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Playing with Science: An Investigation of Young Children's Science Conceptions and Misconceptions

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Abstract

The purpose of this research was to investigate the conceptions and misconceptions of young children (ages 3 – 8) related to science concepts, skills, and phenomena. These conceptions and misconceptions were investigated within the framework of the Pennsylvania Early Learning Standards for Pre-Kindergarten and the Pennsylvania Standards for Kindergarten as developed and published by the Pennsylvania Department of Education in 2005. In addition, the National Science Education Standards also served as a foundation for our research. Findings reveal the most common conceptions related to matter, magnetism, density, and air. Extrapolations from this research can be used by pre-service teachers, in-service teachers, and teacher educators to implement experiences in the classroom that assist in developing and refining young children's understandings of scientific concepts, skills, and phenomena.

Keywords: young children, science education, misconceptions, conceptions, conceptual change, conceptual learning

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Playing with Science: An Investigation of Young Children's

Science Conceptions and Misconceptions

Past research in science education indicates that most educators underestimate the abilities of early childhood age children to learn science concepts (Ayers, 1999; Blosser, 1987; Eaton, Anderson, & Smith, 1984; Kyle, Family, & Shymansky, 1989). This notion is problematic because by holding this idea, teachers often fail to "…capitalize on young children's seemingly innate interest and enthusiasm for science" (Watters, Diezmann, Greishaber & Davis, 2001, p. 2). Children are constantly exploring, and as they investigate their environment, they create naïve understandings about the world in which they live. These naïve understandings become the building blocks for developing more sophisticated understandings and can therefore interfere with subsequent learning. Children are "naturally inquisitive and begin doing science from the moment of birth by observing and sorting out their world" (Martin, Raynice & Schmidt, 2005, p.13). As a result of these exploratory experiences, children often come to school with conceptions that are often inconsistent with commonly held views of scientific concepts, skills and phenomena.

In many early childhood settings, science is often omitted from the classroom. In fact, research indicates that early childhood classrooms spend an average of 119 minutes per day on Reading/Language Arts instruction versus 21 minutes per day for science instruction (Fulp, 2002). In the rare cases when science is taught to young children, teachers often neglect children's prior experiences. When teachers ignore the experiences that have been instrumental in forming students' conceptions of the world, teachers are simultaneously ignoring the misconceptions that students hold about the world. Teacher must understand both the conceptions and misconceptions of students in order to teach in a manner that allows for the correction and replacement of misconceptions with accurate scientific understandings. Hence, the purpose of this research was to investigate the conceptions and misconceptions young children hold in relation to scientific concepts, skills, and phenomena. By understanding the conceptions and misconceptions of young children, educators may be better able to achieve the goal of scientific literacy for all children (National Research Council, 1996).

Framework

Misconceptions

The term misconception is used to describe "a situation in which students' ideas differ from those of scientists about a concept" (Blosser, 1987, A Variety of Terms section, para. 2). As young children explore the world guided by curiosity and interest, children's conceptions and misconceptions are based on their everyday experiences. The way that students characterize and explain the world is often guided by logical but scientifically inaccurate understandings. "In many cases students have developed partially correct ideas that can be used as the foundation for further learning" (as cited in Committee on Undergraduate Science Education, 1997, Misconceptions as Barriers to Understanding section, para. 2). While students' prior experiences serve as the foundation and context for further learning, educators should not underestimate the power of student's misconceptions. "Ausubel, (1968) noted that misconceptions are 'amazingly tenacious and resistant to extinction…the unlearning of preconceptions might well prove to be the most determinative single factor in the acquisition and retention of subject-matter knowledge'" (as cited in Kyle, Family, & Shymansky, 1989, Prior Knowledge and Conceptions of Students section, para. 1).

There are several ways that children develop conceptions and misconceptions. Some of the sources of misconceptions include everyday observations, religious or mythical teachings, science teaching that does not adequately challenge students' misconceptions, and vernacular misconceptions (Committee on Undergraduate Science Education, 1997). There are multiple contexts through which young children encounter information that promotes misconceptions. It is therefore possible for children to have multiple explanations for a given phenomena, depending on the context in which it occurs.

