

The measurement of PCK takes on various forms from one study to the next including interviews, self-reports, surveys, observations, written reflections, and combinations of these. The following section will serve to summarize some of the limitations of current measures of science PCK.

First, measures of science PCK used in previous work fail to align to the current *Framework for K-12 Science Education (NRC, 2012)*. The framework outlines three dimensions of science education: 1) Practices, 2) Crosscutting Concepts, and 3) Disciplinary Core Ideas (content). An essential element of this Framework is the idea of three-dimensional science learning. In essence, these three dimensions are intended to overlap, intertwine, and be introduced to children, not in isolation, but in a working combination of all three. When three-dimensional teaching and learning is the focus of classroom instruction, it ensures that learning is an active process that engages students in critical thinking, knowledge construction, and an overall coherent and comprehensive understanding of the world.

If we expect teachers to knit together these three dimensions and make these concepts visible and meaningful to their students, it is important that teachers themselves have integrated the new framework into their working PCK. Unfortunately, no measures of PCK, to date, have attempted to capture science PCK across these three dimensions.

Another limitation of previous research of science PCK is the lack of validity of measurement tools. For example, William Carlsen measured teachers' content knowledge using teachers' self-report of their level of knowledge of given science topics relevant to their curriculum. The self-reported nature of the knowledge construct potentially fails to capture actual knowledge. A teachers' confidence, their *belief* in knowing a topic well, not their actual knowledge, may instead be relating to positive pedagogy. Similarly, other studies attempting to capture teacher math content knowledge rely on proxy's of teacher knowledge like the number of mathematics courses taken in college (Begle, 1979; Boyd, Grossman,Lankford, Loeb, & Wyckoff, 2009). When relating this construct to student outcomes, however, the relationship varies across studies and often has small effect sizes. Therefore, using such distal measures of teacher knowledge is ineffective and does not validly capture teachers' PCK.

Because PCK is unique to the classroom context (Kagan, 1990; Shulman, 1986) it is important that measurement tools used to capture PCK layer content knowledge within classroom settings (Ball, 1988). Measuring content knowledge in isolation from pedagogy fails to capture the construct fully. A recent study administered a science assessment to pres-service and in-service teachers but failed to find relationships between test scores and classroom practice (Nowicki et al., 2013). Similarly, a study of preschool teachers' literacy knowledge administered the Teacher Knowledge Assessment Survey to capture teacher's understanding of language structures (Cunningham, Zibulsky & Callahan, 2009). The assessment was originally designed for elementary school teachers but was modified for use with preschool educators. Researchers found floor effects with this measure and failed to find significant relationships to child outcomes. This is a clear example of why measures of PCK must be contextually specific to the classroom context. This must include content that is relevant to a particular age group *and* content that situates knowledge as it is applied to classroom teaching and learning.

Other studies fully immerse measurement in classroom contexts by using observational measures. The Munck study (1997), previously described, used the Science Teacher Inquiry Rubric (STIR; Beerer & Bodzin, 2004), an observational measure of teacher directedness. Work from William Carlsen also used classroom observations to capture positive teacher pedagogy. These studies capture facets of PCK (the pedagogy portion), but fail to capture the content that the pedagogy must support. Also, because the knowledge portion of PCK is an internal construct, it may be difficult to capture via observations.

Fortunately, there are a few studies that succeed in capturing PCK. Kanton and Konstantinopolous (2009) used personal videos of teachers teaching (highly contextualized) as a springboard for teachers to reflect and explain the depth and content of students' understanding as well as pedagogical supports specific to the content. With this type of measurement, researchers were able to capture both pedagogy and content in a highly contextualized manner. Although this study captures PCK more fully than the work previously discussed, using essays as a form of measurement introduces biases related to language ability and is cumbersome and time consuming to score. There is also a lack of standardization in that teachers' responses are dependent on the students in their classroom. Each teacher does not have the same opportunities to demonstrate or reflect on PCK due to the differences in the students by classroom. This form of assessment, though rich, is likely difficult to generalize and apply to studies with larger samples.

Jennifer McCray's work with preschool math PCK provides a valid and reliable approach to assessing PCK . Similar to Kanton and Konstantinopolous (2009), McCray's measure is highly contextualized within the preschool classroom. Instead of using personal videos of teacher, however, she uses vignettes to situate the math content into the preschool classroom. These vignettes prompted teachers to identify and explain the math within the scenario, and suggest scaffolding techniques to guide the children depicted in the scenes. This PCK interview predicted child outcomes in math (McCray &

Chen, 2012). Despite these positive findings, however, use of this measure is not easily replicated. All the data were collected by McCray and no specific protocol for administration for others to use was created. For example, the interview does not have a rubric that outlines what *is* and *isn't* considered a correct response. No follow-up work has been done to standardize the administration of this assessment.

In an attempt to ameliorate the limitations of McCray's math PCK interview, researchers in Berlin have adopted components of the original interview and transformed it into a half-standardized questionnaire (Anders & Rossbach, 2015) to tap into teachers' sensitivity toward mathematical content in children's play. Anders borrowed the first vignette from McCray's original measure along with the prompts for teachers to 1) identify parts of the scene that were math, 2) describe why/how it is math and 3) indicate what areas of math are being explored given the categories of numeracy, figure, operations, form, measuring, spatial relations, or classifying. In a sample of 222 German preschool teachers, Ander's questionnaire yielded considerable variance with scores ranging from 0 – 17 out of a possible score of 32 (*M* = 8.53; *S.D.* = 3.86).

The Anders and RossBach (2015) study reports positive findings using a questionnaire to measure teacher sensitivity to math in play (an element of PCK). More importantly, this form of measurement addresses many of the measurement limitations described earlier: 1) it is highly contextualized to the classroom setting and 2) it is standardized and replicable. The major limitation of this measure, however, is that it does not capture elements of pedagogy (e.g., scaffolding and interacting with children) and has yet to be related to child outcomes.

Given this review of the measurement of PCK, it is clear that the field is in dire need of valid and reliable assessments to capture this powerful construct. In the area of preschool science, a subject of growing importance, there is no measure of teachers' PCK. The current study has developed the first measure of preschool teachers' PCK for science, the Early Childhood Science Survey (ECSS).

The ECSS addresses many of the limitations of previous research: 1) it uses vignettes to contextualize the assessment in a preschool setting, 2) it is standardized, can be administered to large samples, and is replicable 3) it captures both content knowledge and pedagogy, and 4) it aligns with the new *Framework for Science Education* (NRC, 2012). With appropriate means to capture PCK for early science, we can finally begin to understand and support the development of our early educators in the domain of science. As a result, we can begin to shift the nature of science in preschool so that educators can fully capitalize on the multitude of benefits that science has to offer our youngest learners.

Current Study

The current study reports on the development, validation, and descriptive statistics of the Early Childhood Science Survey (ECSS) within a sample of preschool teaching staff from across the nation. Considering the lack of research on this construct, this work is exploratory in nature and no hypotheses were formed.

Aim 1. The first aim of this study was to validate a new measure of preschool teachers' PCK for science, the ECSS, and report on its psychometric properties, including the dimensionality, reliability and validity of the measure.

Aim 2. The second aim of this study was to examine trends in teachers' PCK for early science.

CHAPTER TWO

METHOD

Measure Development

Development of the ECSS began in the summer of 2014 within the University of Miami's School Readiness Lab led by Dr. Daryl B. Greenfield. Drawing from the work of Jennifer McCray (2008) and Anders and Rossbach (2015), scenarios of children engaged in naturally occurring interactions were generated along with questions to prompt teachers to identify the science within the scenarios and provide examples of strategies and experiences that could scaffold and extend the learning children were engaged in. After several rounds of review and reflection within the School Readiness Lab, whose members specialize in early science, the initial pilot survey was developed. A total of three scenarios were developed, each one corresponding to a unique science discipline: 1) Life Science (children observing a caterpillar on the playground), 2) Physical Science (children exploring ramps in the block center), and 3) Earth and Space Science (children experiencing weather change outside). Because the science content is contextualized in a preschool setting, it challenges teachers' to combine their understanding of preschool pedagogy and child development with their knowledge of science content and practices.

This first pilot version of the ECSS was administered to a group of seven teachers at a local preschool. These pilot data further informed measurement creation in multiple ways. First, it was noted that the assessment was too long and burdensome as indicated by increasingly limited responses as the survey progressed. As a result, the one survey form with three scenarios was divided into three survey forms each containing one of the original three scenarios. The second point learned from the pilot study was that having all open response fields made it very difficult to score. As a result, open-ended responses were reduced and a multiple choice section was added as a follow-up to the initial open-ended response. Finally, pilot data also revealed that asking teachers to provide examples of scaffolding and extending learning based on the science *they* identified lacked structure and standardization. Therefore, it was too difficult to organize the responses into a reasonable number of relevant categories to analyze and make sense of the data. To provide for more structure in these open-ended responses, a brief, two sentence scenario was added to the survey wherein the science that was being explored was clearly stated. Teachers were then prompted to provide specific forms of scaffolds and extensions directed to support the defined science content.

With this new iteration of the ECSS, a focus group of four preschool teachers from a local Head Start preschool center was formed to assess the appropriateness of the language and scenarios used in the survey, and the clarity of the directions. The focus group took place in March of 2015 and lasted about an hour and a half. Each teacher was given a $25 Visa gift card in appreciation for their participation. After revisions were made from focus group data, a final iteration of the ECSS was created reflecting the changes described above, and subsequently approved by the University of Miami's IRB.

Participants

A total of 816 email addresses of early educators were collected from across the country. Seven-hundred-seven of these emails were valid. Of the 707 individuals queried to participate, 226 of them opened the survey link. Forty of these individuals neither rejected nor confirmed consent, 57 individuals consented, but failed to finish, and 15 individuals denied consent, yielding a total of 114 individuals who consented and completed the survey. Individuals who denied consent were queried to provide a reason. More than half of the individuals that decided not to participate reported that they “do not have enough time to participate in a survey”, one individual reported that she “doesn’t like science”, and four chose not to disclose their reason for not participating. Seven surveys were discarded due to duplicate IDs that overwrote original data entries, resulting in a final sample of 107 participants.

