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Approaches to Teaching Young Children Science Concepts and Vocabulary and Scientific Problem-solving Skills and Role of Classroom Environment

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APPROACHES TO TEACHING YOUNG CHILDREN SCIENCE CONCEPTS AND VOCABULARY AND SCIENTIFIC PROBLEM-SOLVING SKILLS AND ROLE OF CLASSROOM ENVIRONMENT.

by

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The current study was a replication of the study completed by Hong and Diamond (2012) which explored the effectiveness of two approaches to teaching young children science concepts and vocabulary and scientific problem-solving skills related to objects' sinking and floating: responsive teaching (RT) and responsive teaching combined with explicit instruction (RT + EI). The current study also examined the moderating effects of classroom environment and teacher-specific factors on the relation between teaching approaches and children's science learning. Participants included 26 (15 girls) four-and five-year old prekindergarten children. Responsive Teaching (RT) mirrors common approaches to teaching (observing and commenting on behaviors, asking questions, modeling, and playing in parallel) and Responsive Teaching plus Explicit Instruction (RT + EI) builds upon the implicit strategies of responsive teaching by utilizing explicit teaching strategies as well. Results revealed that there was a significant association between teaching approaches and children's outcome of content-specific scientific problem-solving skills. Teacher's perceptions about their ability to teach science to young children were not a significant moderator of the relation between teaching approaches and children's science concepts and vocabulary and scientific problem-solving skills. However, there was a significant negative association between teacher's years of experience and their perception about teaching science. Results also found that classroom environment was not a significant moderator of the relation between teaching approaches and children's science concepts and vocabulary and scientific problem-solving skills. However, there was a significant association between the science-related classroom environment and children's outcome of science concepts and vocabulary. Limitations of the current study, future directions, and implications for practice are also discussed.

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CHAPTER 1

INTRODUCTION

Science-oriented programs are ideal for early childhood education due to children's propensity towards active, experiential, and explorative approaches to learning (National Research Council, 2001). Preschool science curricula provide an exceptional method for teachers to challenge a child's mind because they encourage children's curiosity, wonder, interest in their surroundings, and offer children the opportunity to build theories (Witt & Kimple, 2008; Worth & Grollman, 2003). Young children are enthusiastic when it comes to learning about the world around them and they are cognitively prepared to do so (National Research Council, 2001). Developmental research in the past several decades has led to the conclusion that although preschool children have some age-related limits in terms of their cognitive skills, they are capable learners and their abilities to think and problem solve have frequently been underestimated (Copple & Brekekamp, 2009; Gelman & Brenneman, 2004).

Early childhood classrooms that include science provide children with opportunities to not only gain experience with tools and procedures related to this area, but they also gain ideas that are important to future learning (Worth & Grollman, 2009). According to the National Research Council (2001), children actively build their knowledge by integrating new information into their current understanding about the world around them. Science activities in preschool classrooms that underscore complex phenomena and language promote children's intellectual and linguistic development (French, 2004). Such activities provide children with opportunities to describe and explain scientific processes to others. Participation by children in scientific investigations exponentially increases their understanding of the nature of science (Metz, 2004). The thinking processes associated with these early explorations and engagement in science concepts help children establish a foundation for learning as they continue to develop more advanced understanding in this area (Brenneman, Stevenson-Boyd, & Frede, 2009). Children have an innate curiosity, but they require assistance in understanding their observations and how to relate the new information to their existing knowledge (Lehr, 2005). When adults encourage children to question, predict, explain, and explore in a safe environment, they offer children the support that is essential for becoming successful science students and thinkers.

Preschool science has been emphasized as an area of importance within the domain of General Knowledge in many state readiness standards. In an extensive review of the content and process included in national and state pre-kindergarten and kindergarten science standards and early childhood curricula, Greenfield and his colleagues (2009) noted that three broad content areas emerged from their analysis when they searched for themes and commonalities: Life Sciences (42% of all entries), Earth/Space Sciences (27%), and Physical/Energy Sciences (31%) (Greenfield, Dominguez, Greenberg, Maier, & Fuccillo, 2009). They also noted that eight process skills emerged: observing, describing, comparing, questioning, predicting, experimenting, reflecting, and cooperating. Worth and Grollman (2003) stress that processes as these are important because children need opportunities to contemplate the work they have done, consider what they have experienced, think about concepts related to the materials, try different approaches, and discuss their thoughts with others; and also because these processes enable children to consider not only what they did in new ways, but also how they accomplished it and what is important to them. Science experiments should not solely focus on providing information and explanations for scientific phenomena, but should be carried out with the intention of providing children with the opportunities to expand their thinking and to create new understandings from their experiences (Worth & Grollman, 2003).

In addition, Scott-Little, Kagan, and Frelow (2006) have analyzed the content of 46 early learning standards documents and found that the category which had the highest percentage of standard items was cognition and general knowledge. Their analysis revealed that the category of cognition and general knowledge consisted of four indicator categories: (1) logic-mathematical knowledge, (2) knowledge of the physical world, (3) social knowledge, and (4) social-conventional knowledge. Nearly 80% of the cognitive standard items were coded as either logico-mathematical knowledge or as knowledge of the physical world. Moreover, there are a number of state standards, including the readiness standards of Head Start (U.S. Department of Health and Human Services, 2003), that designate science as its own readiness domain instead of an element of a more generic domain of cognition and general knowledge, thus assigning even more importance to the area of preschool education.

The Nebraska Early Learning Guidelines for ages three to five (Nebraska Department of Education, 2005) emphasize science as its own readiness domain and expresses that scientific skills and methods and scientific knowledge are important skills within this area. Within the sections for each skill, these guidelines stress the expectations for children. For example, in the section for scientific skills and methods, the Nebraska Early Learning guidelines state that a child is expected to “(a) make observations and describe objects and processes in the environment, (b) begin to make comparisons between the objects that have been observed, and (c) begin to find answers to questions through active investigation" (Nebraska Department of Education, 2005, p. 58). The section pertaining to scientific knowledge stresses that children are expected to (a) "show interest in active investigation, (b) begin to make comparisons among objects that have been observed, and (c) describe or represent a series of events in the correct sequence" (Nebraska Department of Education, 2005, p. 59).

In summary, evidence seems to support science as a good context for learning as it is emphasized in many early learning curricula and state standards. However, in general, little is known about effective approaches to teaching science in preschool classrooms (Brenneman et al., 2009).

Effective Early Childhood Teaching Strategies

According to developmentally appropriate practice (DAP), optimal development is more likely to occur in an environment that encourages children to form warm relationships with adults and their peers; provides planned, intentional guidance from adults; and creates environments that invite children to learn and explore objects (Copple & Bredekamp, 2009). The DAP also stresses that a central component to nurturing the learning and development of children is a teacher who provides guidance for children in their classroom by taking an active role in their thinking and attainment of skills and concepts (Copple & Bredekamp, 2009). Teachers promote children's engagement in challenging and intentional ways by the use of well-timed questions that encourage children to reflect and investigate, demonstrations of techniques using tools with which children are not familiar, and modeling procedures that children may not know how to carry out independently. Good teaching is found in environments where children are actively engaged, enjoy what they are learning in the classroom, participate in real-world experiences, and are asked to make connections to their own experiences (Harbeman, 1991) as well as in environments where children's sustained play is encouraged (Copple & Bredekamp, 2009).

Teachers can help children by suggesting ideas for their play; providing props, time, and space for children to engage in play; assisting children to implement guidelines for their play, but then step back to allow children to interact with their peers so they have the opportunity to adopt the skills necessary for sustained play as well as develop cognitive skills (Copple & Bredekamp, 2009). The instructional use of cooperative learning through small groups allows children to work with their peers to enhance each other's learning (Johnson & Johnson, 1999). Research has shown that cooperative learning in small groups enhanced preschooler's mathematics problem-solving abilities (Tarim, 2009). In this approach, teachers guide children as they work together by providing materials and explaining when the children are in need of assistance.

There has been evidence that shows that teacher's specific input and guidance promote (or at least are positively associated with) preschool children's skills and understanding. For example, one study found that preschool children's oral language skills were primarily developed by conversations (Dickinson, McCabe, Anastasopoulos, Peisner-Feinberg, & Poe, 2003); and greater academic success in later years was found for children who participated in rich conversational experiences with adults during their preschool years (Scarborough & Dobrich, 1994). Adult-child conversational exchanges in which the adult responds to the comments and questions of the child have been found to be very important in terms of enhancing children's skills with both receptive and expressive language (French, 2004).

The language that teachers use during their interactions with children has the potential to structure investigations as well as children's understanding of the investigations (French, 2004). By encouraging children to discuss their thoughts, reasoning, and observations as part of activities and play, teachers assist children in developing not only their ability to use language, but also their communication skills and cognizance of their thoughts (Worth, Moriarty, & Winokur, 2004). Teachers who ask children open-ended questions provide them with the opportunity to engage in conversations that allow children to use language in meaningful ways (Bond & Wasik, 2009). While preschool children do not easily learn from lectures, the use of language by the adults around them is a vital element of not only their language acquisition but also their intellectual development (French, 2004).

In addition, a study that examined the association between the variation of mathematical input in the speech of preschool or day-care teachers and the growth of children's mathematical abilities found that there was a substantial relation between the two (Klibanoff, Levine, Huttenlocher, Vasilyeva, & Hedges, 2006). This study included 198 children in 26 classrooms from 13 preschools and day-care centers across the Chicago area. An observer spent 2.5 to 3 hours in each participating classroom audio recording teacher speech during circle time and the time immediately following circle time. These particular times of day were chosen in an attempt to get responses from similar situations across the different classrooms. An hour of the recordings were transcribed and coded to examine transcripts of speech to children so that the researchers could examine mathematical input that was incidental as well as planned instruction (related to the activities the teachers were doing at that time). It was found that amount of mathematical input in teacher speech (instances ranged from 1 to 104 times within the hour of speech transcribed) was significantly related to the growth of children's math skills over the school year.

Among the few studies that examined young children's science learning, the study by Tenebaum, Rappolt-Schilichtmann, and Zanger (2004) showed the effectiveness of a combined museum-classroom intervention program that was targeted at teaching science concepts about water to low-income children. The study included 48 kindergarten (three class rooms in the experimental group and three in the control group) children from one school district that participated in a fieldtrip to a local children's museum. The three classrooms that were part of the experimental group visited three science exhibits and participated in two whole-group classroom lessons on water. Children in the control group did not receive classroom lessons on water and visited exhibits that were not related to water or science. The children who visited the science exhibits and participated in the science lessons exhibited more content knowledge as well as more complex concepts about water than the children who did not participate in the integrated science curriculum. Although this study has a limitation (i.e., no separation between the effects of science lessons from those of the science exhibits) it suggests that content-related lessons combined with a chance to participate in hands-on activities were effective in teaching children science concepts about water.

The results of these studies seem to suggest that children learn more about content and concepts when they participate in hands-on activities that are integrated with explicit lessons about specific content areas and concepts in comparison to children's learning when they participate in child-initiated and child-directed activities that do not include explicit lessons about content and process. However, there are other factors that have the potential to matter as well, such as the classroom environment and teacher preparation or background variables. Because there are findings from studies demonstrating the importance of explicit instruction, I now turn to examining different approaches to direct teaching and associated outcomes, as well as classroom environment and background.

Approaches to Teaching Preschool Children Science

One recent study examined the effectiveness of two approaches used to teach children science concepts, and scientific problem-solving skills related to objects' sinking or floating (i.e., objects' buoyancy) (Hong & Diamond, 2012). These authors compared a control group with two instructional approaches: responsive teaching (RT) and responsive teaching combined with explicit instruction (RT + EI).

Responsive teaching. The RT approach is based on the Constructivist approach. The Constructivist view implies that children build their understanding of the world through their experiences with objects and situations around them (Harlan & Rivkin, 2008). This theory places emphasis on children making sense of the world through child-initiated and child-directed activities with objects (Piaget, 1970). The demonstration of procedures with an object by an adult in the presence of the child loses the informational and formative value that is accessible to children through interactions of their own active involvement with objects (Piaget, 1970). As explained by Piaget (1970), attempting to express logic through language alone is not enough because logic is understood through the coordination of actions. Instead, Piaget emphasized that children's understanding is increased when they interact with objects and materials rather than watching a demonstration by a child or an adult. For example, a study of children from ten different countries found that when preschool experiences at the age of four include an ample amount of child-initiated activities and free-choice activities in a setting that has a low frequency of whole group activities and includes a variety of materials and equipment, children have higher cognitive performance at the age of seven (Montie, Xiang, & Schweinhart, 2006). Children's cognitive development in the preschool years is promoted by hands-on exploration of the objects around them (Piaget, 1970). Although this approach is child-centered, it is the adult's responsibility to place the child in an environment with circumstances that will enable the child to actively construct new understandings (National Research Council, 2001).

In the RT approach, adults are expected to provide the children with opportunities and materials but do not directly provide children with information or lead the activity. Instead, adults observe the children in their self-directed activities, comment on what the children do with the materials, respond to children's questions in a manner that facilitate their activities, and provide implicit suggestions while still encouraging children's self-direction throughout the activity.

Responsive teaching plus explicit instruction. The second approach used in the current study is RT + EI. This is based on the Vygotskian approach in combination with the RT approach. The Vygotskian view expands Piaget's Constructivist theory with the insight that children's learning about the world is enhanced when adults provide intentional support (Harlan & Rivkin, 2008; Copple & Bredekamp, 2009). Children build their understanding of a concept through their interactions with others (Vygotsky, 1978).

Adults guide and supervise children's problem solving by structuring the interaction in a way that leads children through tasks that are just beyond their ability to complete on their own (National Research Council, 2001). By entering into the child's experience the adult has an opportunity to assist the child towards developing higher mental processes, an opportunity which Vygotsky termed the zone of proximal development (ZPD) (Vygotsky, 1978). The ZPD encompasses a range of learning: the lower level is what the child may learn through personal exploration and the upper level is defined by how much children can learn through the assistance of an adult or a more competent peer (Vygotsky, 1978). Vogotsky's theory emphasizes "that cognitive development occurs in situations in which children's problem solving is guided by adults who structure and model appropriate solutions to the problem" (Rogoff, 1990, p.36). These situations provide children with the opportunity to imitate the adult's language and actions, which helps children to develop skills outside the limits of their own capabilities (Vygotsky, 1978).

In the RT +EI method, the adult guides children's learning explicitly as well as implicitly by intentionally planning activities for the children. The adult not only responds to children's initiation but he or she initiates the activities and some of the interactions. Adults ask questions to challenge children's understanding and expand on the activities by providing more materials, or more questions, and directly provide the children with information. In this approach, adults teach children specific skills through explicit instructional lessons (e.g., how to measure objects, important concepts and vocabulary) and also participate in and support child-directed activities and exploration.