Young children are capable of delivering the appropriate answers to questions however, they may simultaneously hold misconceptions in which they believe strongly. For example, in a study reported by William Philips (1991), "…it was estimated that 95% of [second graders] knew that the Earth was a sphere. However, through interviews it was later discovered that while students said they believed it was a spherical planet, they actually believed that Earth was indeed flat" (p. 21). This example demonstrates how students combine their everyday experiences with the world and the knowledge that they are taught in school. When students are exposed to two different explanations of scientific phenomena "it is possible that children develop mutually inconsistent explanations of scientific concepts – one for use in school and one for use in the 'real world'" (Blosser, 1987, Findings Related to Elementary Science section, para. 1). Thus, it is important to consider how to truly uncover misconceptions.

One way to correct the misconceptions that children have is through teaching for conceptual change. "Misconceptions are rarely expressed aloud or in writing and, therefore, often go undetected…but before beginning instruction to challenge misconceptions a teacher must discover the misconceptions that his or her students hold" (Phillips, 1991, p. 21). By understanding the conceptions and misconceptions of young children, educators can better adapt their teaching methods in an attempt to guide students toward accurate and more sophisticated understandings of science.

Conceptual Change

Conceptual change elaborates on the theory of constructivism and refers to the process learners go through in "…coming to comprehend and accept ideas because they are seen as intelligible and rational" (Posner, Strike, Hewson, & Gertzog, 1982, p. 212). The conceptual change learning model is a view of learning that takes into account the interplay between what a student already knows and what the student is being taught (1982). In order for a student to replace a faulty understanding (i.e. misconception) with an accurate understanding, certain conditions must be met. These conditions describe the process by which learners' "…central, organizing concepts change from one set of concepts to another" (p. 211). Specifically three criteria must be met when attempting to replace misconceptions with accurate understandings. First, a student must experience "*dissatisfaction"* with existing conceptions (p. 214). Students are unlikely to change their faulty conceptions unless they come to believe that the conceptions they hold no longer satisfy their need to solve problems (1982). Second, the new conception that is to replace the old must be "*intelligible"* (p. 214). This means that the learner must come to "grasp how experience can be structured by a new concept sufficiently to explore the possibilities inherent in it" (p. 214). Third, the new conception must appear "*plausible"* (p. 214). Plausibility refers to a concepts ability to "at least appear to have the capacity to solve problems and be consistent with other knowledge and/or past experience" (p. 214). Finally, the new concept should be "*fruitful"* (p. 214). In other words, the new concept must present the learner with new avenues for solving problems.

Clearly, the process of conceptual change can at times be a lengthy and complex endeavor due to the fact that students have constructed their conceptions over extended periods of time. Thus, at times, it can be quite difficult for learners to accept that their ideas need adjustment and/or replacement, even when these ideas are not supported by evidence. "Changes can be strenuous and potentially threatening, particularly when the individual is firmly committed to prior assumptions" (Posner, Strike, Hewson, & Gertzog, 1982, p. 223). In fact, some students will go to extreme lengths to defend these ideas. On the other hand, some preconceptions can be easily revised through instruction (Chi & Roscoe, 2002). Regardless of the tenacity of the beliefs, students will resist making a change "…unless they are dissatisfied with their current concepts and find and intelligible and plausible alternative that appears fruitful for further inquiry" (1982, p. 223).

"The conceptual change model is widely accepted among science educators. Though there are competing views of how conceptual change occurs, there seems to be no argument about whether conceptual change occurs; it is central to learning in science" (Suping, 2003, Conclusions section, para. 1). Hence, by understanding the common misconceptions that children have, teachers can come to better understand the ways in which they can begin to scaffold instruction in an effort to encourage students to move through the process of conceptual change. "In science…misconceptions affect the way children understand a variety of scientific ideas," therefore it is imperative that teachers understand why and how misconceptions can exist, as well as how they may be replaced (Eaton, Anderson & Smith, 1984, p. 366).

Although teaching for conceptual change is challenging, it is an attainable goal and has proven benefits or learning. In this style of learning, children confront the inconsistencies in their scientific knowledge, and gain a deeper understanding of science content (Watson & Kopnicek, 1990). As such, providing instructional strategies that address the importance of students' conceptions and prior knowledge is imperative. Consequently, this study is aimed at investigating the conceptions and misconceptions young children hold in relation to science concepts, skills, and phenomena. As a result of this investigation, educators may come to better understand the conceptions and misconceptions that children hold in relation to science. Furthermore, this knowledge will also assist in the development and implementation of instruction that supports conceptual change.