One-hundred percent of participants were female, 72% reported their race as White/Caucasian, 20.6% reported Black or African-American, and 7.5% reported “other”. Thirty percent reported that they were of Hispanic, Latin, or Spanish origin. Fifteen percent of participants were Teaching Assistants with a range of 0.5-15 years of experience as a Teaching Assistant (M = 5.96, SD = 5.62); fifty-eight percent were Teachers with a range of 0.5-36 years of teaching experience (M = 12.23, SD = 9.54); eight percent were Master Teachers with a range of 1-25 years of experience (M = 8.63, SD = 7.56); six percent were Curriculum Specialists with a range of 1-20 years of experience (M = 9.82, SD = 9.13); and 14% reported their position as “other” with a range of 1-18 years of experience (M = 6.60, SD = 4.94). Levels of education were reported as follows: 1.9% High School, 9.3% CDA or equivalent, 15% Associate’s degree, 43% Bachelor’s degree, 29.9% Master’s degree, and one individual held a Doctoral degree. When asked if they had participated in any special workshops, professional trainings, or research projects on science in the past three years, 33.6% responded “yes” they had.

Measures

Pedagogical Content Knowledge for Science. *Early Childhood Science Survey.* The Early Childhood Science Survey (ECSS) is an online survey designed by the author and research team. The ECSS presents teachers with written scenarios depicting young children engaged in a typical interactive experience. After reading the vignettes, teachers are asked to respond to questions asking them to 1) provide examples of scaffolds and strategies to extend and support learning, 2) identify the science in the scenario and 3) explain what the children are doing that maps onto the science (see Appendix A). Average completion time on the ECSS was 40 minutes. However, it is difficult to discern if the time captured on the survey platform represents "active time" only or, if there are instances wherein the time may be inflated due to individuals not completing the survey in one sitting.

The survey can be broken down into four sections. The first section presents teachers with a brief, one to two sentence scenario of a typical interaction during snack time. The science in this scenario is explicitly stated. Teachers are then asked to provide examples of scaffolds and supports to extend and deepen the learning occurring in the scenario across 4 different contexts (e.g., a planned lesson, intentional questioning, changes to the classroom environment, and intentional introduction of new vocabulary). This first section of the survey will be analyzed qualitatively and is not included in the current study.

The second section of the survey was designed for quantitative analyses and constitutes the data analyzed in this current work. Teachers are shown a second, lengthier scenario of children engaged in a typical interactive experience. Teachers are shown three separate lists representing science across three dimensions, as outlined by *the Framework for K-12 Science Education* (National Research Council, 2012): 1) Science Practices (e.g., asking questions and drawing conclusions), 2) Science Content (spanning across four science disciplines: life science, physical science, earth and space science, and technology and engineering), and 3) Crosscutting Concepts (e.g., cause-effect and patterns), and are asked to identify which items on the lists can be identified within the scenario by marking "yes" or "no" to each item. Teachers who mark "yes" for an item on the list are prompted to explain, in a text box, what the children are doing that leads them to believe *that* particular science concept or practice is present in the scenario. As a result of the current study, some items have been dropped from the initial survey (see Data Analysis) resulting in a total of five items per dimension; a total of 15 items contributing to a total PCK score. Items are scored dichotomously; a point is awarded for correctly identifying the science (e.g., correctly selecting "yes") *and* correctly explaining how that concept is occurring in the scenario. A score of zero is assigned to responses that either fail to identify a science behavior or concept *or* fail to correctly explain what the children are doing that leads them to believe *that* particular science concept or practice is present in the scenario. A scoring rubric was used to evaluate explanations and assign points (See Appendix B).

The ECSS has three forms, each particular to a specific discipline of science. The form used for the current study is focused on Life Science. The other two survey forms have yet to be evaluated.

Demographics and Teaching Experience. Twenty-one additional survey questions followed the ECSS and asked teachers to report on demographic information (e.g., gender, age, ethnicity, English proficiency) teaching experience (e.g., time in role, position, what type of school they work in, curriculums used, age of children taught, participation in science PD) and their opinions of the ECSS (e.g., ease of completion and format preference).

Procedure

Throughout the Fall and Winter of the 2014-2015 school year, teaching staff's emails were collected from center directors and public websites. A final pool of 816 emails was established and organized in a database. Because the proposed study design attempted to gather a minimum of 100 views for each of three survey forms, participants' emails were randomly drawn from the participant pool in batches of 150. Participants who failed to complete the survey after a week from the initial invitation were sent two reminders; one a week from the first invitation, and the second two weeks from the first invitation. After sending the first reminder email, an additional 150 emails were drawn from the email pool and sent survey invitations. Once the first form of the survey reached 100 views, participants remaining in the email pool would be randomly assigned to the second survey form and then finally the third form. Due to a low response rate of only 15%, the entire pool of emails was used to elicit the first 100 responses for form one of the survey. Therefore, the current work is only reporting on one of three survey forms.

Participants selected the survey link in their email invitation and were first presented with a consent form. Those agreeing to the terms of the consent began the ECSS, while those that did not consent to participate were asked to provide a reason for denying consent, and were then thanked and exited from the page. Upon completion of the ECSS, participants completed a demographic questionnaire that asked questions about their background and teaching experiences. All participants that completed the survey were entered into a drawing to win one of five $100 gift cards.

Scoring. Analysis of the ECSS first involved generating dichotomous scores from the survey. Initially, scoring procedures included all items. Participants who correctly identified a concept relevant to the scenario *and* correctly explained what the children were doing that was relevant to that science practice or concept received a point for that item. Participants who failed to identify a concept *or* failed to correctly explain it, received a zero for that item.

It should be noted that the scoring procedure described above is an amendment to the initially proposed method of scoring. Originally, a point was to be awarded for correctly identifying the *absence* of a science concept from a scenario (i.e., correctly selecting “no”). After reviewing responses, this procedure was amended. Instead of scoring all items and awarding points for correctly selecting “no”, only “yes” items, practices or concepts that *were* present in the scenario, were scored. The scoring procedure was amended due to the nature of participants reasoning for selecting “no items”. Some participants who selected “yes” to items *not* present in the scenario explained the science concept or behavior correctly yet did so with reasoning derived from information not included in the scenario. For example, a teacher identified “light and shadows” as a concept being explored and explained that children might explore the shadows created from light passing through the leaves of the tree. This explanation accurately describes how children in this scenario *could* explore light and shadows; however, this type of experience was *not* depicted in the scenario but was extrapolated by the participant. Scoring this response as "wrong" would be invalid as the teacher *did* accurately explain the concept in a preschool context.

This anomaly in item responses is believed to be the result of participants' lack of understanding of the directions, and/or perhaps due to a social desirability bias to "see more science" than is actually there. Therefore, it has been determined that these items do not validly contribute to an individual's PCK and so have been dropped from the assessment.

All items were scored "correct" or "incorrect" by the author and a separate scorer who had received training on the framework and its application to this survey. Initial analysis using Cohen's K revealed good agreement between scorers across all items (K > .850). The scorers met to discuss divergences in scoring after independently scoring each item. Other experts in early science provided feedback to resolve discrepancies in scoring. A scoring rubric was generated during this process for future use of the measure.

Raw scores for each of the three dimensions and a total PCK score were generated. Scores for total PCK ranged from 2 – 14 with a total possible score of 15. Scores on the first dimension, Scientific Practices, ranged from 0 – 5; scores on the second dimension, Science Content, ranged from 0 – 5; and scores on the third dimension of the ECSS, Crosscutting Concepts, ranged from 0 – 5. The total possible score for each of the three dimensions was 5.

Data Analytic Plan

To address Aim 1, psychometric evaluation of the ECSS, several statistical analyses were conducted including, item analysis, reliability, exploratory factor analysis, and analyses of bivariate correlations. Aim 2, examining trends in teachers' PCK for early science, was examined using paired samples t-tests.

Item Analysis. Item level data were analyzed to examine the means, standard deviations, skewness, and kurtosis for each item. This type of analyses helps to flag poorly performing items that may not produce significant variability in responses.

Reliability. To ensure adequate reliability of the ECSS, Cronbach's alpha was assessed for the total PCK score across the entire sample and within subgroups of respondents (e.g., variation in ethnicity, level of education, teaching experience, English proficiency, and position). Alpha values were also investigated for each dimension (i.e., total Science Practices, total Crosscutting Concepts, and total Science Content). Values greater than or equal to .70 were interpreted as having reasonable internal consistency.

Exploratory Factor Analysis. An exploratory factor analysis (EFA) was run to examine the dimensionality of the ECSS. Using Factor Reduction in SPSS, a series of analyses were conducted. First, the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO-test) was run to assess whether or not the sample was large enough to run an EFA (KMO > 0.5 indicating a large enough sample; Hair, Anderson, Tatham & Black, 1995; Tabachnick & Fidell, 2007). Additionally, intercorrelation between items was assessed using Bartlett's test of sphericity (Field 2000: 457). Next, a scree plot was run to determine the number of factors to extract (Cattell, 1966). An initial analysis of factor extraction was run using Principal Components Analysis (PCA). This method is less stringent because it assumes no error in variables entered, unlike factor analysis (principal axis factoring; PAF) which accounts for error variance. However, solutions derived from PAF generally do not differ significantly from those derived using PCA

(Field, 2000). Analyses were run using both an orthogonal rotation (Varimax) and an oblique rotation (Promax; Field, 2000). Extracted factors were then evaluated on the following criteria: (a) retained at least four items per factor with salient loadings (e.g., loadings greater than .40; Gorsuch, 1983); (b) yielded reasonable internal consistency within each factor (e.g., alpha coefficients greater than or equal to .70); (c) held a simple structure with mutually exclusive assignment of items to factors; and (d) were coherently aligned with the early science literature and the *Framework for K-12 Science Education* (2012).

Correlations and predictive relationships. Finally, validity of the ECSS was evaluated using independent samples t-tests to assess whether or not individuals participating in a science PD had greater mean scores on the ECSS than individuals who had not participated in a science PD. First, bi-variate correlations were run to assess the relationship of the total PCK scores with selected demographic variables (e.g., participation in a science PD, previous science education, teaching experience, etc.). To further examine the relationship between scores on the ECSS and selected variables of interest, a series of Regression analyses were conducted.

Trends in PCK across three dimensions of science. To address the second aim of the study, current level and range of preschool teachers' PCK for science, raw scores were generated for each of the three science dimensions as defined by the *Framework for K-12 Science Education* (2012; i.e., total Science Practices, total Crosscutting Concepts, and total Science Content), and a total PCK score. A series of paired Samples T-tests were run to evaluate differences in performance between dimensions. All statistical analyses were run using SPSS® (version 22).