Hong and Diamond (2012) found that children in the RT +EI group outperformed the children who participated in the RT group in terms of their science concepts and vocabulary, and both of these groups outperformed the children in the control group. They also found that, although there was only a moderate difference between children in the RT and RT + EI groups in terms of their scientific problem-solving skills, children in the RT + EI group outperformed children in the control group. These results provide evidence that preschool children's learning of science concepts and vocabulary is enhanced by the strategy of responsive teaching or the combined strategy of responsive teaching and explicit instruction; children display improvement in their learning of science concepts and vocabulary when a combination of responsive teaching and explicit instruction is used; and children demonstrate improvement in their learning of scientific problem-solving skills when a combination of responsive teaching and explicit instruction is employed. However, while teaching strategies are important, there could be contextual factors that also influence children's science learning. Thus, my discussion in the following section will be around classroom science environment and teacher background and their perceptions about teaching science.

Preschool Science: Classroom Environment

The classroom environment has been shown to play an important role in children's learning due to the fact that it is the environment that frames children's and teachers' feelings, thoughts, and behaviors (Copple & Bredekamp, 2009; Roskos & Neuman, 2011). When considering how to design classroom environments, Roskos and Neuman (2011) suggest that it is vital to ensure that the environment is related to purpose. The space should be flexible, and allow for immediate reconfiguration to support children's learning goals. Another essential part of creating a classroom environment that supports children's development and learning is to take steps to ensure that the environment engages children's attention and participation (French, 2004). The way that teachers use the environment, their actions as they model how to use materials for children and how they structure time for any content-related activities is also important.

One challenge educators face is to create an environment that includes the early science experiences that will cultivate a lifelong passion for science (Marx & Harris, 2006). During the preschool years children tend to have very positive attitudes towards learning and doing science (Brenneman et al., 2009). Providing children with opportunities to solve problems using logical thinking helps to develop their "curiosity, imagination, flexibility, inventiveness, and persistence" (Brenneman et al, 2009, p.4). To promote scientific thinking, the classroom environment should allow them to exercise their passion for discovery, one in which science-related experiences are based on children's curiosity and natural inclination to explore their surroundings (Tu, 2006). Teachers should establish an environment where children can wonder and "do" science in ways that include questioning, engaging, exploring, explaining, elaborating, and evaluating (Yoon & Onchwari, 2006, p. 421). The materials and opportunities provided to children within the classroom environment are the tools that will help them develop the skills they will draw upon during their explorations. These skills formed during their explorations are the foundation they will rely on in their future experiences.

The National Association for the Education of Young Children (2011) states in their criteria for accreditation that a quality preschool environment supports children by providing them opportunities to think, question, observe, explore, experiment with, record their findings about, and discuss a variety of scientific phenomena and concepts in their every day conversations. However, in spite of the above-mentioned standards and support for incorporating an area such as science into the early childhood curriculum, few science experiences are provided in classrooms (Early et al., 2007) and the few experiences that do occur are rarely of high quality (Brown, 2005; Graham, Nash, & Paul, 1997).

Research has shown that teachers do not spend much of their classroom time engaged in planned or spontaneous activities related to science (Tu, 2006). In a study of science environments in 20 preschool classrooms, Tu (2006) found that the majority of activities in which the preschool teachers engaged (86.8%) were not science-related. The areas in which teachers interacted most often were the art and sensory areas, while the science area was least often (Nayfeld, Brenneman, & Gelman, 2009; Tu, 2006). Only half of the preschool classrooms provided a science area, and, although 70% of the classrooms had a plant, the preschool teachers did not engage the children in conversations about the plant (Tu, 2006). Tu (2006) was the only available study that specifically examined preschool science classrooms. However, it did not include children's science outcomes that may be related to classroom environment.

Because science fits so logically with children's natural way of processing their experiences and their inherent curiosity about the everyday world, it is privileged as a content area in the preschool classroom (French, 2004). Children have numerous skills that aid them as they independently explore and learn about the everyday world (French, 2004) but teachers play an important role in expanding and supporting their curiosity and learning (Worth & Grollman, 2003). There are a number of steps suggested by Worth and Grollman (2003) for teachers to take in order to create an environment which promotes children’s inquiry on a topic. These steps include designing the physical setting, planning the areas of science the teacher intends to focus on, and establishing a set of overall goals. Once the teacher has the environment in place, children's explorations will lead them towards the development of new ideas, questions, and opportunities for learning and comprehension (Worth & Grollman, 2003). Since teachers play such a vital role in creating the environment and expanding children’s learning, I next turn to considering teacher preparation, qualifications and background and the impact it may have on environment and child outcomes.

Teacher Background and Perceptions about Teaching Science

Advocates for early childhood are increasingly insistent that teachers of children between the ages of three-and-four-years-old should have at least a Bachelor’s degree as well as a major in early childhood education or state certification that enables them to teach this age group (Barnett, 2004; Barnett, Carolan, Fitzgerald, & Squires, 2011). According to the National Institute for Early Education Research (NIEER; Barnett et al., 2011), 24 of the 39 states that fund prekindergarten programs require that all lead teachers have a Bachelor’s degree. Additionally, 36 states require that teachers have specialized training in early education for this age group.

The child care literature seems to support this assertion for prekindergarten teachers to hold a Bachelor’s degree in early childhood education. In a study of 553 infant, toddler and preschool classrooms Burchinal, Cryer, Clifford, and Howes (2002) found that teachers with the highest level of formal education (i.e., Bachelor’s degree) or those who attended workshops (at the center, in their community, or professional meetings) had higher ratings of observed classroom quality on a global scale, even after controlling for the adult-child ratio, state-related differences, and classroom types. Results such as these have led to conclusions that higher-quality early childhood education programs are those where the lead teachers have Bachelor's degrees, specifically in majors of child development or similar areas (Whitebook & Ryan, 2011).

However, some research demonstrates that teacher education or certification is not consistently related to higher quality classrooms or better pre-academic skills for children. In a study that examined teacher's level of education and classroom quality in six state-funded prekindergartens, Early et al. (2006) found that teachers who had more than a Bachelor's degree received higher scores on the Teaching and Interaction subscales of the Early Childhood Environment Rating Scale (ECERS) than those teachers who had an Associate's degree. The children in these classrooms had significant gains in math skills, but not in other areas. An analysis of seven longitudinal data sets found similar results (Early et al., 2007). Yet, these authors stress that these findings should be interpreted cautiously due to limitations within these studies.

While there is little research that addresses the competencies in early childhood educators in terms of math and science, it is known that many consider these areas difficult to teach (Copley & Padron, 1998). In study that conducted focus group interviews with Head Start teachers, Greenfield et al. (2009) found that two main themes emerged when teachers discussed their concerns: (1) low self-efficacy with respect to teaching science and (2) though science-related materials were provided in the classroom, many teachers indicated that they did not feel comfortable using them.

Although the majority of child care literature seems to support the conclusion that higher levels of education result in higher-quality classrooms, the inconsistencies in findings and interpretations lead to the consideration of teacher's education, years of experiences, and self-efficacy in terms of their teaching techniques in the current study, with emphasis placed on teacher's perceptions of their ability to teach science, which has not necessarily been a focus of previous literature.

Current Study

The purpose of the current study is to explore the effectiveness of the two approaches to teaching young children science concepts and vocabulary and scientific problem-solving skills implemented in Indiana by Hong and Diamond (2012) and replicate the study with a Nebraska sample. An added, important, component would be the information about their classroom environment (i.e., overall classroom environment that combines frequency of science activities per month, science areas or interest centers, and number of science-related materials available to children) and teacher-specific factors (i.e., years of teaching, perception about teaching techniques, and education level).

Research Questions and Hypotheses

Research Question 1

Is there an association between types of teaching approaches and children's understanding of science concepts and vocabulary and scientific problem-solving skills?

Hypothesis 1. Consistent with findings of Hong and Diamond (2012), the types of teaching approaches will be associated with children's science outcomes. Specifically, children in the RT + EI group will perform at a higher level at the end of the intervention than those in the RT only group (i.e., RT < RT + EI), controlling for their age, gender, and mother's education level.

Research Question 2

Do teacher's perceptions about teaching science moderate the relation between the types of teaching approaches (RT and RT + EI) and children's understanding of science concepts and vocabulary and scientific problem-solving skills?

Hypothesis 2. Teacher's perceptions about teaching science will moderate the relation between the types of teaching approaches and children's understanding of science concepts and vocabulary and scientific problem-solving skills, controlling for children's age, gender, mother's education level, teacher's education level, and teacher's years of experience. The relation between the type of teaching approaches and children's outcomes will differ depending on the level of teachers' perceptions about teaching.

Research Question 3

Does classroom environment moderate the relation between the types of teaching approaches (RT and RT + EI) and children's understanding of science concepts and vocabulary and scientific problem solving skills?

Hypothesis 3. Classroom environment will moderate the relation between the types of teaching approaches and children's understanding of science concepts and vocabulary and scientific problem-solving skills, controlling for children's age, gender, mother's education level, teacher's education level, teacher's years of experience, and teacher's perceptions about their ability to teach science. The relation between the types of teaching approaches and children's outcomes will differ depending on the amount and frequency of science-related materials, activities, and experience provided in the classroom.

CHAPTER 2

METHODS

Participants

Participants included 26 four- and five-year-old prekindergarten children (15 girls; mean age= 52.5 months; *SD* =4.39) attending early care and education programs (six full-day classrooms in three centers) in a mid-sized Midwestern community and their parents and teachers. The demographic information of this sample is provided in Table 1. About 60% of the sample was European American (n = 15), and 72% of the parents had a master's or higher degree (n = 18). There were six teachers included within this study. Five teachers had a bachelor's degree, and one had a master's degree in early childhood education. The average number of years of teaching experience was 10.17 years (*SD*= 7.03).

Study Design and Procedure

The current study was a replication of the study completed by Hong and Diamond (2012). The directors of three early care and education programs were contacted and given consent forms, letters, and recruitment flyers explaining the study. After their approval, researchers went to the centers to speak with and provide information to parents of four- and five- year old children. Around 60 recruitment packets were distributed in total, (i.e., return rate = 43.33%).

After recruitment forms were returned, three research assistants visited the centers to assess children's science concepts, vocabulary, and scientific problem-solving skills. Once the pretest was completed, children were randomly assigned to a small group instruction with two to three of their classmates (i.e., eight small groups in total). The small groups were then randomly assigned to one of two instructional conditions: Responsive Teaching (RT; *n* = 9; three small groups) and Responsive Teaching plus Explicit Instruction (RT + EI; *n* = 17; five small groups). In instances where more than one small group of children came from the same classroom, the groups were assigned to different intervention conditions. Children's pretest results did not have an influence on which group or intervention condition children were assigned to. About one week after the pretest was administered, the children were pulled out from their classrooms to participate in the interventions.

Children participated in four 15-minute intervention sessions focused on objects' sinking or floating (i.e., buoyancy) that were implemented by the author. Children had not met the implementer prior to the interventions. It took approximately two- to two-and-a-half weeks to complete all four intervention sessions. Children were assessed on their science concepts and vocabulary and scientific problem-solving skills related to objects' sinking and floating approximately one week after the four intervention sessions (i.e., posttest). The pre- and posttests were administered by the same three research assistants who were blind to the children's intervention conditions and did not participate in the interventions.

Both RT and RT + EI interventions had the same focus and learning goals as those designed by Hong and Diamond (2012): "(1) to understand the concepts of size and weight and how these relate to floating and sinking by measuring and comparing objects that possess different properties, (2) make correct judgments about an objects' ability to float or sink using scientific problem-solving strategies, such as prediction, measurement, observation, comparison, and categorization; and (3) learn to make an object that floats sink and an object that sinks float by using scientific problem-solving strategies" (p. 3).

For the RT intervention, the materials provided were purposely chosen to contribute children's understanding of objects' sinking and floating. During this intervention condition the implementer did not provide explicit instruction to the children (e.g., lessons about how to measure and objects' size or weight) or direct children's play, but described the observed behaviors, commented on and asked questions about what children were doing, and modeled what children could do with the materials while participating in their play in parallel. In the RT + EI intervention condition, the implementer built upon the implicit strategies of the RT intervention by utilizing explicit teaching strategies as well. In this condition, the implementer gave explicit instruction on science concepts and vocabulary and scientific problem-solving methods by providing a brief lesson (i.e., 10 to 15 minutes) at the beginning of each intervention session, and then used the implicit strategies of the RT intervention (e.g., describing observations of children's behavior and asked questions about what they were doing) through the rest of the intervention session. The specific concepts that were included in these lessons were scientific problem-solving skills (i.e., sorting categorizing, and making experiments) and specific concepts and vocabulary related to objects' floating and skinking (i.e., size, weight, float, sink, large, small, heavy, and light). For the portion that focused on making experiments, children were expected to learn to "make hypothesis, test them, and modify their hypotheses when the original ones were not supported" (Hong & Diamond, 2012, p 3). For detailed descriptions of the intervention protocols and scripts, see Appendix B (excerpted from Hong & Diamond, 2012).

Measures

Science concepts and vocabulary. Children were assessed on science concepts and vocabulary prior to the start of the intervention and then assessed again once the intervention was completed. The vocabulary children were assessed on were size, weight, float, sink, large/big, small, heavy, light, larger/bigger, smaller, heavier, lighter, like, and different (Hong & Diamond, 2012). These specific words were chosen because they were closely related to the intervention content and also because gaining new words and understanding the meanings and ideas represented by both the words and objects (i.e., concepts) was a learning goal of the intervention. During the assessment, children were asked to explain the meaning of the words (e.g., what is size?), point to the correct picture (e.g., point to the picture of 'large'), or choose an object that represented the concept that was being presented to the child (e.g., which one is heavier?). To assess science concepts, children were asked to make judgments regarding if an object would float or sink when put in water. The objects used by research assistants during the pre- and-posttests were different from those presented to children by the implementer during the four intervention sessions. Each item was scored as '1' if the response was correct or '0' if incorrect. A few items with qualitative responses were coded as '2' if the response was correct, '1' if acceptable, or '0' if incorrect or no response.

The total vocabulary and concepts outcome score was calculated by summing all item scores (22 items; possible range = 0-42). The internal consistencies of the items measured by Cronbach's alpha and reported in Hong & Diamond (2012) were α=.77 (pretest) and α=.86 (posttest). For the current study the internal consistencies of the items were α=.48 (pretest) and α=.80 (posttest). One item (i.e., child assessment number 20-2;

see Appendix A) was eliminated from this section since it was lowering the internal consistency of the other items. After eliminating the item, the internal consistencies were α= .52 (pretest) and α= .80 (posttest). The significant and strong correlation between the original measure and the Woodcock-Johnson III Picture Vocabulary subtest (r = .64; p < .001) adds validity to this measure created by Hong and Diamond (2012).