Method

The purpose of this research was to investigate the conceptions and misconceptions young children hold in relation to scientific concepts, skills, and phenomena. This study represents qualitative research. Qualitative data was collected from 63 children from three separate early childhood educational sites in an attempt to investigate the conceptions and misconceptions of young children. The age range of the participants was from 3 – 8 years old and data collection took place over the course of three months. Of the 63 participants, 65% were male and 35% were female (see Table 1). Participants were predominantly white, middle class and resided in a suburban town of Pennsylvanian.

To conduct the research, the researchers created multiple inquiry-based science units for the areas of matter, magnetism, density, and air (see Appendix). These inquiry-based units were developed using the National Science Education Standards. Hence, each unit was designed around the five essential features of classroom inquiry, which are necessary for teaching science as inquiry (National Research Council, 2000). Each of these units was aligned with both state and national standards and required children to express their understandings of science concepts and skills. The units encouraged student participation, thus the researchers assumed the position of uncovering student conceptions and misconceptions. It is important to note that throughout all of the lessons, the researchers were careful not to confirm or deny participant ideas. The goal of this research was to uncover the conceptions and misconceptions held by young children, *not* to teach them scientific content. In addition, within each of the lessons, the research asked the students to justify their thoughts, decisions and responses by giving priority to evidence.

Units were implemented with small groups of young children on multiple occasions. Each site was visited an average of five times over the three month time period. During each visit, a unit was implemented and videotaped in an effort to capture all of the conceptions and misconceptions that children portrayed in both their verbal and non-verbal communication skills. The videotapes from each implementation were transcribed and then analyzed. Data sources were analyzed in an attempt to identify the common conceptions and misconceptions held by the participants with regard to science concepts, skills, and phenomena. The method of choice for analyzing the data was grounded theory (Denzin & Lincoln, 2000) and narrative inquiry (Clandinin & Connelly, 2004). Specifically, the researchers analyzed videotapes and transcripts to uncover the most common conceptions and misconceptions held by the participants in regard to matter, magnetism, density, and air.

Table 1

Demographic Information of Teaching Sites

	Site A	Site B	Site C
Male	20	14	7
Female	8	8	6
Total	28 (44%)	22 (35%)	13 (21%)

Total N = 63

Results

Upon completion of the qualitative data analyses, the researchers were able to identify the common conceptions and misconceptions young children hold related to the specific areas addressed within this study: matter, magnetism, density, and air.

Matter

The common conceptions that children held related to matter included "a brick is a solid" (ages 7, 6, 5, 4) and "water is a liquid" (ages 6, 5, 4). In addition, children were able to provide several accurate examples of both solids and liquids. Specifically, some children categorized liquids as something that "they could drink" (ages 7, 6, 5, 4). Although this notion of 'drinkable' does not always determine if a substance is liquid, children used this idea when providing examples of liquids such as "milk," "juice," "soda," "water…etc." In addition, children also utilized the 'touch test' to determine if a substance was a solid or liquid. For example, children articulated the belief that "you can stick your finger in a liquid, but your finger stops for a solid" (ages 7, 6). Children utilized this 'touch test' process to inform their ideas about additional objects/materials that were presented during the unit.

The common misconceptions that children held related to matter were that “solids are “heavy” (age 5), “hard” (ages 7, 6, 5, 4), solids cannot be “eaten” (age 6), “broken” (ages 7, 6, 5), “bent” (ages 7, 6), “squished” (ages 7, 4), “have holes” (age 7), “be hollow” (age 7), or “soft” (ages 6, 5). In addition, children also believed that “you can drink liquids” (ages 7, 6, 5, 4) and that “if you cannot drink a liquid, it is not a liquid” (ages 5, 4). It is important to note that the conceptions children have oftentimes inform the misconceptions that they have. This notion is particularly evident in the children’s explanation of a solid being something that cannot be “broken” or “bent” (ages 6, 4). This misconception is informed by their conception of a brick being a solid. Although children were able to categorize the brick as a solid, they also generalized the properties of the brick to determine the properties of a solid. Another example of this was in the children’s description of a liquid being something that “you can drink” (ages 7, 6, 5, 4). Although it is true that some liquids can be drank, the children used this idea to incorrectly generalize the idea of drinkable liquids to all liquids. For example, juice is a liquid, but vinegar is not because “you can’t drink it—it doesn’t taste good” (ages 5, 4) These examples are a perfect illustration of how children can hold inconsistent understandings about scientific concepts that lead to the creation of further, more detrimental misconceptions, which may prevent young children from gaining deeper understandings of science.