CHAPTER THREE

RESULTS

Item Analysis

As part of meeting aim 1, psychometric evaluation of the ECSS, analysis of this survey began with item level data. First, means, standard deviations, skewness, and kurtosis were examined for each item (see Table 1). Item means ranged from .02 - .93, skewness ranged from -.357 – 7.2, and kurtosis ranged from -2.01 – 50.92. Items with extreme skewness and kurtosis were examined more closely. Two items had both high skewness and kurtosis (items 13 and 14). First, it was noted that both of these flagged items were within the Crosscutting Concepts dimension. Performance across these items was very poor (*M* = .02, *M* = .03, *M* = .09; respectively) indicating that only few individuals were able to identify and/or explain these science concepts. Although these items yielded limited variability in responses, Cronbach's alpha was not improved by removing them. These items are also central to the cross-cutting dimension so all were retained in the final score.

Other items (items 2 and 10) had only a slightly elevated level of skewness (-3.57 for both items), but their kurtosis was abnormally high (10.92 for both items). A closer examination of performance on items 2 and 10 indicate that nearly all participants correctly identified and explained these items (*M* = .93, for both items). These items were very easily identified in the scenario and yielded limited variability in responses. Cronbach's alpha was not improved by removing these items. These items are also central to science practices and core ideas so both were retained in the final score.

Exploratory Factor Analysis

To further address the psychometric properties of the ECSS as described in Aim 1, dimensionality of the measure was assessed. To statistically examine the factor structures within the ECSS, an Exploratory Factor Analysis was conducted using Dimension Reduction in SPSS. A final, unidimensional factor structure was obtained using principal components analysis with an orthogonal rotation (Varimax). The central criteria for retention were met, including salient factor loadings and adequate internal consistency. All items loaded strongly (loadings greater than .4) onto one factor except for three items, two of which were flagged in the item analysis (see Table 2).

Reliability

Psychometric evaluation of the ECSS, Aim 1, also involved examination of the internal consistency using Cronbach's alpha. The total PCK score yielded adequate reliability (Cronbach's alpha = .75). Internal consistency held across subgroups of ethnicity, educational level, teaching position, and years of teaching experience (with 3 or less years considered novice and 4 or more years considered experienced; see Table 3). Item total correlations were also adequate, ranging from .33 to .48 (De Vaus, 2002) except for three items with low internal consistency (.14, .12, and .13). These items were flagged earlier for extreme skew and kurtosis. These items were retained as they are well established within the literature of science education, specifically within the *Framework for K-12 Education* (NRC, 2012), and removal did not improve overall internal consistency.

Correlations and Validity

The final analyses to meet Aim 1 involved examination of the validity of the ECSS. First, bivariate correlations were analyzed to determine relationships between total science PCK and other variables of interest, including participation in a science PD, language proficiency, ethnicity, years as a member of the teaching staff, current position, level of education, and total science education (see Table 4). Participation in a science PD was not significantly related to total PCK. The lack of relationship between these variables did not warrant further analyses.

Most notably, however, results of the bi-variate correlations indicated significant, positive relationships between total PCK scores and language proficiency (r (105) = .25, p = .009), total science education (r (105) = .25, p = .011), and years in role (r (105) = .30, p = .001).

To further examine the relationship between teaching experience and performance on the ECSS, a linear regression analysis was performed. Years in role (M = 10.11, SD = 8.64) significantly predicted participants' total PCK (M = 8.79, SD = 2.72) when controlling for prior science education and English proficiency. Results of regression analysis indicated that 17.8 % of the variance in total PCK was explained by years of education, total science education, and English proficiency (R^2=. 1.78). The test of the model was significant, F (3, 103) = 7.46, p<.000. Review of the coefficients indicated that for every additional year of teaching experience, an individual is predicted to score .083 points higher in total PCK (b = .083, standard error (b) = .029, t (103) = 2.92, p= .004; CI=.027, .140). Separate analyses regressing Total PCK on total science education (controlling for language proficiency and years of experience) approached significance (*t* (103) = 1.89, *p*= .062; CI= -.012, .495).

Trends in PCK Across Three Dimensions of Science

Aim 2, evaluating trends in teachers' PCK for early science, was addressed by examining teachers' performance among the three dimensions. A series of paired samples t-tests were run. Results indicate that participants scored higher on Science Content (*M* = 3.76, *SD* = 1.31) than Science Practices (*M* = 3.41, *SD* = 1.31); *t* (106) = 2.51, *p* < .014. When compared to Crosscutting Concepts (*M* = 1.62, *SD* = .85), average scores were again significantly greater for Science Content (*M* = 3.76, *SD* = 1.31); *t* (106) = 17.86, *p* < .001. Average scores of Science Practices (*M* = 3.41, *SD* = 1.31) were greater than average scores of Crosscutting Concepts (*M* = 1.62, *SD* = .85); *t* (106) = 15.03, *p* < .001 (see Table 5).

Significant differences between items within dimensions were also analyzed. Within the Science Practices dimension, "observing" (*M* = .93, *SD* = .25) and "questioning" (*M* = .87, *SD* = .34) had the highest mean scores. In contrast, however, measuring (*M* = .38, *SD* = .49) and experimenting (*M* = .46, *SD* = .50) were the most difficult for teachers to identify and explain. Within the Science Content dimensions, "identifying the needs of living things" and "naming and describing living things" items generated the highest means (*M* = .93, *SD* = .25; *M* = .87, *SD* = .34; respectively). "Characteristics of parents and offspring", however had a much lower average score (*M* = .55, *SD* = .50). Finally, within the Crosscutting Concepts dimension, "cause and effect" and "size and amount" items had the highest averages (*M* = .74, *SD* = .44, for both items) whereas "systems", "patterns" and "stability and change" had the lowest averages within this dimension and across the entire survey (*M* = .02, *SD* = .14; *M* = .03, *SD* = .17; *M* = .09, *SD* = .29; respectively). Differences of means by item were not statistically analyzed. The numbers of analyses were prohibitive (see Table 1 for a summary of means).

CHAPTER FOUR

DISCUSSION

The current study developed and evaluated the Early Childhood Science Survey (ECSS), and is the first, to date, to report on preschool teachers' PCK for science. Aim 1, psychometric evaluation of the ECSS, yielded an acceptable range of variability, adequate internal consistency, and a unidimensional factor structure for the ECSS. Item analysis revealed excellent psychometric properties for the majority of the items, although a few items were highly skewed. The primary analysis conducted to assess validity did not produce significant results. For Aim 2, paired samples t-tests yielded statistically significant differences in mean scores between each of the three dimensions. The following section will discuss the implications of these findings as well as review some of the limitations of the study and future directions.

Analysis of Cronbach's alpha indicated that the ECSS has adequate internal consistency ($\alpha > .7$) for the total PCK score and this remained stable across subgroups. These findings suggest that the ECSS can be reliably used within diverse samples of teaching staff including staff with various positions (e.g., teaching assistance, master teachers, and teachers), and staff with various levels of experience. It is important to be able to examine the PCK of various "types" of teaching staff because all of these individuals have an effect on children's experiences. For example, even though teaching assistants do not have the same responsibilities as teachers, in some centers, teaching assistants are responsible for working with small groups of children for the purpose of instruction. It is likely the case, then, that teaching assistants will be involved in interacting with children around science. Supporting teaching assistants' development of good science PCK is then a necessary task to ensure quality experiences for all children no matter which teacher (teacher or teaching assistant) leads the science experience. Similarly, it is important to be able to assess the PCK for early science for master teachers and instructional support staff. These are the individuals charged with supporting teachers and teaching assistants to ensure quality interactions between teachers and children through practices such as coaching, reflective supervision, lesson study, lesson planning, and professional learning communities. It is crucial that these teacher leaders have a solid foundation in PCK in order for them to effectively support and develop the PCK of their staff.

Results of the EFA indicate that the ECSS is capturing a unidimensional construct with all items loading onto a single construct except for three previously flagged items. Although literature on science education conceptualizes science across three dimensions, this same literature also calls for "3D Teaching and Learning" which illustrates the integration and interdependence of the dimensions. Perhaps the unidimensionality of the ECSS reflects this idea. However, because this is the first measure of PCK that aligns with the *Framework for K-12 Science Education* (2012), it is not yet known if *teacher PCK* across the three dimensions is integrated and interdependent. It could be the case that *PCK* varies between the three dimensions even though integration of these components is necessary for effective *teaching and learning*.

The unidimensional factor structure suggested by the EFA could also be driven by item difficulty wherein items are clustering together not because of a shared underlying factor, but instead because of shared difficulty. The general skewness of the data may be influencing the ability to detect latent factors, such as those defined in the K-12 framework. To better understand the nature of PCK for science across three dimensions, additional research (discussed below) is needed.

As noted above, the ECSS contains items skewed strongly in one direction or the other. Some items in the ECSS (e.g., items within the Science Content dimension) assumed a very negative skew and, therefore, little variability in responses. In contrast, items in the Crosscutting Concepts dimension were positively skewed and also resulted in limited variability. To further understand the differences in performance between each dimensions, a series of paired samples t-tests were run. Analyses revealed significant differences in participants' performance between all three dimensions. Participants, in general, excelled in identifying and explaining Science Content (*M* = 3.76, SD = 1.31). They also did fairly well when asked to identity and explain Science Practices (*M* = 3.41, SD = 1.31). As noted in the item analysis, participants had the most difficulty in identifying and explaining Crosscutting Concepts (*M* = 1.62, SD = .85).

The extreme nature of responses to these items and the significant differences between dimensions can be explained in two ways. First, it could be that items demonstrating positive skewness, like those in the Crosscutting Concepts dimension, are not currently a part of teacher education for early educators. It is likely, then, that early science education is not yet aligned to the new *Framework* (NRC, 2012). It will likely be much later in their education when children are first introduced to science learning across three dimensions even though very young children are ready and able to engage in the content, practices, and crosscutting concepts outlined in the K-12 framework (Shillady, 2013).

Moreover, the three dimensional approach to science teaching and learning seeks to shift educators away from teaching science facts in isolation and instead to engage children in the actual *doing* of science as a means for learning science content (NRC, 2012). Therefore, it is possible that early science education could be focused on the rote learning of facts, a practice that we know to be developmentally inappropriate and overall ineffective for meaningful teaching and learning.

Additionally, differences in teachers' ability to identify science concepts and behaviors can be used to help drive the focus of science professional development (PD) for early educators. It is apparent from this study that teachers have the most difficulty identifying and explaining Crosscutting Concepts and so, would benefit from additional PD and knowledge building around the Crosscutting Concepts. Significant differences between items within each dimension can also be used to help further focus PD and teacher education.

Bivariate correlations were analyzed to determine relationships between total science PCK and other variables of interest. Positive relationships were found between total PCK scores and language proficiency, total science education, and years of experience.