Scientific problem-solving skills. Children were assessed on their skills pertaining to sorting and categorizing (Part I: content-general scientific problem-solving skills) and making experiments (Part II: content-specific skills scientific problem-solving skills) as they were in the study by Hong & Diamond (2012). During Part I, children were asked to sort four objects (four boxes for size; four bottles with different amount of water for weight) by weight and then by size (the number of objects that were correctly sorted became the score; possible range in score = 0 to 8) and categorize six objects by their weight (three small boxes and three large boxes) and size (three bottles with a small amount of water and three bottles filled with water)(0 for incorrect and 1 for correct responses; possible range in score = 0 to 2). Although these process skills were not part of the explicit instruction, they were included as part of the assessment in order to examine if these general process skills were learned through participation in the intervention. During Part II, children were asked to construct and test hypotheses regarding the ways they could make an object that floats sink and make an object that sinks float. The objects presented to children by the research assistants in this portion of the assessment were also different from those used by the implementer during the intervention sessions. The internal consistencies of the items measured by Cronbach's alpha were α=.66 (pretest) and α=.58 (posttest) for Part I and α=.45(pretest) and α=.58

(posttest) for Part II of the current study. For the original study (Hong & Diamond, 2012), the internal consistencies were α= .66 (pretest) and α= .58 (posttest) for Part I, and α=.83 (pretest) and α=.88 (posttest) for Part II. An item was eliminated from Part II in this study because it lowered the internal consistency of the other items (i.e., child assessment for content-specific scientific problem-solving skills item number 1; see Appendix A). After eliminating the item, the internal consistencies were α= .59 (pretest) and α= .62 (posttest) for Part II.

Data coding. For open-ended questions, children's responses were coded inductively with regards to the sophistication of the child's response for all three outcomes. Incorrect answers were coded as '0'. With science concepts and vocabulary outcome, answers coded '2' signified correct responses, whereas responses coded as '1' were 'acceptable' responses. A multi-step approach was utilized to code responses regarding the content-specific scientific problem-solving outcome (e.g., Tell me what you can do to make it sink. How can you make it sink?). Initially, all participants were scored based on success or failure and then on the number of attempts made (i.e., 0 = I don't know or No trial; 1 = one trial but failed and gave up; 2 = two or more trials but failed and gave up; 3 = succeeded after one or more trials; 2 items; possible range = 0 to 6). Researchers then coded the children's responses, recorded verbatim, taking into account the accuracy of each response (i.e., 0 = I don't know or incorrect; 4 = accurate and correct; 2 items; possible range = 0 to 8). The sophistication of the children's responses was also coded inductively. For detailed descriptions of how each qualitative item was coded, see Appendix A (excerpted from Hong & Diamond, 2012, pp. 304-305). The average inter-coder percent agreement ranged from 92 to 98% (mean = 96%).

Expressive vocabulary skills. The Woodcock-Johnson III Picture Vocabulary Test was used to assess children's expressive vocabulary skills. Researchers assessed each child's expressive vocabulary by asking her or him to name the objects pictured. As children progressed through the test, each item increased in difficulty toward the end. The reliability of this test reported by the developers is .77 in the ages of five to 19 (Mather & Woodcock, 2001). The *T* scores were used in the analysis of this skill. This is a normalized standard score with a mean of 50 and a standard deviation of 10.

Attendance. The attendance percentage was calculated for children in both interventions. The number of sessions attended by each child was scored as "0" if the child did not attend any of the intervention sessions, "1" for one session, "2" if the child attended two sessions, "3" if three sessions were completed, and "4" if the child attended all four of the intervention sessions. Of the 26 children who participated in the intervention sessions, there was one child who did not attend any of the intervention sessions and one child who only attended one session. There were five children who only completed two of the intervention sessions (23.08%) and five children who only completed three of the intervention sessions (23.08%). A total of 12 children (46.15%) completed all the intervention sessions. The attendance was not significantly associated with children's outcomes so was not included in the analyses.

Fidelity of interventions. To obtain the fidelity of the interventions, the checklists developed by Hong and Diamond (2012) were used. These checklists that reflected critical components for each of the two interventions were completed (18 items for RT; 17 items for RT + EI). There were eight items on the RT checklist that were related to use of explicit instruction, which was not meant to take place during the RT sessions (e.g., Did the implementer initiate the activity? Ask a challenging question? Directly provide information?). Three research assistants who were not the implementer completed the checklists by using videos of each intervention session. The fidelity of intervention was obtained for each session of both the RT and RT + EI interventions. Items on the checklist were scored as 1 (observed) or 0 (not observed). A score was calculated that represented the proportion of completed items for each session (for both intervention groups, the possible range = 0-100%). If higher scores were obtained, this was an indication that the percentage of critical elements of the intervention that occurred in each session was larger (i.e., a score of 100% indicated that all critical elements had been included in the intervention session). The eight items on the RT checklist that are not meant to occur during the intervention sessions were coded in reverse prior to calculating the overall fidelity score for the RT sessions. A session was only considered to meet 100% of the fidelity of implementation when all 10 items of the critical components and none of the eight components that are not meant to take place occurred.

Reliability checks were conducted on 20% of the videotaped sessions, and the average percent agreement was 87% (range = 78-100%). The mean level of fidelity of implementation was 96.1% (range = 82.35 to 100%) for RT and 97.04 % (range = 88.89 to 100%) for RT + EI intervention sessions.

Demographic information. Parents were given a questionnaire to complete as part of the recruitment forms. This questionnaire included demographic information, such as child's gender, age, ethnicity, and mother's level of education.

Classroom environment. Teachers were given a questionnaire to complete as part of the recruitment forms. For the complete teacher survey, see Appendix C (excerpted from Hong & Diamond, 2012). This questionnaire included information about science-related materials that were available to children in the classroom, the availability of science areas or interest centers, and the frequency of science activities per month. Teachers were asked to list or circle all of the items and equipment that were available for children to use in their classroom (e.g., circle all of the science materials that were accessible to children elsewhere in the classroom today). For the questions that directed teachers to circle items, those items that were circled were coded as “1” to indicate that they were available in the classroom and a “0” if not circled to indicate that they were not available. The items circled (coded as “1”) were totaled for each question. For the questions that directed teachers to list all of the items and equipment available, the items that were listed were counted only if they were not listed or circled in other questions to ensure that items were not counted more than once. The number of items for each of the five questions was summed to calculate the total number of science-related materials available to the children in their classroom. There were also five questions regarding science areas or interest centers that are present in the classroom (e.g., do you have a sandbox at your preschool center?). For each question, teachers were asked to mark “yes” or “no”. Answers of “yes” were coded as “1” and answers of “no” were coded as “0”. The answers marked as “yes” for each of the questions were summed to calculate the total number of science areas or interest centers in the classroom (5 items; possible range = 0-5). There were also five questions that focused on the frequency of science activities (e.g., how often do you use the water table?). The possible responses were coded so that answers would reflect how often the activities occurred in a month. The answers given were summed to calculate the total for the frequency of science activities per month (5 items; possible range = 0-52). The total number from each of these categories (i.e., number of science-related materials available to children, science areas or interest centers, and frequency of science activities per month) was then summed to calculate the overall classroom environment score.

Teacher perceptions about teaching science. The questionnaire given to teachers included one question pertaining to their perceptions about their ability to teach science (i.e., how adequately do you feel you have been prepared for teaching science with children three- to five-years-old?) (Tu, 2006). Teachers were asked to circle one of the answers provided (i.e., 1 = *very unprepared*; 2 = *fairly unprepared*; 3 = *moderately prepared*; 4 = *fairly prepared*; 5 = *very well prepared*). The average rating marked by teachers was 2.77 (SD = .82; range = 2 - 5).

CHAPTER 3

RESULTS

Preliminary Analyses

Descriptive statistics were calculated for each variable (see Table 2). Bivariate correlations among main variables (i.e., Pearson's correlations) are presented in Table 3. Children's posttest science concepts and vocabulary scores were significantly correlated with their pretest score (r (24) = .52, p = .01). There was also a significant correlation between children's posttest score on the content-general portion of scientific problem-solving skills and their pretest scores (r (24) = .73, $p < .01$). Children's posttest scores for the combined portions of scientific problem-solving skills (Part I and Part II) were significantly correlated with their pretest score (r (24) = .41, p = .04). The classroom environment measure was significantly correlated with children's posttest score on science concepts and vocabulary (r (24) = .43, p = .03,). Teacher's years of experience had a significant, but negative correlation with teacher's perceptions about teaching science (r (24) = -.76, $p < .01$). Children's age was also found to be significantly and positively correlated with children's posttest score on the content-general portion of scientific problem-solving skills (Part I: sorting and categorizing) (r (24) = .46, p = .02) and the combined portions of scientific problem-solving skills (Part I and Part II) (r (24) = .40, p = .05).

There were no significant differences between the two intervention groups on any of the background variables (e.g., children's ethnicity). There were no significant group differences in children's initial performance for both content-general (Part I) and content-specific (Part II) scientific problem-solving skills, or for the combined total scientific problem-solving skills outcome (see Table 2). There was a significant group difference between the RT (*M* = 18.67, *SD* = 3.50) and RT + EI (*M* = 22.65, *SD* =4.27) intervention groups on children's initial science concepts and vocabulary outcome [t (24) = -2.40, p = .03, d = -1.02]. There was a significant group difference between the RT (*M*= 23.78, *SD*= 6.14) and RT + EI (*M* = 29.59, *SD* = 5.56) on children's posttest science concepts and vocabulary outcome [t (24) = -2.45, p = .02, d = -.10]. There was a significant group difference between the RT (*M* = 12.22, *SD* = 2.82) and RT + EI (*M* = 14.71, *SD* = 2.82) on children's posttest content-specific scientific problem-solving skills outcome [t (24) = -2.14, p = .04, d = -.88]. There was a significant group difference between RT (*M*= 45.33, *SD* = 12.52) and RT + EI (*M* = 58.29, *SD* = 14.60) for the classroom environment measure [t (24) = -2.26, p = .03, d = -.95]. There were no significant group differences in children's expressive vocabulary skills (W-J Picture Vocabulary), teacher's years of experience, teacher's perceptions about teaching science, and children's age. There was also no significant difference in attendance between the groups. Since none of the outcome variables were significantly associated with children's attendance, it was not included in the analyses.

Regression Results

Several of the control variables were not included in the regression models due to the fact that they were not significantly correlated with science concepts and vocabulary and scientific problem-solving skills outcomes. These variables include children's gender, mother's education level, teacher's years of experience, and teacher's education level. The variables that were included in the regression models are shown in Table 4. Four hierarchical multiple regression models were created for each research question.

Research question 1: Is there an association between types of teaching approaches and children's understanding of science concepts and vocabulary, and scientific problem-solving skills? In the first model, a hierarchical multiple regression was used to test the association of two teaching approaches (RT and RT + EI) (independent variable) with children's understanding of science concepts and vocabulary (dependent variable), after controlling for children's pretest scores. Children's pretest scores were entered as Step 1, explaining 26.7% of the variance (R^2) in children's understanding of science concepts and vocabulary at time 2. After entry of teaching approach at Step 2, the total variance explained by the model as a whole was 32.7%; however, the R^2 change (.06) was not significant (see Table 5). There was no significant association between teaching approaches and children's understanding of science concepts and vocabulary after controlling for the pretest score.

Hierarchical multiple regression was also used in the second model to test the association of two teaching approaches (RT and RT + EI) (independent variable) with children's scientific problem solving skills (dependent variable), after controlling for children's pretest scores and their age. Children's pretest scores and age were entered as Step 1, explaining 26.2% of the variance (R^2) in children's understanding of scientific problem-solving skills at time 2. After entry of teaching approach at Step 2 the total variance explained by the model as a whole was 32.1%; however, the R^2 change (.06) was not significant (see Table 6). There was no significant association between teaching approaches and children's understanding of scientific problem-solving skills after controlling for the pretest scores and their age.

The third model used hierarchical multiple regression was to test the association of two teaching approaches (RT and RT + EI) (independent variable) with the content-general portion of children's scientific problem-solving skills (Part I: sorting and categorizing) (dependent variable), after controlling for children's pretest scores and children's expressive vocabulary score (W-J Picture Vocabulary). Children's pretest scores and expressive vocabulary scores were entered as Step 1, explaining 53.8% of the variance (R^2) in the content-general portion of children's scientific problem-solving skills at time 2. After entry of teaching approach at Step 2 the total variance explained by the model as a whole was 58.4%; however, the R^2 change (.05) was not significant (see Table 7). There was no significant association between teaching approaches and children's content-general scientific problem-solving skills (Part I: sorting and categorizing) after controlling for the pretest score and expressive vocabulary.

The fourth and final model used hierarchical multiple regression to test the association of two teaching approaches (RT and RT + EI) (independent variable) with the content-specific portion of children's scientific problem-solving skills (Part II: making experiments) (dependent variable), after controlling for children's pretest scores. Children's pretest scores were entered at Step 1, explaining 4.9% of the variance (R^2) in the content-specific portion of children's scientific problem-solving skills at time 2. After entry of teaching approach at Step 2 the total variance explained by the model as a whole was 19.3%; however, the R^2 change (.14) was not significant (see Table 8). There was a significant association between teaching approaches and children's content-specific scientific problem solving skills (Part II: making experiments) after controlling for the pretest score. This demonstrates that teaching approach did make a difference in children’s learning of content-specific scientific problem solving skills even after controlling for children’s initial understanding.

Research question 2: **Do teacher’s perceptions about teaching science moderate the relation between the types of teaching approaches (RT and RT + EI) and children’s understanding of science concepts and vocabulary and scientific problem-solving skills?** Four regression models were used to test the second research question as well. In the first model, a hierarchical multiple regression was used to test whether teacher’s perceptions about teaching science could act to moderate relations between teaching approach (RT and RT + EI) (independent variable) and children’s understanding of science concepts and vocabulary (dependent variable), after controlling for children’s pretest scores. Children’s pretest scores were entered as Step 1, explaining 26.7% of the variance (R^2) in children’s understanding of science concepts and vocabulary at time 2. After entry of teaching approach and teacher’s perceptions at Step 2, the model explained 32.7% of the variance in children’s scores at time 2. The interaction between teaching approaches and teacher’s perceptions about teaching science was entered at Step 3, explaining 35.8% of the variance by the model as a whole. The two measures entered at Step 2 explained an additional 6.1% of the variance in children’s time 2 score; however, the R^2 change (.06) was not significant (see Table 9). The interaction between teaching approaches and teacher’s perceptions entered at Step 3 explained an additional 3.1% of the variance in children’s time 2 score; however, the R squared change (.031) was not significant. Teacher’s perceptions about teaching science were not a significant moderator of the relation between teaching approaches and children's understanding science concepts and vocabulary after controlling for the pretest score.