Regression analysis proved years of experience to significantly predict scores of Total PCK. This finding suggests that teaching staff who have spent more time in the early childhood setting are more attuned to "seeing the science" in children's play. Less experienced teachers, however, experienced greater difficulty in identifying and explaining the science within the vignette.

This finding has implication for informing teacher prep programs and PD, especially for new teachers. Because much of early learning takes place in children's play (Hirsh-Pasek, Golinkoff, Berk & Singer, 2009) being able to identify learning (in this case science) is especially important for early childhood practitioners (Weisberg, Hirsh-Pasek, & Golinkoff, 2013). Educational institutions could potentially better prepare teachers to being sensitive to learning occurring in children's play by utilizing vignettes (like the one in the ECSS), case studies, and videos of children naturally exploring. Contextualizing the content in the early learning setting may help to improve PCK for new teachers.

Validity of the ECSS could not be confirmed by examining the relationship between total PCK and recent participation in a science PD. This is likely due to the variability in science PD and the general lack of quality in current PD practices. Over 90% of teachers participate in brief, one-time workshops or trainings throughout the year (Darling-Hammond, Chung Wei, Andree, & Richardson, 2009), yet most do little to change teacher practice or student achievement (Yoon, Duncan, Lee, Scarloss, & Shapley, 2007). Effective PD, in contrast, consists of multiple hours of ongoing instruction, practice, and coaching before teachers reach mastery of the new concept or practice (Banilower, 2002; Yoon et al., 2007).

Limitations and Future Directions

This study is the first to examine the PCK for early science and the first to study PCK aligned to the *Framework for K-12 Science Education* (NRC, 2012). Findings suggest that teachers' ability to recognize science differs between the three dimensions of science education and that less experienced teachers have a more difficult time recognizing and explaining science in children's play. This study also aimed to evaluate the psychometric properties of the ECSS. Analyses indicate adequate reliability. However, item level analysis reveals a few skewed items, potentially limiting the variability in responses and dampening the ability to generate predictive relationships, or uncover latent factors within the measure.

The skewed nature of responses may be a result of sample bias. Although the initial pool of participants was quite large, and a monetary incentive was provided, there was a low response rate of 15%. Individuals who completed the survey were likely those that were 1) comfortable using the computer, 2) proficient in the English language and 3) comfortable with science. Therefore, findings from this study may represent an *overestimation* of teachers' PCK for early science and fail to report on the PCK of the general teaching population.

A more representative sample might yield more normally distributed data. Future work will recruit a larger, more diverse sample of teachers. Recruiting the participation of school directors will likely be a promising way to elicit more teacher responses. The response rate improved for a specific school district wherein the director informed her teachers about the survey and requested that they participate. Converting the survey to a paper based form may also serve to access more individuals.

Another explanation for the lack of variability in some items, and the difference in performance between dimensions, may be a result of how the vignette depicts behaviors and concepts across the three dimensions. It could be the case that some concepts and behaviors are more explicitly depicted in the scenario and others are more subtly presented, making it more difficult to identify and explain the science concept. Future work may involve fine tuning the vignettes to make negatively skewed items more subtle and positively skewed items more explicit. The extent to which the differences between dimensions reflect teachers' knowledge versus the explicitness of these dimensions in the scenario, therefore, requires further investigation.

Analyses of bi-variate correlations uncovered a positive relationship between PCK scores and English proficiency such that greater English ability related to higher PCK scores. This is an indication that language proficiency accounted for some of the variance in PCK scores. Translating the survey will help to produce a more valid PCK score for individuals more proficient in another language. Translation will also help to capture a wider range of PCK that is more representative of the current teaching population.

Capturing PCK in languages other than English is of particular relevance for early educators who are encouraged to use and support children's home language (August & Shanahan 2008; Espinosa, 2008; NAEYC, 2005; National Task Force on Early Childhood Education for Hispanics, 2007; Office of Head Start, 2007; Pinkos, 2007; Tabors, 2008). Because of this, it is possible that teacher-child interactions around science are occurring in a language other than English. A teachers' science PCK, therefore, may be best measured in the language used in the classroom.

Future work replacing written scenarios with videos of children engaged in experiences may also help to reduce the influence of language on survey performance as individuals will not be asked to read and comprehend the text. Similarly, restructuring the ECSS into a semi-structured interview may also serve to minimize the reliance on language and reading comprehension.

As discussed previously, validity could not be confirmed using participation in a science PD as concurrent validity. Because it is difficult to capture the quality and content of self-reported participation in PD for early science, future work will seek to examine this relationship in the context of a science intervention. Validity will be confirmed if teachers' PCK after participation in the intervention is higher than their baseline level of PCK. Other forms of validity may include comparing PCK scores to observations of science teaching and child level science achievement.

Conclusion

Understanding what constitutes an *effective* early educator is of great importance. PCK is a prime construct of interest that can help define what it means to be a high-quality educator. Because of the need for improvement in science education in the United States, and the profound benefits of engaging young children in science, understanding PCK for early science is of immediate importance. However, PCK for early science remains understudied. The current study helps to meet this growing need and begins to close the gap in the literature by examining the PCK for early science and the psychometric properties of a new PCK measure, the Early Childhood Science Survey. A greater understanding of the PCK for early science is sorely needed to ensure that the benefits of early science are truly capitalized on. This study takes the first steps toward uncovering this vital information to improve teacher education and ultimately, the experiences of our youngest learners.

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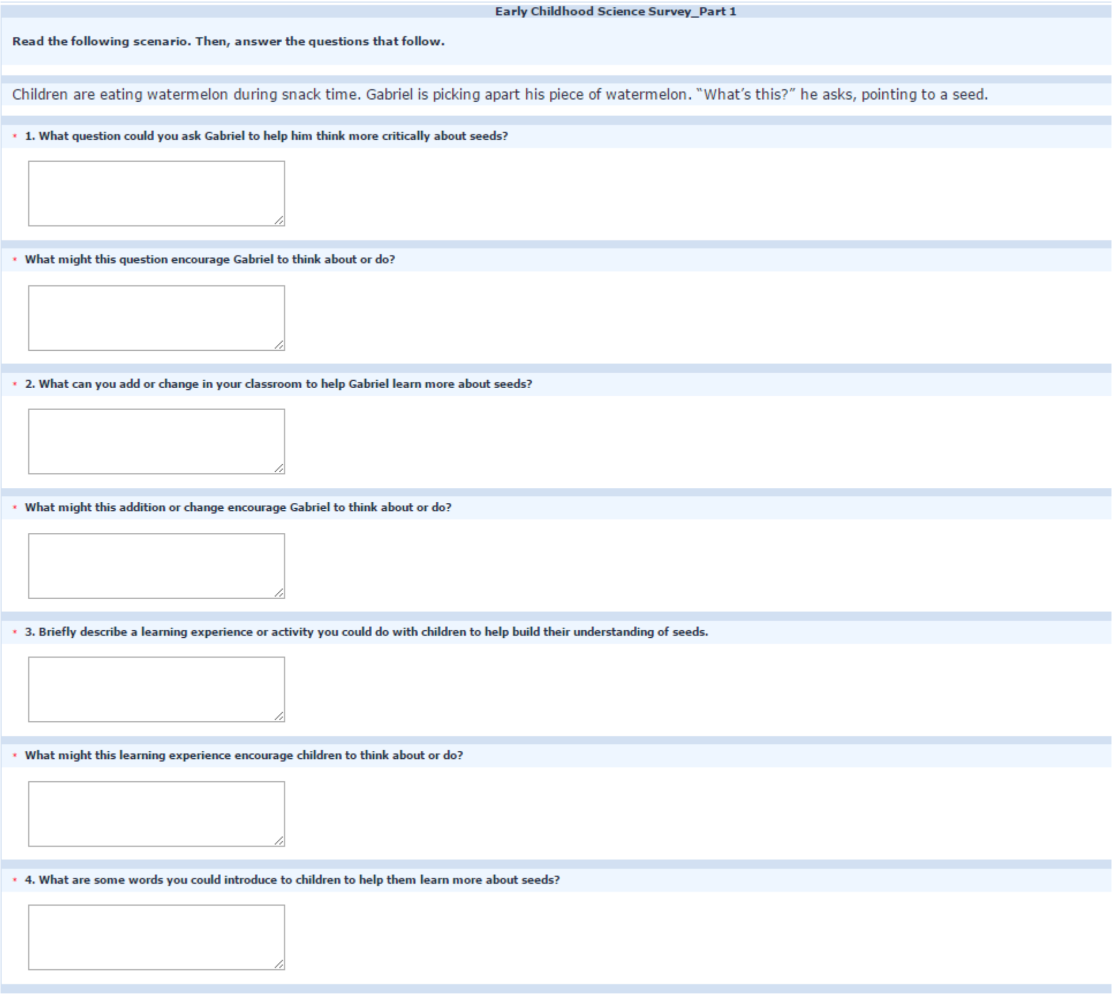
APPENDICES

Appendix A

Screenshots of the Early Childhood Science Survey



Early Childhood Science Survey_Part 1

Read the following scenario. Then, answer the questions that follow.

Children are eating watermelon during snack time. Gabriel is picking apart his piece of watermelon. "What's this?" he asks, pointing to a seed.

* **1. What question could you ask Gabriel to help him think more critically about seeds?**

* **What might this question encourage Gabriel to think about or do?**

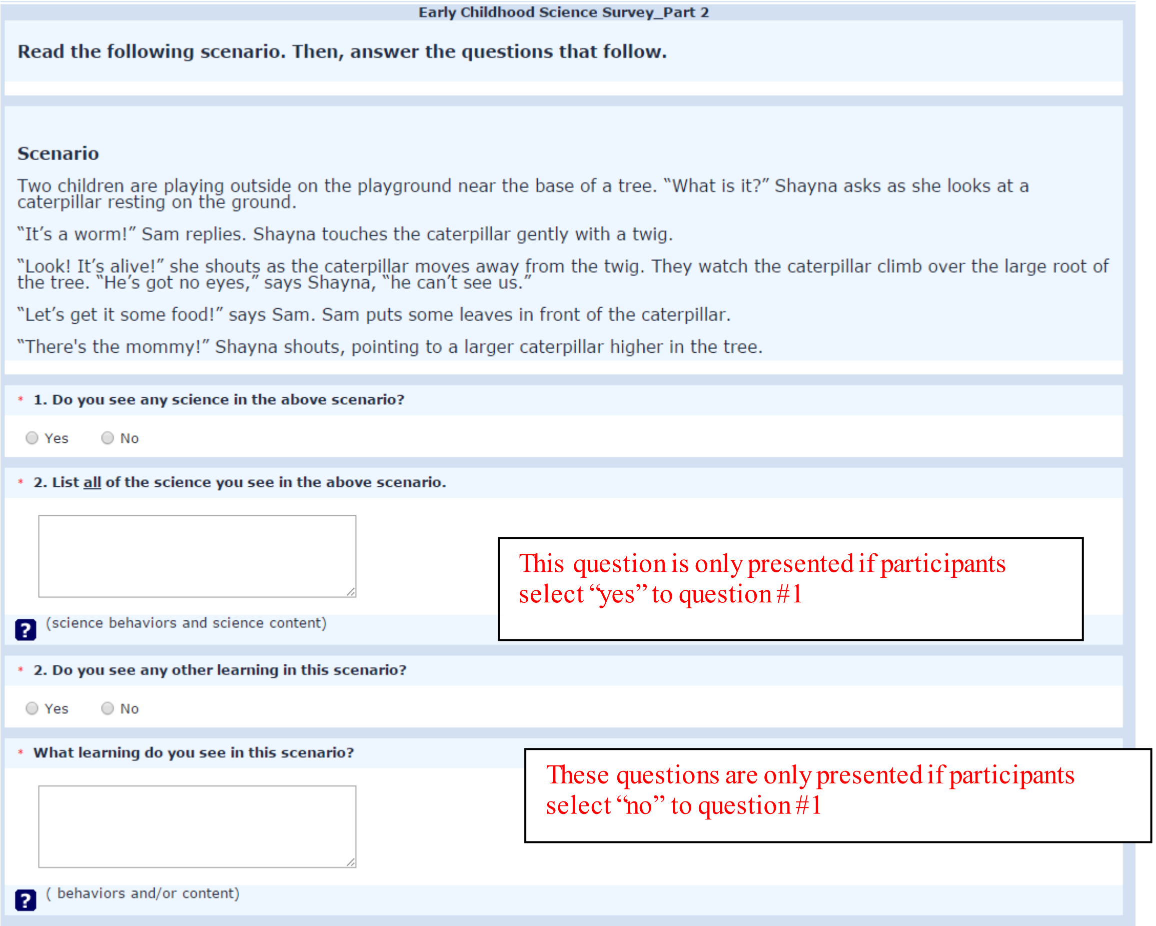
* **2. What can you add or change in your classroom to help Gabriel learn more about seeds?**

* **What might this addition or change encourage Gabriel to think about or do?**

* **3. Briefly describe a learning experience or activity you could do with children to help build their understanding of seeds.**

* **What might this learning experience encourage children to think about or do?**

* **4. What are some words you could introduce to children to help them learn more about seeds?**



Early Childhood Science Survey_Part 2

Read the following scenario. Then, answer the questions that follow.

Scenario

Two children are playing outside on the playground near the base of a tree. "What is it?" Shayna asks as she looks at a caterpillar resting on the ground.

"It's a worm!" Sam replies. Shayna touches the caterpillar gently with a twig.

"Look! It's alive!" she shouts as the caterpillar moves away from the twig. They watch the caterpillar climb over the large root of the tree. "He's got no eyes," says Shayna, "he can't see us."

"Let's get it some food!" says Sam. Sam puts some leaves in front of the caterpillar.

"There's the mommy!" Shayna shouts, pointing to a larger caterpillar higher in the tree.

* **1. Do you see any science in the above scenario?**

○ Yes ○ No

* **2. List <u>all</u> of the science you see in the above scenario.**

(science behaviors and science content)

This question is only presented if participants select "yes" to question #1

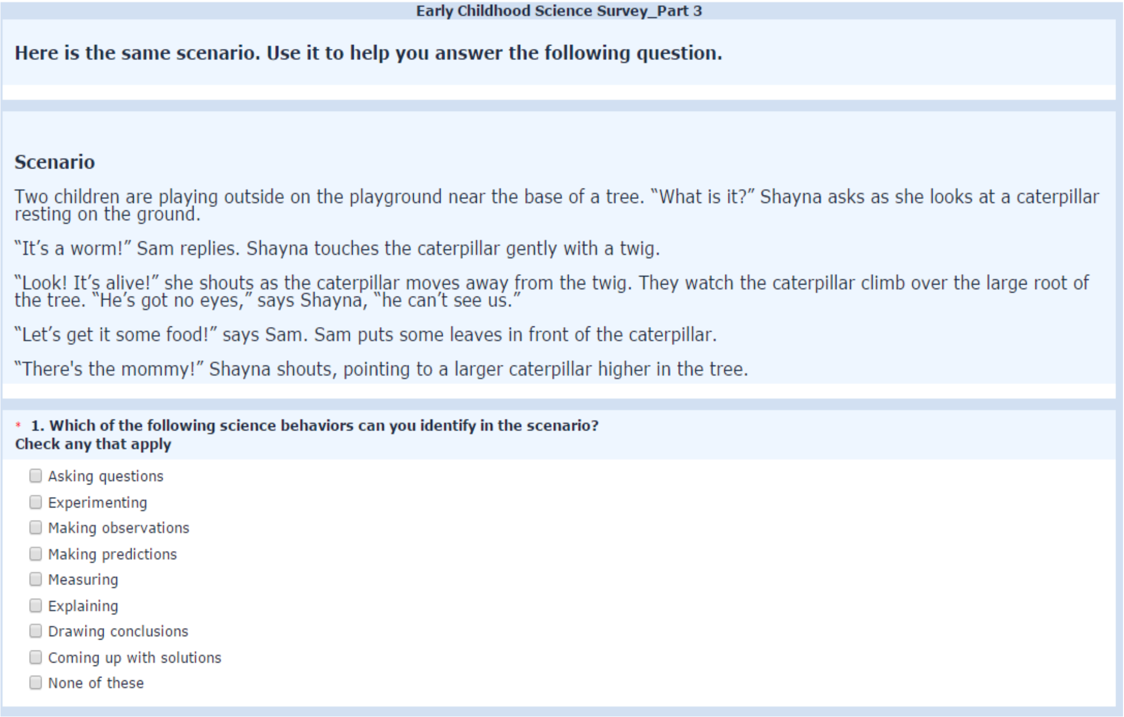
* **2. Do you see any other learning in this scenario?**

○ Yes ○ No

* **What learning do you see in this scenario?**

(behaviors and/or content)

These questions are only presented if participants select "no" to question #1



Early Childhood Science Survey_Part 3

Here is the same scenario. Use it to help you answer the following question.

Scenario

Two children are playing outside on the playground near the base of a tree. "What is it?" Shayna asks as she looks at a caterpillar resting on the ground.

"It's a worm!" Sam replies. Shayna touches the caterpillar gently with a twig.

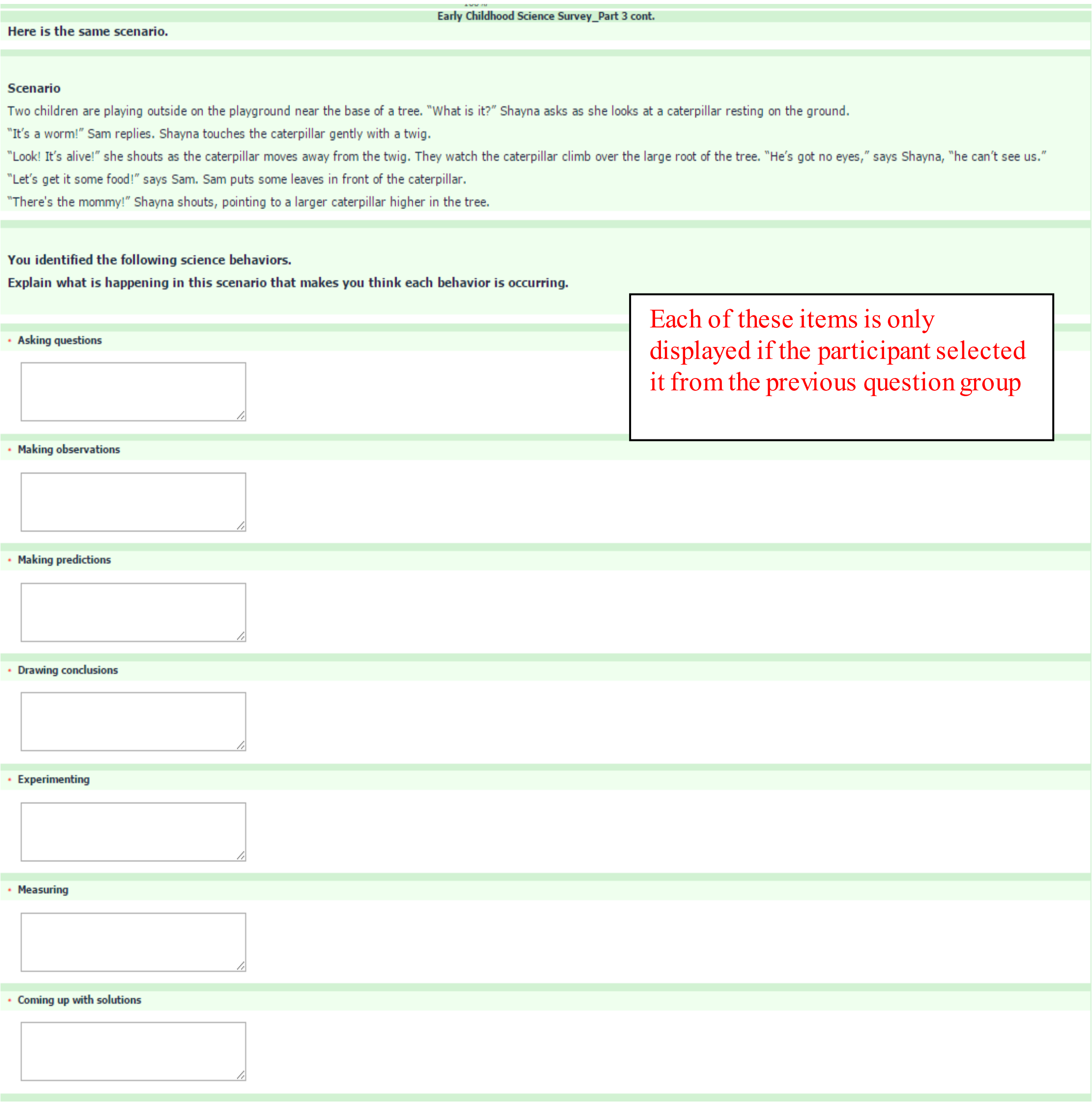
"Look! It's alive!" she shouts as the caterpillar moves away from the twig. They watch the caterpillar climb over the large root of the tree. "He's got no eyes," says Shayna, "he can't see us."