The second model utilized hierarchical multiple regression to test whether teacher's perceptions about their ability to teach science could act to moderate the relations between teaching approach (RT and RT + EI) (independent variable) and children's understanding of scientific problem-solving skills (dependent variable), after controlling for children's pretest scores and age. Children's pretest scores and age were entered as Step 1, explaining 26.2 % of the variance (R^2) in children's understanding of scientific problem-solving skills at time 2. After entry of teaching approach and teacher's perceptions about teaching science at Step 2, the model explained 32.1% of the variance in children's scores at time 2. The interaction between teaching approaches and teacher's perceptions about teaching science was entered at Step 3, explaining 32.5% of the variance by the model as a whole. The two measures entered at Step 2 explained an additional 5.9% of the variance in children's time 2 score; however, the R^2 change (.06) was not significant. The interaction between teaching approaches and teacher's perceptions about teaching science entered at Step 3 explained an additional .2% of the variance in children's time 2 score; however, the R squared change (.002) was not significant (see Table 10). Teacher's perceptions about teaching science were not a significant moderator of the relation between teaching approach and children's understanding of scientific problem-solving skills after controlling for the pretest score and children's age.

Hierarchical multiple regression was also used in the third model to test whether teacher's perceptions about their ability to teach science could act to moderate the relation between teaching approach (RT and RT + EI) (independent variable) and children's understanding of the content-general portion of scientific problem-solving skills (Part I: sorting and categorizing) (dependent variable), after controlling for children's pretest scores and their expressive vocabulary scores (W-J Picture Vocabulary). Children's pretest scores and expressive vocabulary scores were entered at Step 1, explaining 54.3% of the variance (R^2) in children's content-general scientific problem-solving skills at time 2. After entry of teaching approach and teacher's perceptions about teaching science at Step 2, the model explained 61.3% of the variance in children's scores at time 2. The interaction between teaching approaches and teacher's perceptions about teaching science was entered at Step 3, explaining 61.4% of the variance by the model as a whole. The two measures entered at Step 2 explained an additional 7% of the variance in children's time 2 score; however, the R^2 change (.07) was not significant. The interaction between teaching approaches and teacher's perceptions about teaching science entered at Step 3 explained an additional .1% of the variance in children's time 2 score; however, the R^2 change (.001) was not significant (see Table 11). Teacher's perceptions about teaching science did not moderate the relation between teaching approach and children's content-general scientific problem-solving skills (Part II: making experiments) after controlling for the pretest and expressive vocabulary scores.

For the fourth model, Hierarchical multiple regression was used to test whether teacher's perceptions about teaching science would act to moderate the relation between teaching approach (RT and RT + EI) (independent variable) and the content-specific portion of children's scientific problem-solving skills (Part II: making experiments), after controlling for children's pretest scores. Children's pretest scores were entered at Step 1, explaining 4.9% of the variance (R^2) in children's content-specific scientific problem-solving skills at time 2. After entry of teaching approach and teacher's perceptions about teaching science at Step 2, the model explained 22.3% of the variance in children's scores at time 2. The interaction between teaching approaches and teacher's perceptions about teaching science was entered at Step 3, explaining 22.8% of the variance by the model as a whole. The two measures entered at Step 2 explained an additional 17.4% of the variance in children's time 2 score; however, the R^2 change (.174) was not significant. The interaction between teaching approaches and teacher's perceptions about teaching science entered at Step3 explained an additional 0.5% of the variance in children's time 2 score; however, the R^2 change (.005) was not significant (see Table 13). Teacher's perceptions about their ability to teach science did not moderate the relation between teaching approaches and children's content-specific scientific problem-solving skills (Part II: making experiments) after controlling for the pretest scores.

Research question 3: Does classroom environment moderate the relation between the types of teaching approaches (RT and RT + EI) and children's understanding of science concepts and vocabulary and scientific problem solving skills? For the third research question, four regression models were used once again to test each of the child outcomes. In the first model, a hierarchical multiple regression was used to test whether classroom environment could act to moderate relations between teaching approach (RT and RT + EI) (independent variable) and children's understanding of science concepts and vocabulary (dependent variable), after controlling for children's pretest scores. Children's pretest scores were entered at Step 1, explaining 26.7% of the variance (R^2) in children's understanding of science concepts and vocabulary at time 2. After entry of classroom environment and teaching approach at Step 2, the model explained 36.5% of the variance in children's scores at time 2. The interaction between teaching approaches and classroom environment was entered at Step 3, explaining 38.4% of the variance by the model as a whole. The two measures entered at Step 2 explained an additional 9.8% of the variance in children's time 2 score; however, the R^2 change (.10) was not significant. The interaction between teaching approaches and classroom environment entered at Step 3 explained an additional 1.9% of the variance in children's time 2 score; however, the R^2 change (.02) was not significant (see Table 13). Classroom environment was not a significant moderator of the relation between teaching approach and children's understanding of science concepts and vocabulary after controlling for the pretest score.

For the second model, a hierarchical multiple regression was used to test whether classroom environment could act to moderate relations between teaching approach (RT and RT + EI) (independent variable) and the children's scientific problem-solving skills (dependent variable), after controlling for children's pretest scores and the age of the child. Children's pretest scores and child age were entered at Step 1, explaining 26.2% of the variance (R^2) in children's scientific problem-solving skills at time 2. After entry of classroom environment and teaching approach at Step 2, the model explained 35% of the variance in children's time 2 score. The interaction between classroom environment and teaching approach was entered at Step 3, explaining 35.1% of the variance by the model as a whole. The two measures entered at Step 2 explained an additional 8.8% of the variance in children's time 2 score; however, the R^2 change (.09) was not significant).

The interaction between classroom environment and teaching approach entered at Step 3 explained an additional .1% of the variance in children's time 2 score; however, the R^2 change (.001) was not significant (see Table 14). Classroom environment was not a significant moderator of the relation between teaching approaches and children's scientific problem-solving skills after controlling for the pretest score and children's age.

Hierarchical multiple regression was used in the third model to test whether classroom environment could act to moderate relations between teaching approach (RT and RT + EI) (independent variable) and the content-general portion of scientific problem-solving skills (Part I: sorting and categorizing) (dependent variable), after controlling for children's pretest scores and their expressive vocabulary score (W-J Picture Vocabulary). Children's pretest scores and expressive vocabulary scores were entered at Step 1, explaining 54.3% of the variance (R^2) in the content-general portion of children's scientific problem-solving skills at time 2. After entry of classroom environment and teaching approach at Step 2, the model explained 58.5% of the variance in children's time 2 score. The interaction between classroom environment and teaching approach was entered at Step 3, explaining 58.5% of the variance by the model as a whole. The two measures entered at Step 2 explained an additional 4.2% of the variance in children's time 2 score; however, the R^2 change (.04) was not significant. The interaction between classroom environment and teaching approach at Step 3 explained an additional .0% of the variance in children's time 2 score; however, the R^2 change (.000) was not significant (see Table 15). Classroom environment was not a significant moderator of the relation between teaching approach and children's score on children's content-general scientific problem-solving skills after controlling for the pretest score and children's expressive vocabulary scores.

In the last model for the third research question, a hierarchical multiple regression was used to test whether classroom environment could act to moderate relations between teaching approach (RT and RT + EI) (independent variable) and the content-specific portion of scientific problem-solving skills (dependent variable), after controlling for children's pretest scores. Children's pretest scores were entered at Step 1, explaining 4.9% of the variance (R^2) in children's content-specific scientific problem-solving skills at time 2. After entry of classroom environment and teaching approach at Step 2, the model explained 23.7% of the variance in children's time 2 score. The interaction between classroom environment and teaching approach was entered at Step 3, explaining 23.7% of the variance by the model as a whole. The two measures entered at Step 2 explained an additional 18.8% of the variance in children's time 2 score; however, the R^2 change (.188) was not significant. The interaction between classroom environment and teaching approach at Step 3 did not explain any additional variance in children's time 2 score; the R^2 change (.00) was not significant (see Table 16). Classroom environment was not a significant moderator of the relation between teaching approach and children's content-specific scientific problem-solving skills (Part II: making experiments) after controlling for the pretest scores.

Additional Analyses

Children's Time 1 scores were examined in relation to all teacher factors (i.e., classroom environment, teacher's education level, teacher's years of teaching, and teacher's perceptions about their ability to teach science) to gain a general idea of which teacher factors may be associated with children's initial science outcomes. Bivariate correlations among main variable (i.e., Pearson's correlations) were used to determine if there were significant correlations between any of the variables and are presented in Table 17. Mother's education level had a significant, but negative correlation with children's initial scientific problem-solving skills outcome (r (24) = -.53, p = .01). Mother's education level also had a significant, but negative correlation with the content-specific portion of children's initial scientific problem-solving skills outcome (r (24) = -.46, p = .02)

Hierarchical regression models were used to test the association between teacher factors and children's initial performance on all four outcomes (i.e., scientific concepts and vocabulary, scientific problem-solving skills, content-general scientific problem-solving skills, and content-specific problem-solving skills). Since mother's education level was significantly correlated with two of the four outcomes (i.e., children's initial scientific problem-solving skills outcome and the content-specific portion of children's initial scientific problem-solving skills outcome), it was used as a control variable in those models. In the first model, hierarchical multiple regression was used to test the association of teacher factors (independent variables) with children's initial science concepts and vocabulary outcome (dependent variable). Teacher factors were entered as Step 1, explaining 57.7% of the variance (R^2) in children's initial understanding of the science concepts and vocabulary outcome (see Table 18). There was a significant association between teacher factors and children's initial understanding of science concepts and vocabulary. This means that teacher factors (i.e., classroom environment, teacher's education level, teacher's years of teaching, and teacher's perceptions about their ability to teach science) did make a difference in children's initial understanding of science concepts and vocabulary.

The second model used hierarchical multiple regression to test the association of teacher factors (independent variable) with children's initial scientific problem-solving skills outcome (dependent variable), after controlling for mother's education level. Mother's education was entered as Step 1, explaining 28.4% of the variance (R^2) in children's initial understanding of the scientific problem-solving skills outcome. After entry of teacher factors at Step 2 the total variance explained by the model as a whole was 39.9%; however, the R^2 change (.16) was not significant (see Table 19). There was no significant association between teacher factors and children's initial understanding of the scientific problem-solving skills outcome.

Hierarchical multiple regression was also used in the third model to test the association between teacher factors (independent variable) with the content-general portion of children's initial scientific problem-solving skills outcome. Teacher factors were entered as Step 1, explaining 6.2% of the variance (R^2) in children's initial understanding of the content-general portion of the scientific problem-solving skills outcome (see Table 20). There was no significant association between teacher factors and children's initial understanding of the content-general portion of the scientific problem-solving skills outcome.

The fourth and final model used hierarchical multiple regression to test the association between teacher factors (independent variable) with the content-specific portion of children's initial scientific problem-solving skills outcome, after controlling for mother's education level. Mother's education was entered as Step 1, explaining

21.1% of the variance (R^2) in children's initial understanding of the content-specific portion of the scientific problem-solving skills outcome. After the entry of teacher factors at Step 2 the total variance explained by the model as a whole was 33.7%; however, the R^2 change (.13) was not significant (see Table 21). There was no significant association between children's initial understanding of the content-specific portion of the scientific problem-solving skills outcome.

CHAPTER 4

DISCUSSION

This study examined the effectiveness of two approaches (RT and RT + EI) to teaching young children science concepts and vocabulary, and scientific problems solving skills related to objects' floating and sinking implemented in Indiana by Hong and Diamond (2012) and replicated the study with a Nebraska sample. An additional component of the current study was the information about children's classroom environment (i.e., combination of frequency of science activities per month, science areas or interest centers, and number of science-related materials available to children) and teacher-specific factors (i.e., perceptions about teaching science, teacher background).

Association between Teaching Approaches and Children's Science Outcomes

First, it was hypothesized that children's learning of science concepts and vocabulary and their scientific problem-solving skills related to object's floating and sinking would be associated with teaching approach (RT and RT + EI). Results revealed that there was no significant association between teaching approaches and children's outcomes of science concepts and vocabulary. However, there was a significant association between teaching approaches and children's content-specific scientific problem-solving skills. These results are inconsistent with the original study implemented by Hong and Diamond (2012), which found significant effects of teaching approaches on children's learning of science concepts and vocabulary and scientific problem-solving skills. Their results demonstrated that children in the RT and the RT + EI groups performed at a higher level than children in the control group, and children in the RT + EI group performed at a higher level than children in the RT group.

In the current study, the RT and RT + EI groups differ on their pre and posttest scores for concepts and vocabulary. However, Figure 1 demonstrates the pattern that children who participated in the intervention that combined responsive teaching with explicit instruction (RT + EI) seemed to learn more concepts and vocabulary related to objects' floating and sinking. This result is similar to the findings of the original study done by Hong and Diamond (2012), Tenenbaum et al. (2004), and the results from French and her colleagues' (e.g., French, 2004) series of quasi-experimental studies. The results of each of these studies found that the combination of implicit teaching (that involved children's exploration) with explicit instructional conversations and class lessons were valuable tools for enhancing children's understanding of concepts and vocabulary. Figure 2 and Figure 3 show the pattern that children have learned more content-general (Part I) and content-specific scientific (Part II) problem-solving skills related to objects' sinking and floating when explicit teaching strategies were incorporated with implicit teaching strategies (RT + EI), although there were not statistically significant relations. Figure 4 also shows the positive pattern of children's learning for the overall scientific problem-solving skills outcome (Part I and Part II combined), which was not statistically significant either.

Teacher Background and Perceptions about Teaching Science as Moderators

This study also examined whether teacher's perceptions about their ability to teach science to young children would act to moderate the relation between teaching approaches (RT and RT + EI) and children's understanding of science concepts and vocabulary and scientific problem-solving skills related to objects' sinking and floating. I hypothesized that the relation between the types of teaching approaches and children's outcomes would be different depending on the level of teachers' perceptions about teaching science. However, results revealed that teacher's perceptions about teaching science were not a significant moderator. An interesting finding was the significant negative association between the teacher's years of experience and their perceptions of their ability to teach science, suggesting that the more experience teachers have, the lower their perceptions of their ability to teach science to young children. This may be due to a lack of science-related coursework in teacher preparation programs or an absence of professional support for practicing teachers within their schools and centers.