"Let's get it some food!" says Sam. Sam puts some leaves in front of the caterpillar.

"There's the mommy!" Shayna shouts, pointing to a larger caterpillar higher in the tree.

* **1. Which of the following science behaviors can you identify in the scenario?**
Check any that apply

☐ Asking questions
☐ Experimenting
☐ Making observations
☐ Making predictions
☐ Measuring
☐ Explaining
☐ Drawing conclusions
☐ Coming up with solutions
☐ None of these



Early Childhood Science Survey_Part 3 cont.

Here is the same scenario.

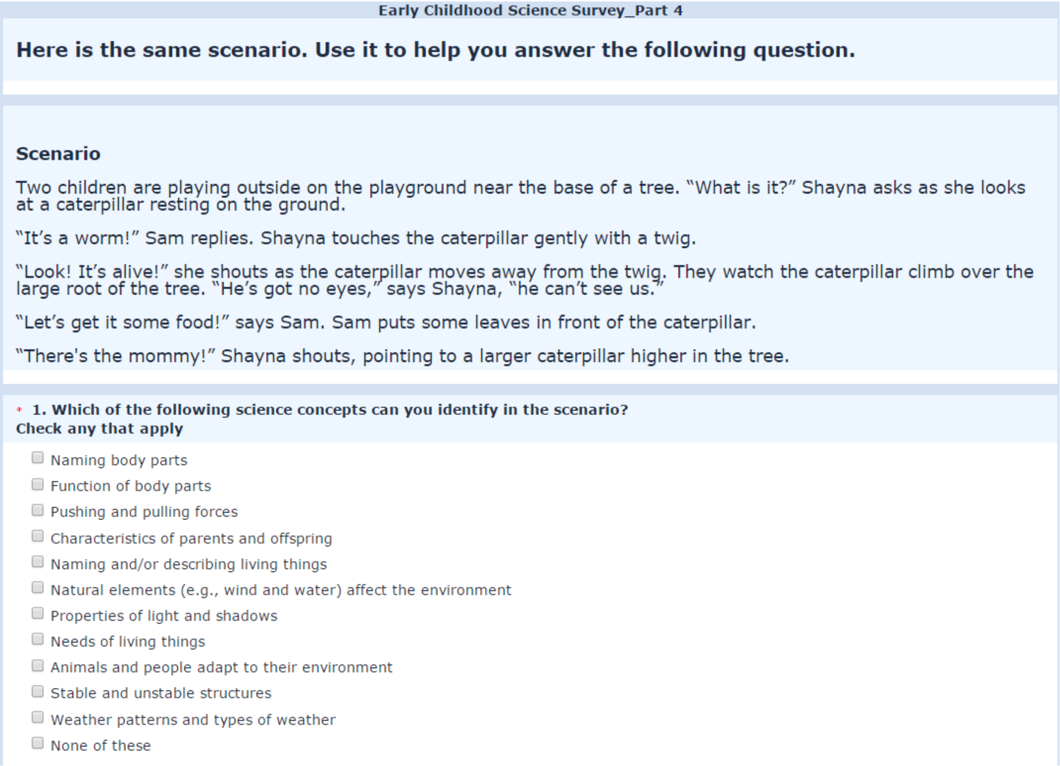
Scenario

Two children are playing outside on the playground near the base of a tree. "What is it?" Shayna asks as she looks at a caterpillar resting on the ground.
"It's a worm!" Sam replies. Shayna touches the caterpillar gently with a twig.
"Look! It's alive!" she shouts as the caterpillar moves away from the twig. They watch the caterpillar climb over the large root of the tree. "He's got no eyes," says Shayna, "he can't see us."
"Let's get it some food!" says Sam. Sam puts some leaves in front of the caterpillar.
"There's the mommy!" Shayna shouts, pointing to a larger caterpillar higher in the tree.

You identified the following science behaviors.
Explain what is happening in this scenario that makes you think each behavior is occurring.

Each of these items is only displayed if the participant selected it from the previous question group

- Asking questions
- Making observations
- Making predictions
- Drawing conclusions
- Experimenting
- Measuring
- Coming up with solutions



Early Childhood Science Survey_Part 4

Here is the same scenario. Use it to help you answer the following question.

Scenario

Two children are playing outside on the playground near the base of a tree. “What is it?” Shayna asks as she looks at a caterpillar resting on the ground.

“It’s a worm!” Sam replies. Shayna touches the caterpillar gently with a twig.

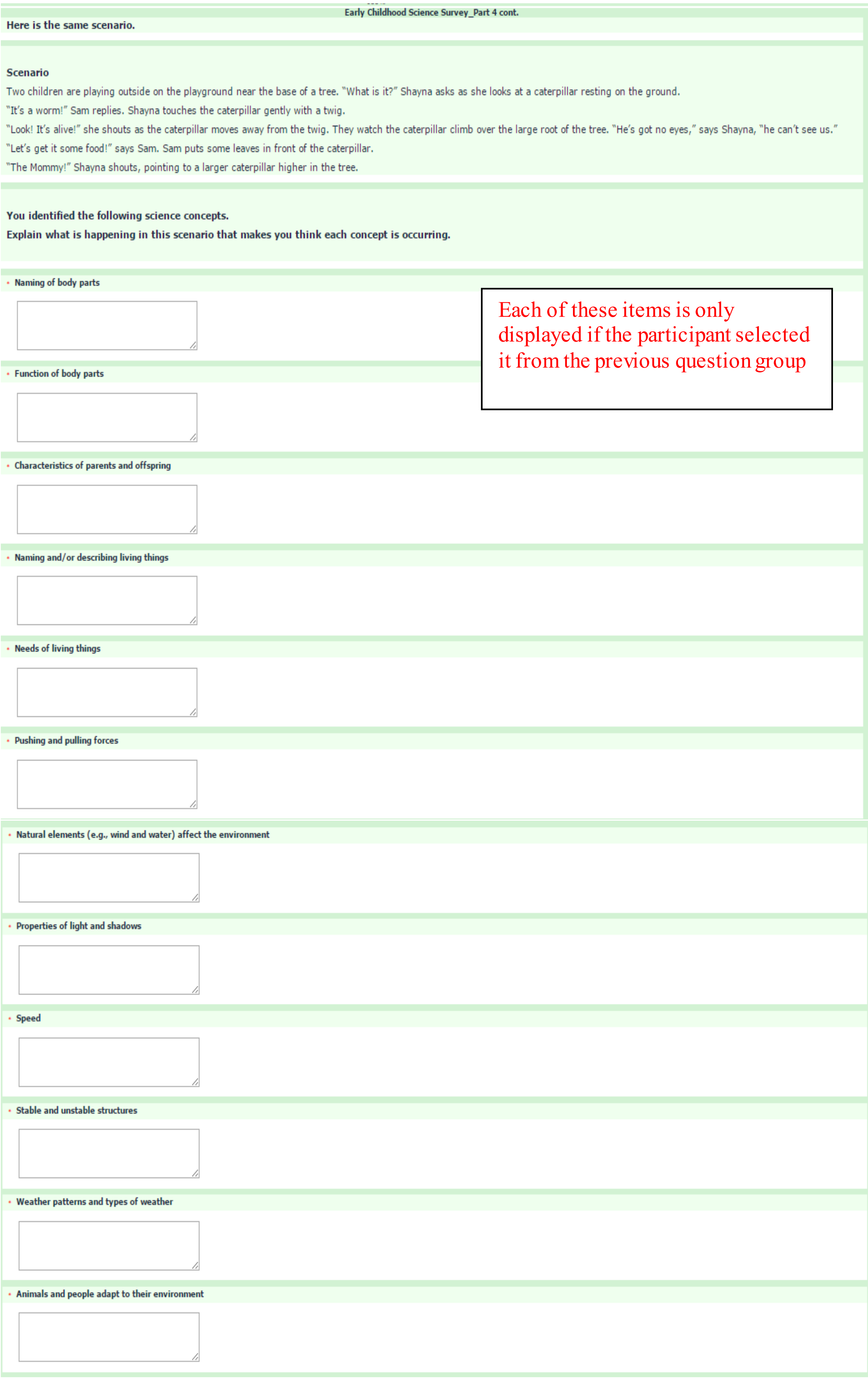
“Look! It’s alive!” she shouts as the caterpillar moves away from the twig. They watch the caterpillar climb over the large root of the tree. “He’s got no eyes,” says Shayna, “he can’t see us.”

“Let’s get it some food!” says Sam. Sam puts some leaves in front of the caterpillar.

“There's the mommy!” Shayna shouts, pointing to a larger caterpillar higher in the tree.

* **1. Which of the following science concepts can you identify in the scenario?**
Check any that apply

☐ Naming body parts
☐ Function of body parts
☐ Pushing and pulling forces
☐ Characteristics of parents and offspring
☐ Naming and/or describing living things
☐ Natural elements (e.g., wind and water) affect the environment
☐ Properties of light and shadows
☐ Needs of living things
☐ Animals and people adapt to their environment
☐ Stable and unstable structures
☐ Weather patterns and types of weather
☐ None of these



Early Childhood Science Survey_Part 4 cont.

Here is the same scenario.

Scenario

Two children are playing outside on the playground near the base of a tree. "What is it?" Shayna asks as she looks at a caterpillar resting on the ground.

"It's a worm!" Sam replies. Shayna touches the caterpillar gently with a twig.

"Look! It's alive!" she shouts as the caterpillar moves away from the twig. They watch the caterpillar climb over the large root of the tree. "He's got no eyes," says Shayna, "he can't see us."

"Let's get it some food!" says Sam. Sam puts some leaves in front of the caterpillar.