Research has shown that teachers may not receive much training in teaching science to young children. Brenneman and her colleagues (2009) noted that despite the presence of learning standards and the increased attention to science curriculum, teacher preparation and in-service development programs have a tendency not to put emphasis on this content area and research suggests that science is not usually supported in preschool classrooms. In a review of requirements for pre-service, early childhood teachers in New Jersey, Lobman, Ryan, and McLaughlin (2005) found that relatively little coursework on science was required in teacher preparation programs and science was rarely linked to a practicum experience. Brenneman and her colleagues (2009) also mention that the case for in-service, professional development in the area of science is likewise unpromising. In 2008, 41 of the 50 state-funded preschool programs required their teachers to complete at least 15 hours of in-service training each year (Barnett et al., 2009). Because decisions concerning content are usually determined locally, there is no guarantee that teachers will receive science training professionally (Brenneman et al., 2009). These authors also mention that workshops provided to teachers frequently do not include opportunities for teachers to participate in experiences that are essential to bring about the kind of changes that will be significant in terms of content knowledge or teaching practices. As a result, researchers suggest that professional development should progress from workshops to models which will permit teachers a deeper exploration of the content and teaching practices for the areas of mathematics and science (NAEYC & National Council of Teachers of Mathematics [NCTM], 2002; Sarama & DiaBiase, 2004).

The general level of teacher's perceptions of their ability to teach science to young children in the current study was moderately prepared ($n = 4$, about 66.7%). Since the majority of teachers had neither higher- nor lower-level perceptions of their ability to teach science to young children, this may have influenced the insignificant association of my analyses. If future work includes more questions that relate to teachers' perceptions of their ability to teach science to young children (i.e., course work, practicum experience, in-service development programs, and so on), the influence of teacher perceptions may become more apparent. Further investigation is needed to better understand teacher's perceptions of their ability to teach science to young children and what can be done to support them in their preparation and professional development.

While teacher's perceptions of their ability to teach science were not found to be a significant moderator of the relation between teaching approaches (RT and RT + EI) and children's outcomes, teachers' years of experience was significantly and positively associated with scores on the science-related classroom environment and children's expressive vocabulary (W-J Picture Vocabulary). These results suggest that teachers who have more years of experience have classrooms that may provide children with more science-related materials and science experiences, and that children in the classrooms of more experienced teachers have higher expressive vocabulary scores.

Science-related Classroom Environment as a Moderator

The last research question examined if classroom environment would act to moderate the relation between teaching approaches (RT and RT + EI) and children's understanding of science concepts and vocabulary and scientific problem-solving skills. It was hypothesized that the relation between the types of teaching approaches and children's outcomes would be different depending on the amount and frequency of science-related materials, activities, and experiences provided in the classroom. Results found that classroom environment was not a significant moderator of the relation between teaching approaches and children's science concepts and vocabulary and scientific problem-solving skills outcomes. The strength/magnitude of the associations changed from Time 1 to Time 2 although the significance was not reached. For the scientific concepts and vocabulary outcome, there was a positive increase from children's Time 1 scores to Time 2 ($r = .37$; $r= .43$, respectively). For the scientific problem-solving skills outcome, there was also a positive increase from children's Time 1 score to their Time 2 score ($r = .09$; $r = .34$, respectively). If a larger sample size were used, the moderating effect of classroom environment might be detected.

However, a significant correlation was found between the science-related classroom environment and children's outcome of science concepts and vocabulary. This may mean that, when classrooms provide children with more opportunities to manipulate science-related materials and engage in science-related activities and experiences, children may gain more skills and knowledge in regards to science-content. With a larger class-level sample size and more variability in classroom environment scores, further studies may be able to provide more meaningful results.

Limitations and Future Directions

There were several limitations within this study to consider when planning future studies. First, the sample size within this study was very small and there were unequal group sizes. This limited the ability to show significant results in the analyses. In future studies, a larger sample of children and classrooms, and groups of more equivalent size should be used. The original study by Hong and Diamond (2012) included a sample of 104 children with groups that were more equal in size. With a larger sample size and more equal group sizes, differences between the two groups may become more apparent.

Second, although the fidelity was very high, the attendance was lower than the original study, which may contribute to the non-significance of the relationships. Only 46.15% of the children attended all of the intervention sessions in the current study, whereas about 70% of the children in the original study attended all of the intervention sessions (Hong & Diamond, 2012). With higher attendance, significant differences in the relationships may become more obvious.

Third, there was only one question on the survey given to teachers related to their perceptions of their ability to teach science to young children. Further studies should include more questions about what is needed to make teachers feel more confident or sure of their abilities in regards to teaching science (e.g., their perceptions of science in general, curriculum restraints within their programs or centers, and so on). In addition, teacher background information was collected only in terms of their overall education level and years of teaching experience. Further studies should be done which contain multiple questions about teacher's preparation for teaching science that include questions about teacher's course work, practicum experiences, and in-service training in the area of early childhood science education. Similarly, the researcher in the current study implemented the interventions, so it is not known whether or not early childhood teachers would be able to effectively implement the strategies (e.g., RT and RT + EI) used in this study in their classrooms.

Fourth, the data was only examined at the individual child's level in the current study. However, children are nested within small groups, and each small group was nested within a classroom in their center. Therefore, future studies should take into account the nature of the nested data by treating small group and classroom as different levels in the analyses. By using a method such as hierarchical linear models, each of these levels would be represented by their own submodel, which conveys relationships among the variables within that level and indicates the ways in which a variable at one level may influence the relations taking place within a different level (Raudenbush & Bryk, 2002).

Fifth, children were randomly assigned to small groups instead of being matched according to their initial assessment (i.e., pretest) and other characteristics, which can be very challenging. There was a significant group difference between RT and RT + EI in children's pretest scores on the science concepts and vocabulary outcome as well as their pretest scores on content-specific scientific problem-solving skills outcome. The number of children in the two groups were also very uneven (i.e., for RT, n = 9; for RT + EI n =17). Therefore, the random assignment did not produce two equal groups. In a future study with a larger sample with various characteristics, it would be interesting to use random assignment with some restrictions since completely matching the groups would be impossible. By using random assignment with some restrictions, researchers can match their groups by focusing on the variables that might contribute to the outcomes the most (e.g., both older and young children in each group).

Implications for Practice

This study provides evidence that preschool-aged children show a positive pattern in their learning of science concepts and vocabulary and scientific problem-solving skills that are age-appropriate when they are provided with developmentally appropriate instruction and guidance. Although both responsive teaching and explicit instruction are valuable approaches to teaching preschool-aged children science concepts and vocabulary and scientific problem-solving skills, the incorporation of explicit strategies into teaching (RT + EI) demonstrated more positive patterns in children's understanding of science concepts and vocabulary related to object's sinking and floating (e.g., weight, size, sink, and float and the relation of these concepts) than the use of only implicit strategies (RT). The use of implicit teaching strategies combined with explicit teaching strategies (RT + EI) reinforces Developmentally Appropriate Practices (Copple & Bredekamp, 2009), which emphasize that children's optimal development is more likely to occur when teachers not only provide opportunities and materials for children to explore, but when teachers include explicit instructions and intentional guidance to assist children to better understand their exploration and learning.

The RT intervention utilized a variety of responsive teaching strategies, such as modeling, imitating, commenting on what children are saying and doing with the materials provided to them, and playing with children in parallel. The role of the teacher is not to become simply an observer as children explore and build their knowledge through manipulation of the materials, but to intentionally model how to appropriately use the materials and describe children's actions in a manner that encourages their further exploration. However, the pattern of children's learning demonstrated in this study suggests that the inclusion of explicit instruction may be more beneficial in teaching science concepts and vocabulary and scientific problem-solving skills to preschool-aged children. Although there was only one significant result found in the current study, the original study conducted by Hong and Diamond (2012) found that children learned science concepts and vocabulary when the teacher utilized a variety of responsive teaching strategies; and children learned scientific problem-solving skills as well as concepts and vocabulary when the component of explicit instruction was combined with the responsive teaching strategies.

Result of the current study also indicated classroom environment was significantly related with children's science concepts and vocabulary. This suggests that children who are in classrooms that provide more opportunities to explore and manipulate science-related materials and to participate in science-related activities may have more knowledge and skill related to science-content. This supports NAYEC (2011) criteria for accreditation, which states that quality programs provide children opportunities to think, question, explore, experiment with, record their findings about, and to have conversations that include discussions pertaining to a variety of scientific phenomena every day. If early childhood educators provide a classroom environment with rich science-related activities and materials (e.g., a balance scale, a water table, making hypotheses and predictions and encouraging children to test them, and so on), children may be more likely to learn more science concepts, vocabulary, and scientific problem-solving skills.

While science materials alone have the potential to provide young children with learning opportunities, it is necessary for teachers to have foundational understanding of how children develop scientific thinking and learning (Baroody, 2004). Brenneman et al. (2009) explain that with an understanding of how children develop, teachers are more prepared to identify moments in which children are learning science, to evaluate what individual children know or need to know about specific concepts, and to better plan for future instruction in this area. Marx and Harris (2006) emphasized that to ensure children "receive high quality instruction, we need to invest in teachers and adequately prepare those already in the field" (p. 475). Further investigation should be done to understand the role of teacher perceptions and classroom environment in young children's science learning.

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Table 1

Participant's Demographic Information

	Teaching Approaches											
	RT (n = 9)				RT + EI (n = 17)				Total (N = 26)			
	n (%)	*Min*	*M* (*SD*)	*Max*	*n* (%)	*Min*	*M* (*SD*)	*Max*	*N* (%)	*Min*	*M* (*SD*)	*Max*
Child's Gender												
Girl	7 (77.80)	0			8 (47.10)				15 (57.70)			
Boy	2 (22.20)				9 (52.90)				11 (42.30)			
Child's Age	9	48	51 (2.19)	55	17	47	54 (4.94)	62	26	47	52.54 (4.39)	52
Child's Ethnicity												
Asian	3 (33.30)				1 (6.30)				4 (16.00)			

	Teaching Approaches											
	RT (n = 9)				RT + EI (n = 17)				Total (N = 26)			
	n (%)	*Min*	*M* (*SD*)	*Max*	*n* (%)	*Min*	*M* (*SD*)	*Max*	*N* (%)	*Min*	*M* (*SD*)	*Max*
African American	0 (0.00)				1 (6.30)				1 (4.00)			
White/Hispanic/Latino	0 (0.00)				1 (6.30)				1 (4.00)			
White/Non-Hispanic/ Non-Latino	5 (55.60)				10 (62.50)				15 (60.00)			
Mixed	1 (11.10)				3 (18.80)				4 (16.00)			
Mother's Education												
One or more years of college or Associates degree	2 (22.20)				1 (5.90)				3 (12.00)			
Bachelor's degree	0				4 (25.00)				4 (16.00)			

	Teaching Approaches											
	RT ($n = 9$)				RT + EI ($n = 17$)				Total ($N = 26$)			
	n (%)	*Min*	*M* (*SD*)	*Max*	*n* (%)	*Min*	*M* (*SD*)	*Max*	*N* (%)	*Min*	*M* (*SD*)	*Max*
Master's, Doctoral, or Professional degree	7 (77.80)				11 (68.80)				18 (72.00)			

Table 2

Descriptive Statistics and Group Comparisons

	Teaching Approaches								
	RT (*n* = 9)			RT + EI (*n* = 17)			Total (*N* = 26)		
	Min	*M* (*SD*)	*Max*	*Min*	*M* (*SD*)	*Max*	*Min*	*M* (*SD*)	*Max*
Concepts/Vocabulary Time1	11	18.67 (3.50)*	23	18	22.65 (4.27)*	33	11	21.27 (4.40)	33
Concepts/Vocabulary Time 2	11	23.78 (6.14)*	31	17	29.59 (5.56)*	38	11	27.58 (5.31)	38
Problem-Solving Skills total Time 1	12	16.89 (2.89)	22	11	16.65 (3.08)	22	11	16.73 (2.96)	22
Problem-Solving Skills total Time 2	15	17.78 (3.19)	23	13	20.29 (3.90)	27	13	19.42 (3.81)	27
Problem-Solving Skills/Content-general Time1	3	7.67 (2.12)	10	2	7.12 (2.29)	10	2	7.31 (2.20)	10
Problem-Solving	5	7.56 (1.59)	10	4	7.89 (2.12)	10	4	7.77 (1.92)	10

Skills/ Content-general Time 2									
Problem-Solving Skills/ Content-specific Time 1	8	10.67 (1.22)	12	5	11.18 (3.00)	16	5	11.00 (2.51)	16
Problem-Solving Skills/ Content-specific Time 2	9	12.22 (2.82)*	17	11	14.71 (2.82)*	20	9.00	13.85 (3.02)	20
W-J Picture Vocabulary	51	59.33 (6.48)	70	48	57.06 (5.26)	66	48	57.85 (5.69)	70
Classroom Environment	32.50	45.33 (12.52)*	61.00	32.50	58.29 (14.60)*	84	32.50	53.81 (15.04)	84
Science Preparation	2	2.67 (.50)	3	2	2.82 (.95)	5	2	2.77 (.82)	5

Note. * *Significant group difference*

Table 3

Correlations among Main Variables

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1. Concepts and Vocabulary Time 1	--												
2. Concepts and Vocabulary Time 2	.52**	--											
3. Problem-solving Skills/ Content-general Time 1	.07	.39	--										
4. Problem-Solving Skills/ Content-specific Time 1	.13	.03	-.07	--									
5. Problem-solving Skills Total Time 1	.08	.29	.63**	.66**	--								
6. Problem- solving Skills/ Content-general Time 2	.13	.38	.73**	-.06	.46*	--							
7. Problem-solving Skills/ Content-specific Time 2	-.01	.53**	.10	.22	.34	.31	--						
8. Problem-solving Skills Total Time 2	.03	.53**	.36	.10	.41*	.69**	.88**	--					

9. W-J Picture Vocabulary	.26	.21	.35	.06	.21	.32	.06	.15	--				
10. Classroom Environment	.37	.43*	-.13	.16	.09	.09	.38	.34	.22	--			
11. Teacher's Perceptions about Teaching Science	-.27	-.06	-.03	-.06	.12	-.21	.20	.06	-.22	.16	--		
12. Teacher's Years of Experience	.21	.22	-.05	.21	-.01	.19	.08	.12	.36	.36	-.76**	--	
13. Child's Age	.13	.22	.28	.50	.24	.46*	.33	.40*	.02	.21	-.03	.10	--

Note. * $p < .05$; ** $p < .01$

Table 4

Regression Model Description

Dependent Variable	Control Variables	Independent Variables
Concepts and Vocabulary Time 2		
	C. Age (*ns*)	CV-Time 1(r = .52 **)
	C. Gender (*ns*)	Classroom Envir (r = .43*)
	Mother's Education Level (*ns*)	Teaching Approaches (t =-2.45*)
	C. W-J Picture Vocab (*ns*)	T. Perceptions (*ns*)
	T. Years of Experience (*ns*)	
	T. Education Level (*ns*)	
Scientific Problem-Solving Skills Time 2		
	C. Age (r = .40*)	PS-Time 1 (r = .41*)
	C. Gender (*ns*)	Classroom Envir (r = .34*)
	Mother's Education Level (*ns*)	Teaching Approaches (*ns*)
	C. W-J Picture Vocab (*ns*)	T. Perceptions (*ns*)
	T. Years of Experience (*ns*)	
	T. Education Level (*ns*)	
PS-ContGen Time 2		
	C. Age (*ns*)	PS-ContGen Time 1 (r = .73**)
	C. Gender (*ns*)	Classroom Envir (*ns*)

Dependent Variable	Control Variables	Independent Variables
	Mother's Education Level (*ns*)	Teaching Approaches (*ns*)
	C. W-J Picture Vocab (r = .35*)	T. Perceptions (*ns*)
	T. Years of Experience(*ns*)	
	T. Education Level (*ns*)	
PS-ContSpec Time 2		
	C. Age (*ns*)	PS-ContSpec Time 2 (*ns*)
	C. Gender (*ns*)	Classroom Envir (r = .38*)
	Mother's Education Level(*ns*)	Teaching Approaches (t = -2.14*)
	C. W-J Picture Vocab (*ns*)	T. Perceptions (*ns*)
	T. Years of Experience (*ns*)	
	T. Education Level (*ns*)	

Note. C. = Child, T. = Teacher, PS = Scientific problem-solving skills, ContGen = Content general portion of scientific problem-solving skills, ContSpec = Content specific portion of scientific problem-solving skills.

Table 5

Model Summary for Research Question1: Science Concepts and Vocabulary Outcome

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.516[a]	.267	.236	5.51179	.267	8.730	1	24	.007
2	.572[b]	.327	.268	5.39493	.60	2.051	1	23	.166

a. Predictors: (Constant), Science Concepts and Vocabulary Time 1 total
b. Predictors: (Constant), Science Concepts and Vocabulary Time 1 total, Teaching Approaches

Table 6

Model Summary for Research Question 1: Scientific Problem-solving Skills outcome

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.512[a]	.262	.197	3.41052	.262	4.076	2	23	.031
2	.567[b]	.321	.228	3.34431	.059	1.920	1	22	.180

a. Predictors: (Constant), Child's Age, Scientific Problem-solving Skills Time 1 total
b. Predictors: (Constant), Child Age, Scientific Problem-solving Skills Time 1 total, Teaching Approaches

Table 7

Model Summary Research Question 1: Content-general Portion of Scientific Problem-solving Skills Outcome

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.737[a]	.543	.503	1.35637	.543	13.671	2	23	.000
2	.757[b]	.573	.514	1.34137	.029	1.517	1	22	.231

a. Predictors: (Constant), W-J III Picture Vocabulary, Content-general portion of Scientific Problem-solving skills Time 1
b. Predictors: (Constant), W-J III Picture Vocabulary, Content-general portion of Scientific Problem-solving Skills Time 1, Teaching Approaches

Table 8

Model Summary Research Question 1: Content-specific Portion of Scientific Problem-solving Skills Outcome

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.222[a]	.049	.009	3.00153	.049	1.239	1	24	.277
2	.440[b]	.193	.123	2.82425	.144	4.108	1	23	.054

a. Predictors: (Constant), Content-specific portion of Scientific Problem-solving Skills Time 1
b. Predictors: (Constant), Content-specific portion of Scientific Problem-solving Skills Time 1, Teaching Approaches

Table 9

Model Summary Research Question 2: Science Concepts and Vocabulary Outcome

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.516[a]	.267	.236	5.51179	.267	8.730	1	24	.007
2	.572[b]	.327	.236	5.51350	.061	.993	2	22	.387
3	.599[c]	.358	.236	5.51241	.031	1.009	1	21	.327

a. Predictors: (Constant), Science Concepts and Vocabulary Time 1 total
b. Predictors: (Constant), Science Concepts and Vocabulary Time 1 total, Teacher's Perceptions about Teaching Science, Teaching Approaches
c. Predictors: (Constant), Science Concepts and Vocabulary Time 1 total, Teacher's Perceptions about Teaching Science, Teaching Approaches, Interaction between Teaching Approaches and Teacher's Perceptions about Teaching Science

Table 10

Model Summary Research Question 2: Scientific Problem-solving Skills Outcome

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.512[a]	.262	.197	3.41052	.262	4.076	2	23	.031
2	.567[b]	.321	.192	3.42298	.059	.916	2	21	.415
3	.570[c]	.325	.156	3.49697	.002	.121	1	20	.732

a. Predictors: (Constant), Child's Age, Scientific Problem-solving Skills Time 1 total
b. Predictors: (Constant), Child Age, Scientific Problem-solving Skills Time 1 total, Teacher's Perceptions about Teaching Science, Teaching Approaches
c. Predictors: (Constant), Child Age, Scientific Problem-solving Skills Time 1 total, Teacher's Perceptions about Teaching Science, Teaching Approaches, Interaction between Teaching Approaches and Teacher's Perceptions about Teaching Science

Table 11

Model Summary Research Question 2: Content-general Portion of Scientific Problem-solving Skills Outcome

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.737[a]	.543	.503	1.35637	.543	13.671	2	23	.000
2	.783[b]	.613	.540	1.30605	.070	1.903	2	21	.174
3	.784[c]	.614	.518	1.33665	.001	.050	1	20	.826

a. Predictors: (Constant), W-J III Picture Vocabulary , Content-general portion of Scientific Problem-solving Skills
b. Predictors: (Constant), W-J III Picture Vocabulary , Content-general portion of Scientific Problem-solving Skills, Teacher's Perceptions about Teaching Science, Teaching Approaches
c. Predictors: (Constant), W-J III Picture Vocabulary , Content-general portion of Scientific Problem-solving Skills, Teacher's Perceptions about Teaching Science, Teaching Approaches, Interaction between Teaching Approaches and Teacher's Perceptions about Teaching Science

Table 12

Model Summary Research Question 2: Content-specific Portion of Scientific Problem-solving Skills Outcome

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.737[a]	.543	.503	1.35637	.543	13.671	2	23	.000
2	.765[b]	.585	.506	1.35328	.042	1.053	2	21	.367
3	.765[c]	.585	.482	1.38588	.000	.024	1	20	.879

a. Predictors: (Constant), Content-specific portion of Scientific Problem-solving Skills Time 1
b. Predictors: (Constant), Content-specific portion of Scientific Problem-solving Skills Time 1, Teacher's Perceptions about Teaching Science, Teaching Approaches

c. Predictors: (Constant), Content-specific portion of Scientific Problem-solving Skills Time 1, Teacher's Perceptions about Teaching Science, Teaching Approaches, Interaction between Teaching Approaches and Teacher's Perceptions about Teaching Science

Table 13

Model Summary Research Question 3: Science Concepts and Vocabulary Outcome

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.516[a]	.267	.267	5.51179	.267	8.730	1	24	.007
2	.604[b]	.365	.278	5.35924	.098	1.693	2	22	.207
3	.619[c]	.384	.266	5.40236	.019	.650	1	21	.429

a. Predictors: (Constant), Science Concepts and Vocabulary Time 1 total
b. Predictors: (Constant), Science Concepts and Vocabulary Time 1 total, Classroom Environment, Teaching Approaches
c. Predictors: (Constant), Science Concepts and Vocabulary Time 1 total, Classroom Environment, Teaching Approaches, Interaction between Teaching Approaches and Classroom Environment

Table 14

Model Summary Research Question 3: Scientific Problem-solving Skills Outcome

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.512[a]	.262	.197	3.41052	.262	4.076	2	23	.031
2	592[b]	.350	.226	3.34894	.088	1.427	2	21	.262
3	.593[c]	.351	.189	3.42794	.001	.043	1	20	.838

a. Predictors: (Constant), Child's Age, Scientific Problem-solving Skills Time 1 total
b. Predictors: (Constant), Child's Age, Scientific Problem-solving Skills Time 1 total, Classroom Environment, Teaching Approaches

c. Predictors: (Constant), Child's Age, Scientific Problem-solving Skills Time 1 total, Classroom Environment, Teaching Approaches, Interaction between Teaching Approaches and Classroom Environment

Table 15

Model Summary Research Question 3: Content-general Portion of Scientific Problem-solving Skills Outcome

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.737[a]	.543	.503	1.35637	.543	13.671	2	23	.000
2	.765[b]	.585	.506	1.35328	.042	1.053	2	21	.367
3	.765[c]	.585	.482	1.38588	.000	.024	1	20	.879

a. Predictors: (Constant), W-J III Picture Vocabulary , Content-general Portion of Scientific Problem-solving Skills Time 1

b. Predictors: (Constant), W-J III Picture Vocabulary, Content-general Portion of Scientific Problem-solving Skills Time 1, Classroom Environment , Teaching Approaches

c. Predictors: (Constant), W-J III Picture Vocabulary, Content-general Portion of Scientific Problem-solving Skills Time 1, Classroom Environment, Teaching Approaches, Interaction between Teaching Approaches and Classroom Environment

Table 16

Model Summary Research Question 3: Content-specific Portion of Scientific Problem-solving Skills Outcome

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.222[a]	.049	.009	3.00153	.049	1.239	1	24	.277
2	.487[b]	.237	.133	2.80850	.188	2.706	2	22	.089
3	.487[c]	.237	.092	2.87386	.000	.011	1	21	.919

a. Predictors: (Constant), Content-specific portion of Scientific Problem-solving Skills Time 1
b. Predictors: (Constant), Content-specific portion of Scientific Problem-solving Skills Time 1, Classroom Environment, Teaching Approaches
c. Predictors: (Constant), Content-specific portion of Scientific Problem-solving Skills Time 1, Classroom Environment, Teaching Approaches, Interaction between Teaching Approaches and Classroom Environment

Table 17

Correlations among Main Variables for Additional Analyses

	1.	2.	3.	4.	5.	6.	7.	8.
1. Child's Age	--							
2. Child's Gender	.15	--						
3. Mother's Education	.01	.16	--					
4. W-J III Picture Vocabulary	.02	-.25	-.14	--				
5. Concepts and Vocabulary Time 1	.13	.27	.02	.26	--			
6. Problem-Solving Skills Time 1	.24	-.06	-.53**	.21	.08	--		
7. Content-general Portion of Scientific Problem-solving Skills Time 1	.29	-.30	-.20	.35	.07	.63**	--	
8. Content-specific portion of Scientific Problem-solving skills Time 1	.05	.32	-.46*	.06	.13	.66**	-.07	--

Note. * $p < .05$; ** $p < .01$

Table 18

Model 1 Summary: Science Concepts and Vocabulary Outcome Time 1

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.759[a]	.577	.496	3.12038	.577	7.154	4	21	.001

a. Predictors: (Constant), Classroom Environment, Teacher's perceptions about teaching science, Teacher's total number of years taught, Teacher's education level

Table 19

Model 2 Summary: Scientific Problem-solving Skills Outcome Time 1

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.532[a]	.284	.252	2.60256	.284	9.102	1	23	.006
2	.632[b]	.399	.241	2.62196	.116	.915	4	19	.475

a. Predictors: (Constant), Mother's Education

d. Predictors: (Constant), Mother's Education, Classroom Environment, Teacher's perceptions about teaching science, Teacher's total number of years taught, Teacher's education level

Table 20

Model 3 Summary: Content-general Portion of Scientific Problem-solving Skills Outcome

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.250[a]	.062	-.116	2.32962	.062	.349	4	21	.842

a. Predictors: (Constant), Classroom Environment, Teacher's perceptions about teaching science, Teacher's total number of years taught, Teacher's education level

Table 21

Model 4 Summary: Content-specific Portion of Scientific Problem-solving Skills Outcome

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.459[a]	.211	.177	2.32815	.211	6.150	1	23	.021
2	.580[b]	.337	.162	2.34839	.126	.901	4	19	.483

a. Predictors: (Constant), Mother's Education

b. Predictors: (Constant), Mother's Education, Classroom Environment, Teacher's perceptions about teaching science, Teacher's total number of years taught, Teacher's education level