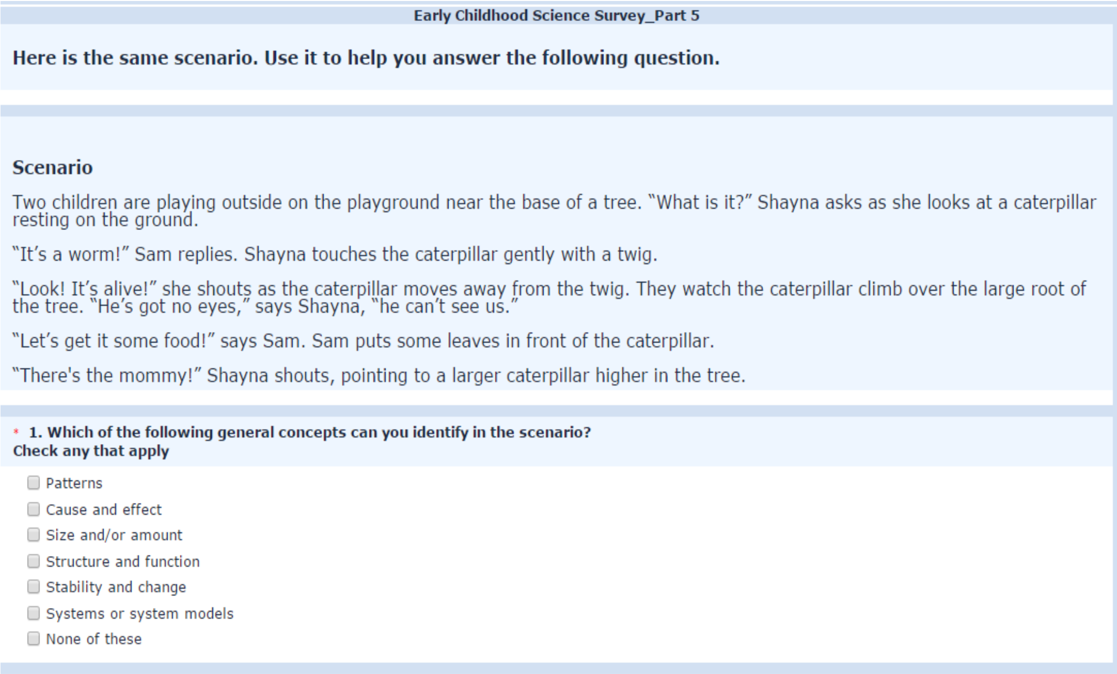
"The Mommy!" Shayna shouts, pointing to a larger caterpillar higher in the tree.

You identified the following science concepts.

Explain what is happening in this scenario that makes you think each concept is occurring.

- **Naming of body parts**
- **Function of body parts**
- **Characteristics of parents and offspring**
- **Naming and/or describing living things**
- **Needs of living things**
- **Pushing and pulling forces**
- **Natural elements (e.g., wind and water) affect the environment**
- **Properties of light and shadows**
- **Speed**
- **Stable and unstable structures**
- **Weather patterns and types of weather**
- **Animals and people adapt to their environment**

Each of these items is only displayed if the participant selected it from the previous question group



Early Childhood Science Survey_Part 5

Here is the same scenario. Use it to help you answer the following question.

Scenario

Two children are playing outside on the playground near the base of a tree. “What is it?” Shayna asks as she looks at a caterpillar resting on the ground.

“It’s a worm!” Sam replies. Shayna touches the caterpillar gently with a twig.

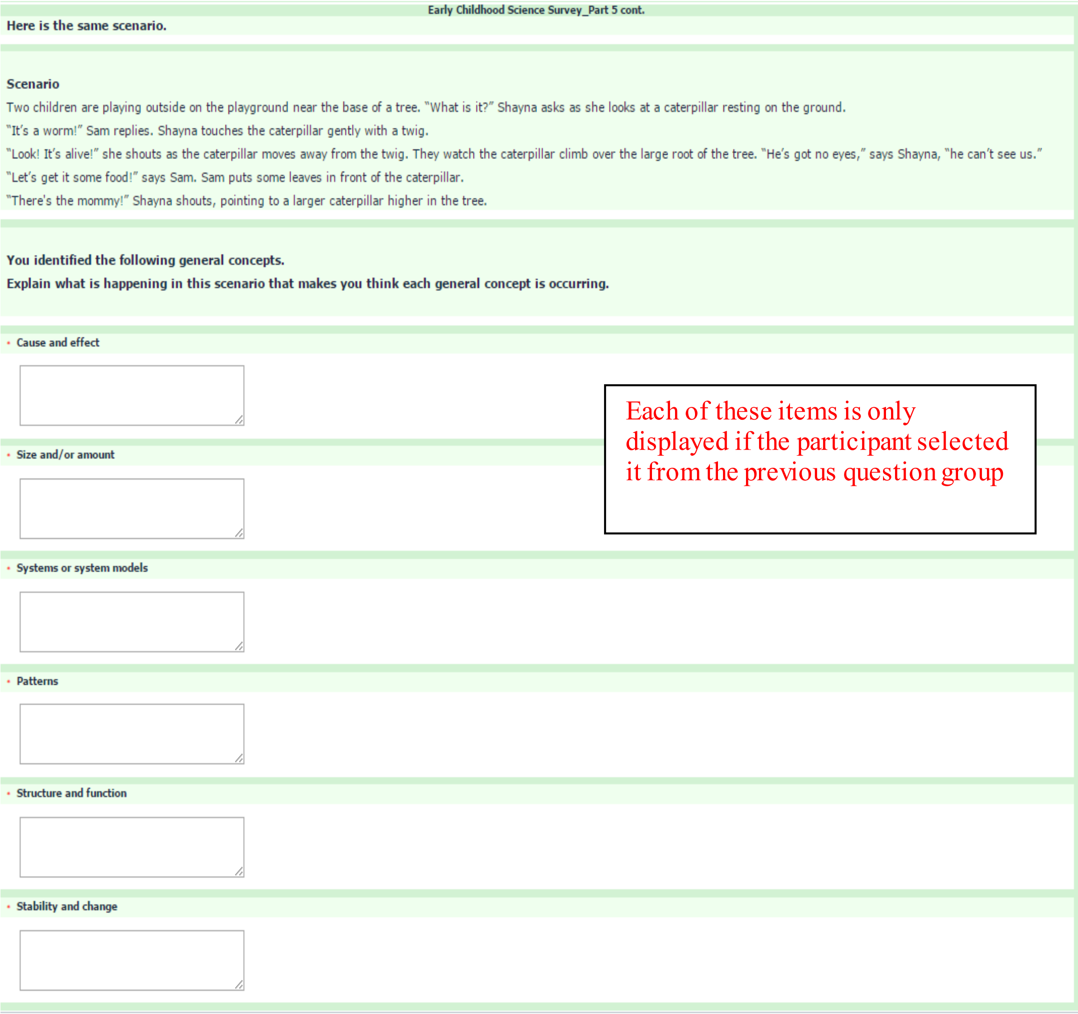
“Look! It’s alive!” she shouts as the caterpillar moves away from the twig. They watch the caterpillar climb over the large root of the tree. “He’s got no eyes,” says Shayna, “he can’t see us.”

“Let’s get it some food!” says Sam. Sam puts some leaves in front of the caterpillar.

“There's the mommy!” Shayna shouts, pointing to a larger caterpillar higher in the tree.

* **1. Which of the following general concepts can you identify in the scenario?**
Check any that apply

☐ Patterns
☐ Cause and effect
☐ Size and/or amount
☐ Structure and function
☐ Stability and change
☐ Systems or system models
☐ None of these



Early Childhood Science Survey_Part 5 cont.

Here is the same scenario.

Scenario

Two children are playing outside on the playground near the base of a tree. "What is it?" Shayna asks as she looks at a caterpillar resting on the ground.

"It's a worm!" Sam replies. Shayna touches the caterpillar gently with a twig.

"Look! It's alive!" she shouts as the caterpillar moves away from the twig. They watch the caterpillar climb over the large root of the tree. "He's got no eyes," says Shayna, "he can't see us."

"Let's get it some food!" says Sam. Sam puts some leaves in front of the caterpillar.

"There's the mommy!" Shayna shouts, pointing to a larger caterpillar higher in the tree.

You identified the following general concepts.

Explain what is happening in this scenario that makes you think each general concept is occurring.

- **Cause and effect**
- **Size and/or amount**
- **Systems or system models**
- **Patterns**
- **Structure and function**
- **Stability and change**

Each of these items is only displayed if the participant selected it from the previous question group

Appendix B

Early Childhood Science Survey
Scoring rubric

The framework for K-12 science education was used to generate items and score responses. Participants received a point for an item if they correctly selected that item from the list *and* correctly explained why they selected the item. All items were scored correct or incorrect by the author and a separate scorer who had received training on the framework and its application to this survey. Initial analysis using Cohen's K revealed good agreement between scorers, k > .850 for all items. The scorers met to discuss divergences in scoring after independently coding each item. Other experts in early science provided feedback to resolve divergences in scoring.
This scoring rational document was created by the author to serve as a rubric for scoring and to summarize and explain scoring decisions.

Practices
5 scored items

Asking questions

Correct responses for "asking questions" needs to refer to the child asking "what is it?"

Examples of accepted responses:

- What is it?
- Shayna asked what is it?
- The friends ask about the kind of bug
- The discovery of something they first thought was a worm. Need to ask questions to determine if what they are looking at is a worm or a caterpillar.
- One of the children asks the other one about: what is the animal they are observing?
- They want to know what the animal is that they see.

Examples of unaccepted responses:

- Answer the question if caterpillar has eyes
- what do they eat
- the children are asking themselves where are its eyes can it see
- The teacher could ask questions as to why they think it's a worm; why did they choose leaves to give to the caterpillar.

Making Observations

Correct responses for "making observations" must refer to noticing/observing the caterpillar and/or its characteristics (e.g., that it is living, doesn't have eyes, differences in sizes, watching it climb)

Examples of accepted responses:

- looking at the caterpillar
- child says it has no eyes
- they observed how it climbed over the root
- the child notices its alive
- they see its similar to a worm

Examples of unaccepted responses:

- Observing how the caterpillar eats, will it change, where it lives, etc.
- What kind of leaves does a caterpillar eat?
- Encourage students to examine the caterpillar and then compare/contrast those features with that of a worm.
- They are observing closely

Making predictions:

This item is not explicitly present in the scenario and therefore **will be dropped from the score**. The scenario is not written clearly enough, nor the directions explicit enough, to elicit a precise explanation.

Drawing conclusions

A correct response for "drawing conclusions" must refer to the children indicating that the larger caterpillar is the mommy, that the caterpillar cannot see, the caterpillar is a worm, and/or that the caterpillar is alive. Although some individuals referenced giving the caterpillar food was indication of the child drawing the conclusion that it was hungry, that example alone, given the other three stronger examples, is not a sufficient explanation. Reference to feeding the caterpillar, or that caterpillars will eat leaves is also a weak example of drawing conclusions because there is no evidence to suggest that the caterpillar is hungry or that it will eat leaves (this is drawn on prior knowledge).

Examples of accepted responses:

- It must be the mommy because it looks like it and it is bigger. It is alive because it moves.
- Concluding that the larger caterpillar is the smaller caterpillar's mother
- If it moves is it living? If it eats is it alive?
- the caterpillar cannot see me
- "There's the mommy!"
- They conclude it is a worm perhaps since they were exposed to worms prior and it has similar characteristics.