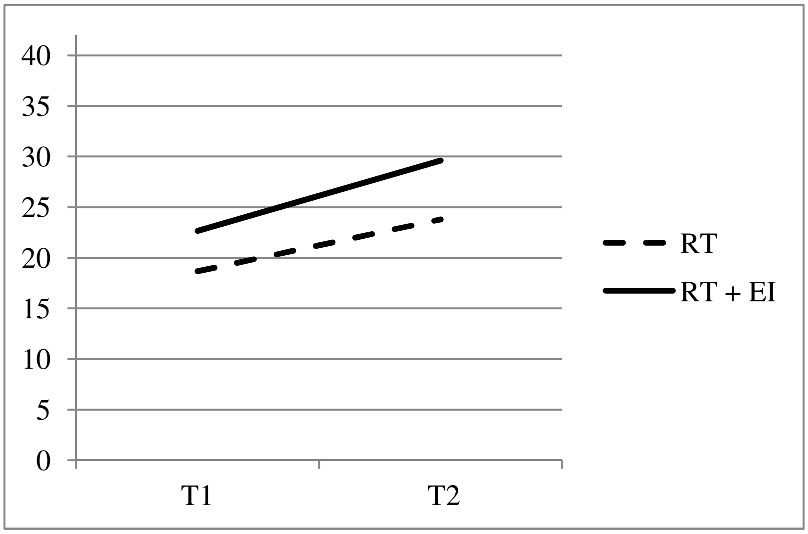

Figure 1

Change in Concept and Vocabulary Outcome

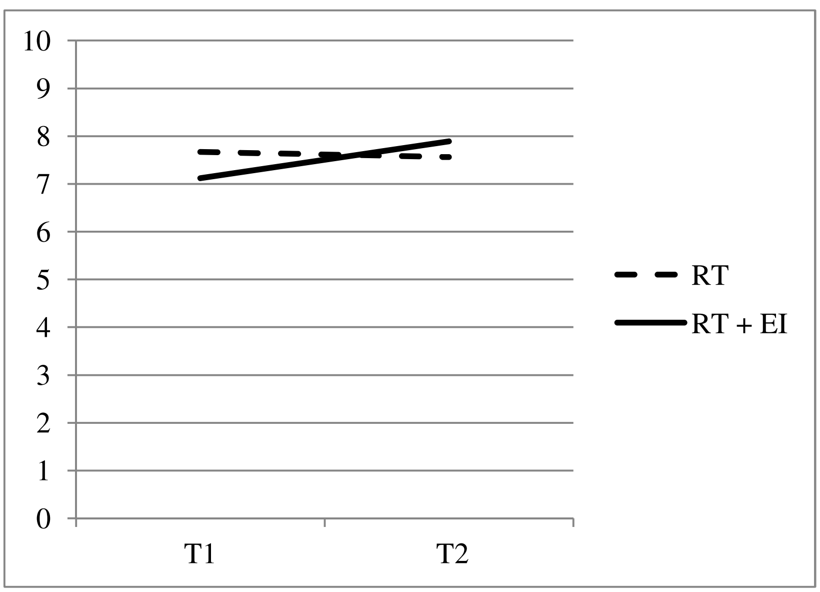

Figure 2

Change in Content-general Scientific Problem-Solving Skills Outcome

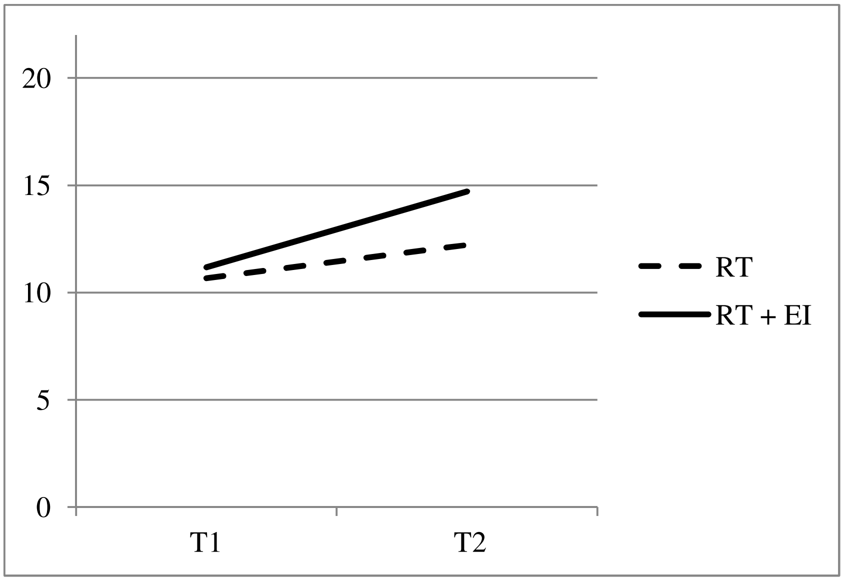

Figure 3

Change in Content-specific Scientific Problem-Solving Skills Outcome

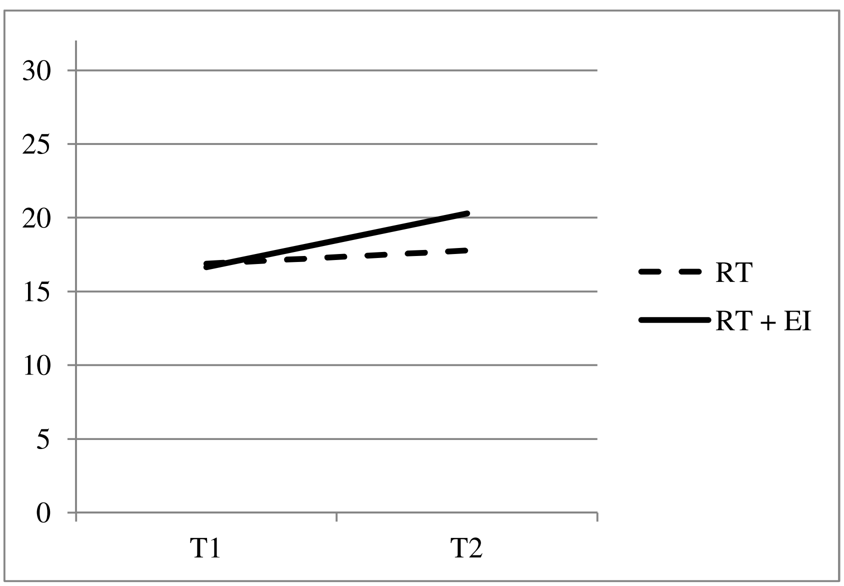

Figure 4

Change in Total Scientific Problem-Solving Skills Outcomes

Appendix A: Items from the Coding System of Children's Responses to Assessment Questions

Categories	Assessment Items	Scores
	SCIENCE CONCEPTS/VOCABULARY (0 ~ 42)	
Large, Big, Small, Heavy, Light *Pictures of two objects (1-3); Two objects (4 and 5)*	1. Point to the picture of Large. ***Large car** / small car*	0 = incorrect 1 = correct
	2. Point to the picture of Big. ***Big house** / small house*	0 = incorrect 1 = correct
	3. Point to the picture of Small. ***Small dog** / large dog*	0 = incorrect 1 = correct
	4. Hold these balls and tell me which one is Heavy. ***Golf ball** / table tennis ball*	0 = incorrect 1 = correct
	5. Hold these boxes and tell me which one is Light. ***Light box** / heavy box*	0 = incorrect 1 = correct
Size, Weight	6. What is size? Do you know what size means? *I don't know / No (0)* *Big (1)* *Small (1)* *It means that you measure people (1)* *Something small and something big / little, big (2)*	0 = incorrect 1 = acceptable 2 = correct
	7. What is weight? Do you know what weight means? *I don't know / No (0)* *Wait for somebody to get off / stop (0)* *Strong or not strong / when you get stronger (1)* *It means you are growing (1)* *It means when you work out your body (1)* *You lift up something (1) / exercise (1)* *Like heavy, like that box (1)* *Heavier or not heavier (2)* *How much you weigh (2)* *You weigh heavy or less (2)*	0 = incorrect 1 = acceptable 2 = correct
Float, Sink	8. What does it mean when we say something floats? Do you know what float means? *I don't know / No (0)* *If you put something in water then it floats away (0)* *Bathtub (0) water (0)* *Something floats in the water (0)* *Something floats on the water (1)* *Move like a boat going down the stream / a boat (1)* *Swimming. When you swim you float / you swim (1)* *A boat floats (1)* *It means .. in water or in the air (1)* *Floating stuff that has air in it (1)* *Flying (1) / Flying, floating (gesture) (1)* *If it's heavy, then it won't float (2)* *It means it's light (2)*	0 = incorrect 1 = acceptable 2 = correct

Categories	Assessment Items	Scores
	Something is on the water like a boat and a chip (2) *It means that you stay up at the top of the water (2)*	
	9. What does it mean when we say something <u>sinks</u>? Do you now what <u>sink</u> means? *I don't know / No / a hole (0)* *You wash dishes (0) water (0)* *If you put something in the sink, it sinks down and you can't get it out / sinking into the water (1)* *A boat sink. It breaks. (1)* *The toy is gone in the sink (1)* *It goes down (1)* *Sinking stuff that stuff with no air in it (1)* *Sinking, going down (gesture) (1)* *It means it's heavy (2)* *Someone sinks. It means they are heavy (2)* *You go under water / you are going down below the water (2)* *If means you are drowning (2)* *It goes down to the bottom of the water (2)*	0 = incorrect 1 = acceptable 2 = correct
Larger, Bigger, Smaller, Heavier, Lighter Pictures of two objects	10. Which one is <u>Larger</u>? ***Large circle** / small circle*	0 = incorrect 1 = correct
	11. Which one is <u>Bigger</u>? ***Big triangle** / small triangle*	0 = incorrect 1 = correct
	12. Which one is <u>Smaller</u>? ***Small square** / large square*	0 = incorrect 1 = correct
	13. Which side is <u>Heavier</u>? *Picture of a balance scale with objects*	0 = incorrect 1 = correct
	14. Which side is <u>Lighter</u>? *Picture of a balance scale with objects*	0 = incorrect 1 = correct
Similar (like), Different *Picture of one object on the top and four objects in the bottom (15 & 16)*	15-1. Look at these pictures. Which one is <u>like</u> the one on the top? *Size (1 large circle on top; 3 small and **1 large** circles)*	0 = incorrect 1 = correct
	15-2. Why? *Because they are the same (1)*	0 = incorrect 1 = acceptable 2 = correct
	16-1. Look at these pictures. Which one is <u>different</u> from the one on the top? *Size (1 large square on top; 3 large and **1 small** squares)*	0 = incorrect 1 = correct
	16-2. Why? *Because they are the same (1)*	0 = incorrect 1 = acceptable 2 = correct
One heavy/light object and four	17-1. Hold this box (heavy one). You can hold each of these boxes and tell me which one is <u>like</u> the one that you have. *Weight (1 heavy box; 3 lighter and **1 heavy box**)*	0 = incorrect 1 = correct

Categories	Assessment Items	Scores
objects (3 heavy/light and 1 light/heavy) presented (17 & 18)	17-2. Why? *Shake / Shaking (0)* *Because they are the same (1)* *Something is in it (1)*	0 = incorrect 1 = acceptable 2 = correct
	18-1. Hold this ball (light one). You can hold each of these balls and tell me which one is <u>different</u> from the one you have. *Weight (3 light ball; **1 heavier** and 3 light ball)*	0 = incorrect 1 = correct
	18-2. Why? *Because it has something in it (1)*	0 = incorrect 1 = acceptable 2 = correct
Floating *Prepare two objects (one floats and one sinks)*	19-1. I have two bottles. If I put them in water, only one of them will float. Which one do you think will <u>float</u>? *Same size / different weight* *(a bottle with water vs. **an empty bottle**)*	0 = incorrect 1 = correct
	19-2. Why? *It doesn't have any water in it (1)* *It's empty (1)*	0 = incorrect 1 = acceptable 2 = correct
	20-1. I have two balls. These balls have the same weight. If I put them in water, only one of them will float. Which one do you think will <u>float</u>? *Different size / same weight* *(**a large ball** vs. a small ball; with same weight)*	0 = incorrect 1 = correct
	20-2. Why?	0 = incorrect 1 = acceptable 2 = correct
Sinking *Prepare two objects (one floats and one sinks)*	21-1. I have two pipes. If I put them in water, only one of them will sink. Which one do you think will <u>sink</u>? *Same size / different weight* *(a plastic pipe vs. **a metal pipe**)*	0 = incorrect 1 = correct
	21-2. Why?	0 = incorrect 1 = acceptable 2 = correct
	22-1. I have two boxes. These boxes have the same weight. If I put them in water, only one of them will sink. Which one do you think will <u>sink</u>? *Different size / same weight* *(a large box vs. **a small box**; with same weight)*	0 = incorrect 1 = correct
	22-2. Why?	0 = incorrect 1 = acceptable 2 = correct
	VOCABULARY/CONCEPTS **TOTAL SCORE**	

Categories	Assessment Items	Scores
CONTENT-GENERAL SCIENTIFIC PROBLEM-SOLVING SKILLS (0 ~10)		
Sorting	1. Look at these boxes. Show me how you can put them in order by size. *4 boxes in different sizes*	0 = failed 1 = 2 corrects 2 = 3 corrects 3 = 4 corrects
	2. Look at these water bottles. Show me how you can put them in order by weight. *4 bottles with different amount of water*	0 = failed 1 = 2 corrects 2 = 3 corrects 3 = 4 corrects
Categorizing	3. Look at these boxes. Some are large/big, and some are small. Show me how you can put them in groups. How can you put them in groups? *3 small boxes and 3 large boxes*	0 = incorrect 1 = acceptable 2 = correct
	4. Look at these water bottles. Some are heavy, and some are light. Show me how you can put them in groups. How can you put them in groups? *3 bottles with little water and 3 bottles filled with water*	0 = incorrect 1 = acceptable 2 = correct
	SCIENTIFIC PROBLEM-SOLVING SKILLS PART I **TOTAL SCORES**	
CONTENT-SPECIFIC SCIENTIFIC PROBLEM-SOLVING SKILLS (0 ~ 22)		
Making experiments	15. I have toys in the water here. I am going to put this foil container in the water. What happened? It floats in water. See? It floats. 15-1. Tell me what you can do to make it sink. How can you make it sink? *0: Be stronger* *0: I don't know or no response* *1: Go under water* *1: You turn it and it will sink* *1: If it's small and if it's not heavy then it will float* *1: If it's a smaller pan* *1: Add/put more water in this box (water box, not the container)* *1: Make it (container) smaller* *1: Touch and move it around* *2: Push it down; put your hand on it; put it under water* *2: Turn it over and push it down* *3: Hole in it* *3: Put big balls in it* *3: Put something very big in there* *3: Put too much water in it (container)* *3: Put things (balls, blocks, toys, stuff, etc.) in it* *4: Put heavy things in it / on top of it*	0 1 2 3 4

Categories	Assessment Items	Scores
	15-2. Now, pull your sleeves up and make it sink. You can touch the toys inside now. *1. Success / Failure & # of Trials (0~3)* ▪ *I don't know; no trial (0)* ▪ *1 trial; failed (1)* ▪ *2 or more trials; failed (2)* ▪ *Succeeded (3)* *2. Child's action* ▪ *Use the codes for 15-1*	0 1 2 3 0 1 2 3 4
	16. Look at this bottle with water in it. I am going to put this bottle in the water. What happened? It sinks in water. See? It sinks. 16-1. Tell me what you can do to make it float. *0: I don't know or no response* *0: Make a magic* *1: Put more water in it* *1: A little ball, put it on top* *1: Push it up; pull it up; lift it up; grab it and pull over* *1: With something else* *1: Move it around in the water* *1: Put the bottle on top of the water* *1: Touch it and push it a little* *1: When you stand it up; when it stands up* *1: Put our hands on it* *1: It floats with tiny bubbles* *1: Hold it up and put it back up* *1: Use your hands* *1: Put pipes in there* *1: Put something under it. It might keep it up and float* *1: With little balls* *1: Make the water deeper and move it around* *1: Push it and it will float* *1: Touch and move it around* *1: Put the bottle upside down* *1: Pick up the bottle and drop it* *2: Put it in the container; put it in a boat* *2: If get in a boat* *2: Put air down under the water then it will float*	0 1 2 3 4

Categories	Assessment Items	Scores
	2: Put light things on it *3: Make it lighter (didn't say how)* *3: If it's not heavy (didn't say how)* *4: No water in the bottle* *4: If nothing is inside the bottle* *4: Hole in it; all the water out of it* *4: Put a little bit of water in it and it floats* *4: Dumping all the water out; put water out; empty it* 16-2. Now, pull your sleeves up and make it float. You can touch the toys inside now. *1. Success / Failure & # of Trials (0~3)* ▪ *I don't know; no trial (0)* ▪ *1 trial; failed (1)* ▪ *2 or more trials; failed (2)* ▪ *Succeeded (3)* *2. Child's action* ▪ *Use the codes for 15*-1	 0 1 2 3 0 1 2 3 4
	SCIENTIFIC PROBLEM-SOLVING SKILLS PART II **TOTAL SCORE**	