Examples of unaccepted responses:

- They try to feed it because it needs their help.
- It wants to eat; therefore they will feed it leaves.
- How the change from caterpillar to butterfly happens.
- Caterpillar will eat the leaves.

Experimenting

A correct response for "experimenting" must refer to the child poking the caterpillar with a stick. Although there are a few responses that refer to placing the leaf in front of the caterpillar or feeding it as proof of experimentation, these examples are not sufficient. Reference to touching the caterpillar with a stick is a better example of experimenting because 1) it follows a question (i.e., what is it) 2) the behavior (i.e., poking it) was likely related to attempting to answer the question 3) the behavior resulted in an observable situation that helped to answer the question by drawing conclusions. Because this situation contained all of these elements, it is a better example of an experiment than feeding the caterpillar. If the child had wondered what the caterpillar would eat, if it was hungry, or how it ate, then putting leaves in front of it would be a good experiment.

Examples of accepted responses:

- Using the twig to test and see if the caterpillar is still alive
- They touch it gently with a twig.

Examples of unaccepted responses:

- Giving the leaves to the caterpillar
- finding food for the caterpillar
- They are experimenting by putting a leaf in front of the caterpillar.

Measuring

A correct response for measuring must refer to the children comparing the size of the caterpillars. When the child says, "it's the mommy", it indicates that she has noticed one is bigger than the other.

Examples of accepted responses:

- bigger is thought to be mommy
- that must be the mommy- bigger
- comparing sizes of caterpillars
- The other caterpillar is larger.

Examples of unaccepted responses:

- Some leaves are large
- They can measure the caterpillar
- The root was large

Coming up with solutions

This item is not explicitly present in the scenario and therefore **will be dropped from the score**. Some responses to this item referred to giving the caterpillar food and/or finding the mommy as solutions. However, in order for there to be a solution, there must first be a problem. It could be inferred that the conclusion about the caterpillar not having eyes was a problem and that by providing it with food and finding its mom, the children were coming up with a solution. Because there is no explicit problem, there is not opportunity to come up with a solution.

Core Ideas
5 scored items

Naming of Body Parts

A correct response must include reference to the children noticing the caterpillar's lack of eyes.

Examples of accepted responses:

- eyes
- noticing lack of eyes
- "He's got no eyes," says Shayna
- They identified that it had no eyes.

Examples of accepted responses:

- Children describe how it looks
- Legs, furry feeling

Function of Body Parts

A correct response must include reference to eyes seeing.

Examples of accepted responses:

- Statement: He can't see us
- Because they noticed he didn't have eyes they realized he was not able to see.
- What do eyes do? How come we can't see the eyes. Can it still see if we can't see the eyes.
- eyes are needed for seeing
- see
- "the caterpillar can't see us"

Examples of accepted responses:

- "It's Alive" moves away from the twig
- Children talk about what it is doing
- It moves from twig using its body
- eyes

Characteristics of parents and offspring

A correct response must include reference to the "mother" caterpillar being larger.

Examples of accepted responses:

- The mommy-pointing to a larger caterpillar
- "The Mommy!" Shayna shouts, pointing to a larger caterpillar higher in the tree.

Examples of unaccepted responses:

- What does its babies look like? Are they born or eggs?
- Why is the baby by its mom

- Same/different
- It’s the mommy

Naming and/or describing living things
A correct response must include reference to the children’s comments about the caterpillar.

Examples of accepted responses:
- They identify the caterpillar as a worm
- “it’s a worm!” Sam replies
- Children say it is alive
- Naming parts of a tree and naming the insects.
- sight, hunger

Examples of unaccepted responses:
- Transformations of the life cycle
- Helping students understand how insects differ from animals.
- a caterpillar its long

Identifying the Needs of Living Things
A correct response must include reference to feeding the caterpillar.

Examples of accepted responses:
- eats leaves
- food
- the caterpillar needs to eat
- "Let's get it some food"

Examples of unaccepted responses:
- it moves
- To see how things survive and function
- That it needs to see

Pushing and pulling forces
This item is not explicitly present in the scenario and therefore **will be dropped from the score**.

Properties of light and shadows
This item is not explicitly present in the scenario and therefore **will be dropped from the score**.

Speed
This item is not explicitly present in the scenario and therefore **will be dropped from the score**.

Stable and unstable structures

This item is not explicitly present in the scenario and therefore **will be dropped from the score**.

Weather patterns and types of weather

This item is not explicitly present in the scenario and therefore **will be dropped from the score**.

Animals and people adapt to their environment

This item is not explicitly present in the scenario and therefore **will be dropped from the score**.

Crosscutting Concepts

5 scored items

Cause and effect

A correct response must include reference to the twig causing the caterpillar to move and/or not having eyes causing inability to see.

Examples of accepted responses:

- no eyes can't see
- Pushing caterpillar makes it move
- Touch the worm and it moves. No eyes means it can’t see.
- The child touched it with a twig and the caterpillar moved away

Examples of unaccepted responses:

- hungry so they got it food
- let’s get food- putting leaves so it can eat
- Feeding the caterpillar and it's life cycle
- moving and therefore hungry
- The caterpillar in the tree was bigger so the kids assumed it was the mother.

Size and/or amount

A correct response must include reference to the mother caterpillar or reference to the children noticing the larger caterpillar.

Examples of accepted responses:

- small caterpillar and the big caterpillar
- "There's the mommy!" pointing to a larger caterpillar
- They identified that the mom was bigger.
- Compared sizes
- Mommy is bigger

Examples of unaccepted responses:

- Long worm to a butterfly form
- They give a few leaves to the caterpillar; his size determines how much he might eat.
- Measure both insects and compare.
- The large root of the tree

Systems and system models

A correct response must include reference to the ecosystem of the tree providing shelter and food and/or the presence of a family system

Examples of accepted responses:

- The system of "family" - child and mommy caterpillar.
- parent and offspring
- The caterpillar is part of the ecosystem on the playground. If something happens to its home, the tree, the caterpillar will also be affected.

Examples of unaccepted responses:

- The life cycle of a butterfly
- They are on the tree
- Its hungry

Patterns

A correct response must include reference to identifying the mother caterpillar based on similarities and/or naming the caterpillar a worm because it looked similar.

Examples of accepted responses:

- the two caterpillars must have looked the same for them to think that they were related
- All the animals with those characteristics are worms.
- There's the mommy!" Shayna shouts, pointing to a larger caterpillar higher in the tree

Examples of unaccepted responses:

- Climbing up a tree or over a root, is a pattern that caterpillars do
- Patterns on the caterpillar
- The caterpillar needing food and the next event finding the food and then giving it to the caterpillar.
- The patterns of the caterpillar, (black, yellow, white)

Structure and function

This item is not explicitly present in the scenario and therefore **will be dropped from the score**.

Stability and change

A correct response must include reference to the caterpillar moving and/or the caterpillar growing into an adult (mom).

Examples of accepted responses:

- resting on the ground and then moving when touched with a twig
- review the effects of change over the life span of the insects.
- small one the child, large one is mommy
- tree it was on was stable. The caterpillar was still when it was on the sand but after being touched it crawled away.
- The firm nature of the twig compared to the fluid movement of the caterpillar, experienced by the children in a subtle way, in my opinion

Examples of unaccepted responses:

- If the tree dies, where will the insect go?
- the larger caterpillar near the smaller caterpillar

TABLES

Table 1.

Item means, standard deviations, skewness, and kurtosis

Dimension	Item	N	Mean	Standard Deviation	Skewness	Kurtosis
Science Practices	1. Questioning	107	.87	.34	-2.22	2.99
	2. Observing	107	.93	.25	-3.57	10.92
	3. Drawing conclusions	107	.77	.43	-1.28	-.38
	4. Experimenting	107	.46	.50	.17	-2.01
	5. Measuring	107	.38	.49	.49	-1.80
Science Content	6. Naming body parts	107	.77	.43	-1.28	-.38
	7. Function of parts	107	.64	.48	-.57	-1.71
	8. Characteristics of offspring	107	.55	.50	-.21	-1.99
	9. Naming and describing living things	107	.87	.34	-2.22	2.99
	10. Needs of living things	107	.93	.25	-3.57	10.92
Crosscutting concepts	11. Cause and effect	107	.74	.44	-1.10	-.81
	12. Size and amount	107	.74	.44	-1.10	-.81
	13. Systems	107	.02	.14	7.21	50.92
	14. Patterns	107	.03	.17	5.80	32.24
	15. Stability and change	107	.09	.29	2.83	6.14

Note: means scores presented are derived from raw scores; N = 107 across all items.

Table 2.

Exploratory factor analysis

	Varimax loading	Percent of total variance explained
1. Questioning	.569	23.42%
2. Observing	.548	
3. Drawing conclusions	.632	
4. Experimenting	.497	
5. Measuring	.445	
6. Naming body parts	.514	
7. Function of parts	.532	
8. Characteristics of offspring	.596	
9. Naming and describing living things	.447	
10. Needs of living things	.542	
11. Cause and effect	.433	
12. Size and amount	.622	

Note: N = 107 across all dimensions. Items 13, 14, and 15 are not displayed on this table due to weak factor loadings. Loadings are based on oblique, principal-components analysis.

Table 3.

Internal consistency within subgroups

Subgroup		n	Cronbach's alpha
	Full Sample	107	.75
Ethnicity			
	White	77	.74
	African American	22	.73
	Hispanic	33	.77
Educational level			
	High school/ AA/ CDA	28	.76
	BA	46	.75
	MA/PhD	33	.76
Position			
	Teacher assistant	16	.76
	Teacher	62	.74
	Master teacher/Curriculum specialist	14	.76
	Other	15	.82
Experience level			
	Novice	31	.75
	Experienced	76	.74

Table 4.

Bivariate correlations between total PCK scores and selected demographic characteristics

	PCK	Education	Position	Years in role	English proficiency	Science PD
Education	.045					
Position	.043	.254**				
Years in role	.304**	.071	-.066			
English proficiency	.251**	.158	-.061	.033		
Science PD	-.060	-.001	-.032	.009	-.038	
Science education	.246*	.243*	.004	.181	.114	.050

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 5.

Paired samples t-tests comparing means differences between dimensions

		Paired Differences				
		Means	Standard Deviation	95% Confidence Interval of the Difference	t	df
Pair 1	Content - Crosscutting	2.14	1.24	1.90, 2.38	17.86*	106
Pair 2	Practices - Content	-.346	1.43	-.62, -.07	-2.51*	106
Pair 3	Practices - Crosscutting	1.79	1.23	1.56, 2.03	15.04*	106

* p <.01
Note: N = 107 across all dimensions