Appendix B: Detailed Intervention Protocol

	Intervention	Outcome	Assessment
	Responsive Teaching (4 sessions)		
Session 1	Objective: Children will understand the concept of size and its relation to floating and sinking. Interactions: -Prepare materials (objects with different sizes and tools for measurement) and choices -Have children explore the materials for at least 10 minutes and make observation notes based on the questions provided by Forman & Kuschner (1983): Questions to Ask while Teachers Observe Children Play in Small Group - What most attracts the child's attention? - What action patterns is the child repeating? - What variations is the child introducing in these patterns? - What determines these variations? - Has the child done similar things with different materials? - What consequences is the child producing? Is the child aware of these consequences? - What is the child saying while he works? Is the child aware of an audience as he talks? Does he assume that he is listened to? - What class of objects or events does the child describe most often? - How does the child cope with momentary distractions? - Does the child integrate the actions of others into his own play? - Does the child reflect on his own actions? If so, by looking or by verbal description? -Repeat what children say	Outcome: -Children understand the concept of size and its relation to sinking and floating -Children know the vocabulary related to the concept of size -Children know how to use measurement tools to measure objects' size (length and height)	-Understanding of the concept of size -Understanding of the relation between objects' size and their floating and sinking -Knowing vocabulary, such as size, height, length, large, big, small, larger, smaller, and bigger -Knowing how to use a tape measure and a ruler

	Intervention	Outcome	Assessment
	-Imitate what children do; **Do not** enter children's play until children explore the materials at least 3 times -Model what else children could do using the objects and describe what you are doing; **Do not** directly say what children could or should do -Describe what happens -Describe what children do -Create comments on what happens -Ask questions about what children say & do; **Do not** pose a problem that is not based on what children do -Use vocabulary (float, sink, large, small, etc.) as playing with children; **Do not** directly teach the vocabulary -Document what children say & do		
Session 2	Objective: Children will understand the concept of weight and its relation to floating and sinking. -Prepare materials (objects with different weights and tools for measurement) and choices -Same as above	Outcome: -Children understand the concept of weight and its relation to sinking and floating -Children know the vocabulary related to the concept of weight -Children know how to use measurement tools to measure objects' weight (with a balance scale and small blocks)	-Understanding the concept of weight -Understanding the relation between objects' weight and their floating and sinking -Knowing vocabulary, such as heavy, light, heavier, lighter, and weight -Knowing how to use a balance scale with small blocks
Session 3	Objective: Children will learn to make an object that floats sink. -Prepare materials (objects that float and tools for measurement) and choices -Have children explore the materials for	Outcome: -Children know how to make an object that floats sink. -Children know the	-Knowing how to make two different things become alike -Knowing how to

	Intervention	Outcome	Assessment
	at least 10 minutes and make observation notes based on the questions provided by Forman & Kuschner (1983) – see notes above ; **Do not** tell children to make objects that float sink (**Do not** tell children what the objective of this session is) -Repeat what children say -Imitate what children do; **Do not** enter children's play until children explore the materials at least 3 times -Model what children could do using the objects to make an object that floats sink and describe what you are doing; **Do not** directly say what children could or should do -Describe what happens -Describe what children do -Create comments on what happens -Ask questions about what children say & do; **Do not** pose a problem that is not based on what children do -Use vocabulary (float, sink, large, small, heavy, light, etc.) as playing with children; **Do not** directly teach the vocabulary -Document what children say & do	vocabulary related to objects' floating and sinking -Children know that objects that originally float can sink with some changes on the objects properties or using other objects that sink.	make an object that floats sink by using another object or by making a change in the object's properties -Explaining why a floater sink -Knowing vocabulary, such as float, sink, similar, different.
Session 4	Objective: Children will learn to make an object that sinks float Prepare materials (objects that sink, objects that can make objects float, and tools for measurement) and choices -Have children explore the materials for at least 10 minutes and make observation notes based on the questions provided by Forman & Kuschner (1983) – see notes above ; **Do not** tell children to make objects that sink float (**Do not**	Outcome: -Children know how to make an object that sinks float. -Children know the vocabulary related to objects' floating and sinking -Children know that objects that originally sink can	-Knowing how to make two different things become alike -Knowing how to make an object that sinks float by using another object or by making a change in the object's properties

	Intervention	Outcome	Assessment
	tell children what the objective of this session is) -Repeat what children say -Imitate what children do; **Do not** enter children's play until children explore the materials at least 3 times -Model what children could do using the objects to make an object that sinks float and describe what you are doing; **Do not** directly say what children could or should do -Describe what happens -Describe what children do -Create comments on what happens -Ask questions about what children say & do; **Do not** pose a problem that is not based on what children do -Use vocabulary (float, sink, large, small, heavy, light, etc.) as playing with children; **Do not** directly teach the vocabulary -Document what children say & do	float with some changes on the objects properties or using other objects that float. -Children know that even heavy objects can float in water	-Explaining why a sinker floats -Knowing vocabulary, such as float, sink, similar, different.

	Intervention	Outcome	Assessment
Responsive Teaching + Explicit Instruction (4 sessions)			
Session 1	<u>Objective</u>: Children will understand the concept of size and its relation to floating and sinking. <u>Vocabulary</u>: size, length, height, big, large, bigger, larger, small, smaller, float, sink, similar, different, measuring tape, ruler, etc. <u>Interactions</u>: -Prepare materials and choices -Introduce objects (their names and characteristics) and have children explore them; ask how they are similar and how they are different; allow children to touch the objects while doing	<u>Outcome</u>: -Children understand the concept of size and its relation to sinking and floating -Children know the vocabulary related to the concept of size -Children know how to use measurement tools to measure objects' size (length	-Understanding of the concept of size -Understanding of the relation between objects' size and their floating and sinking -Knowing vocabulary, such as size, height, length, large, big, small, larger, smaller, and bigger

	Intervention	Outcome	Assessment
	this; make a chart -Reflect & Ask: talk about the experience of playing with toys in their bath tub -Plan & Predict: tell children that they will be find out which object will float and which will sink; Ask what would happen if the objects are put in water; Ask whether they would float or sink and why they think so; -Act & Observe: Put each object in water and see whether they float or sink -Report & Reflect: categorize them into floaters and sinkers -Reflect & Ask: ask why some objects float but some sink when put in water; write down children's ideas -Plan & Predict: talk about what to do next; talk about testing hypotheses that children had about floating and sinking -Act & Observe: try out each of the ideas that children suggested; Measure length and height of each object with children and discuss how they are alike or different; explain how to measure length and height; make a chart -Report & Reflect: review the chart and make a conclusion	and height) -Children know how to compare objects according to their size (children know what to do to compare objects' size)	-Knowing how to use a tape measure and a ruler
Session 2	Objective: Children will understand the concept of weight and its relation to floating and sinking. Vocabulary: heavy, heavier, light, lighter, similar, different, sink, float Interactions: -Prepare materials and choices -Introduce objects (their names and characteristics) and have children explore them; ask how they are similar and how they are different; allow	Outcome: -Children understand the concept of weight and its relation to sinking and floating -Children know the vocabulary related to the concept of weight -Children know how	-Understanding the concept of weight -Understanding the relation between objects' weight and their floating and sinking -Knowing vocabulary, such as heavy, light, heavier, lighter,

	Intervention	Outcome	Assessment
	children to touch the objects while doing this; make a chart -Reflect & Ask: review (summarize) what they have learned in session 1 -Plan & Predict: tell children that they will be find out which object will float and which will sink again with different objects; Ask what would happen if the new objects are put in water; Ask whether they would float or sink and why they think so; -Act & Observe: Put each object in water and see whether they float or sink -Report & Reflect: categorize them into floaters and sinkers -Reflect & Ask: ask why some objects float but some sink when put in water; write down children's ideas -Plan & Predict: talk about what to do next; talk about testing hypotheses that children had about floating and sinking -Act & Observe: try out each of the ideas that children suggested; Measure weight of each object with children and discuss how they are alike or different; explain how to measure objects' weight; make a chart -Report & Reflect: review the chart and make a conclusion (e.g., objects whose weight is 5 or greater sink, but objects whose weight is less than 5 float)	to use measurement tools to measure objects' weight (with a balance scale and small blocks) -Children know how to compare objects according to their weight (children know what to do to compare objects' weight)	and weight -Knowing how to use a balance scale with small blocks
Session 3	Objective: Children will learn to make an object that floats sink. Vocabulary: float, sink Interactions: -Prepare materials and choices -Introduce objects (their names and characteristics) and have children explore them; ask how they are similar	Outcome: -Children know how to make an object that floats sink. -Children know the vocabulary related to objects' floating and sinking	-Knowing how to make two different things become alike -Knowing how to make an object that floats sink by using another object or

	Intervention	Outcome	Assessment
	and how they are different; allow children to touch the objects while doing this; make a chart -Reflect & Ask: review what they have learned in sessions 1 and 2; ask children to reflect on how they made a light toy sink in their bath tub -Plan & Predict: tell children that they will be find out how they could make an object that floats sink; ask what they think they could do to make a floater sink; write down their ideas/hypotheses and ask why they think so -Act & Observe: try out each of the ideas that children suggested and record if each idea worked (whether each hypothesis was true or false); make a chart -Report & Reflect: review the chart and make a conclusion (e.g., objects that originally float can sink with some changes on the objects' properties; they can make objects sink by putting more weight on them, etc.)	-Children know that objects that originally float can sink with some changes on the objects properties.	by making a change in the object's properties -Explaining why a floater sink -Knowing vocabulary, such as float, sink, similar, different.
Session 4	Objective: Children will learn to make an object that sinks float Vocabulary: float, sink Interactions: -Prepare materials and choices -Introduce objects (their names and characteristics) and have children explore them; ask how they are similar and how they are different; allow children to touch the objects while doing this; make a chart -Reflect & Ask: review what they have learned in sessions 1, 2, and 3; ask children to reflect on how they made a heavy toy float in their bath tub or in	Outcome: -Children know how to make an object that sinks float. -Children know the vocabulary related to objects' floating and sinking -Children know that objects that originally sink can float with some changes on the objects properties or using other objects	-Knowing how to make two different things become alike -Knowing how to make an object that sinks float by using another object or by making a change in the object's properties -Explaining why a sinker floats -Knowing vocabulary, such as

Intervention	Outcome	Assessment
their classroom activity. -<u>Plan & Predict:</u> tell children that they will be find out how they could make an object that sinks float; ask what they think they could do to make a sinker float; write down their ideas/hypotheses and ask why they think so -<u>Act & Observe:</u> try out each of the ideas/hypotheses that children suggested and record if each idea worked (whether each hypothesis was true or false); make a chart -<u>Report & Reflect:</u> review the chart and make a conclusion (e.g., objects that originally sink can float with some changes on the objects' properties or by using another object that makes a sinker float; they can make objects float either by taking out what makes the object sink or by using another object that floats, etc.)	that float. -Children know that even heavy objects can float in water	float, sink, similar, different.

Appendix C: Complete Teacher Questionnaire

Teacher Questionnaire: Teaching Practice and Classroom Context
(13 items on teaching practice and classroom context; 2 items on teacher experience)

1. How often do you provide the following activities in your early childhood classroom (either as an activity during free-choice time or as a small/large group activity)?

1 = Twice a month   4 = Once a week
2 = Monthly   5 = Twice a week
3 = Every other week   6 = Daily

a. Language and literacy	1	2	3	4	5	6
b. Mathematics	1	2	3	4	5	6
c. Science	1	2	3	4	5	6
d. Health, Safety, and Nutrition	1	2	3	4	5	6
e. Social studies	1	2	3	4	5	6
f. Aesthetic expression (art, music, drama, movement)	1	2	3	4	5	6
g. Gross motor and outdoors	1	2	3	4	5	6

2. Do you have a science area(s) or interest center(s) in your classroom? (Circle only one)

   a. YES
   b. NO (If no, skip to question 7)

   2-a. If yes, list all the items in your science area(s) that children could use today.
   ____
   ____
   ____

3. Circle all the science materials that were accessible to children elsewhere in the classroom today.

   a. Flashlights
   b. Cooking measures
   c. Planting materials
   d. Magnifying glasses
   e. Thermometers
   f. Scales
   g. Microscope
   h. Animals
   i. Magnets
   j. Mirrors
   k. Metric weight set

   Others (Please specify) ____________________________________

4. How many field trips have you scheduled for your class in the last 2 months? _________
   What was (were) the location(s)? ____________________________________

5. Circle the science activities that were available in your classroom today.

    a. Cooking
    b. Sand box
    c. Water play
    d. Assorted metal and nonmetal objects
    e. Others (please specify): ____

6. How many cooking activities have been completed in your classroom during the last 2 weeks in which for example, the preschoolers were actually involved in the food preparation such as measuring, pouring, or mixing? (Circle only one)

    a. None
    b. 1 – 2 times
    c. 3 – 4 times
    d. More than 5 times

7. Do you have a sand box at your preschool center? (Circle only one)

    a. NO (If no, skip to question 8)
    b. YES, indoors
    c. YES, outdoors
    d. YES, both indoors and outdoors

7-a. Circle all the materials and equipment (e.g., toys, cups) that were available in your sand box today (indoors or outdoors)

a. Sand	d. Rocks	f. Digging items
b. Gravel	e. Pebbles	g. Stones
c. Pouring items		

Others (Please specify) ____

8. Do you have a water table available to use in your classroom? (Circle only one)

    a. YES
    b. NO (If no, skip to question 9)

8-a. If yes, how often do you use the water table? (Circle only one)

    a. Less than once a week
    b. Once a week
    c. Twice a week
    d. Three times a week

e. Four times or more a week

8-b. Circle <u>all</u> the items that were available in your <u>water table</u> the last time it was used.

a. Plastic tubing
b. Containers
c. Colanders
d. Straws
e. Funnels
f. Eyedroppers
g. Strainers
h. Objects that float/sink

Others (Please specify) ____

9. Do you have an outdoor or indoor garden available for children and teachers to work together? (<u>Circle only one</u>)

    a. YES
    b. NO

10. Do you have an animal in your classroom? (<u>Circle only one</u>)

    a. YES (Please specify the kind of animal(s))______________________
    b. NO

11. How many of the <u>storybooks</u> in your classroom today are related to <u>science</u>? ________

12. How many <u>resource books</u> for children in your classroom today are related to <u>science</u>? ___________

13. How adequately do you feel you have been prepared for teaching science with children 3 to 5 years old? (<u>Circle only one</u>)

    a. Very unprepared
    b. Fairly unprepared
    c. Moderately prepared
    d. Fairly prepared
    e. Very well-prepared

14. What is the highest education level you have completed? (<u>Circle only one</u>)

    a. High school diploma
    b. Junior college or equivalent (Please specify major: ________________________)
    c. B.A./B.S. degree (Please specify major: ________________________________)
    d. M.A./M.S. or professional degree (Please specify major: ___________________)
    e. Other (Please specify major: ____)

15. The total number of years you have taught in preschool or kindergarten?

    ______________ years (<u>include this year</u>)