Magnetism

The common conceptions about magnetism included that magnets “stick” (ages 8, 7, 6, 5, 4) and magnets “help you stick pictures/paper to the refrigerator” (ages 5, 4), In addition, children were able to generate some correct predictions about what magnets would and would not be attracted to in a classroom or recreational space. Children also acknowledged that magnets are different "colors" (ages 8, 7, 4), "shapes" (ages 8, 7), "sizes" (ages 8, 7), magnets "have North and South poles" (age 8), and magnets have "different strengths" (ages 8, 7, 6).

It is important to note that children were able to use real world examples and experiences such as the refrigerator, to inform some of their scientifically accurate conceptions. However, the children's overgeneralizations of their conceptions again lead to misconceptions. For example, a common misconception was that "magnets stick to all refrigerators" (ages 8, 7, 6, 5, 4). While this may be a logical extrapolation based on their previous experiences, the children failed to recognize that there might be some circumstances where a magnet will not be attracted to a particular refrigerator. Furthermore, this overgeneralization communicates the children's lack of understanding related to *why* magnets are attracted to certain objects and not others.

Another common misconception among children was the idea that magnets "stick." At all of the sites, children explored the room with magnets looking for items that the magnet would "stick to" and would "not stick to." As the children tested their predictions, many children tried to "stick" their magnets to a filing cabinet; the magnets did attract to the cabinet but the magnets then slid down the cabinet door. As a result, because the magnet did not "stick" and stay stationary, the magnet was not "sticking" to the cabinet and thus the magnet was not attracted to the cabinet.

Additional misconceptions about magnets are that magnets are "magic" (age 5), "hard" (ages 4, 5), "stick to all metal" (ages 7, 6, 5), "stick to silver"(ages 6, 5) the "size of a magnet" affects its magnetic field (ages 8, 7), the poles "do not stick equally" (ages 7, 6), magnets will not attract through objects that are "heavier" than the magnet itself (ages 8, 7), and magnets will not attract through items that are "harder" (age 8), "thicker" (ages 8, 7), "stronger" (age 7), and "bigger" than the magnet (ages 8, 7).

Density

The common conceptions that children held about density primary correlated with the children's ability to predict and identify objects that would sink and float. Children knew that: "a marble sinks" (ages 8, 7, 6, 5) and "corks" (ages 8, 7, 6, 5, 4), "boats" (age 5), and "ducks" (ages 6, 3) float. However, the young children were also able to express that water inside a boat would impact the boat's ability to float. This finding illustrates the children's understanding of mass being important in determining the density of an object.

It is clear that the children used their prior knowledge and experiences with sinking and floating to inform their conceptions as their list of conceptions included many examples from their everyday lives, and the same is true of their misconceptions. Common misconceptions were that "glass sinks" (age 5), "heavy metal sinks" (ages 7, 6, 4), "plastic floats" (ages 6, 5), "all wood floats" (ages 8, 7, 6), "objects with air inside them float" (age 8). While these conceptions are sometimes true, they are not true all of the time and thus again, illustrate how incomplete conceptions can create misconceptions.

Additional misconceptions that the children held were related to the task of manipulating a piece of clay so that it would both sink and float, but at different times. To accomplish this task, the children were provided a piece of clay. To make the clay sink, most children immediately formed a ball and put it in the water. However, when asked if they could take that same piece of clay and make it float, the children needed time to experiment with the clay in an effort to test their ideas. Many children attempted to remove amounts of clay from the original piece thinking that by decreasing the mass, the clay would then float. This strategy clearly illustrated inconsistencies associated with the concept of density. Specifically, children articulated the following misconceptions when manipulating the piece of clay: "heavy objects sink" (ages 8, 7, 6, 5, 4, 3), "light objects float" (ages 8, 7, 6, 5, 4, 3), "thin objects float" (ages 8, 7, 6), "big things sink" (ages 8), and "small things float" (ages 8).

With time to explore, children were able to conclude that their initial ideas were not accurate and eventually, all children were able to make their piece of clay float by creating a boat-like object that spread the mass of the clay over a greater area without "flooding." Although children arrived at the understanding of the relationship between mass and volume, this understanding was certainly naïve. Specifically, children articulated that, "walls make things float" (ages 8), "flattening it will make it float" (ages 8, 7, 6, 5, 4, 3), and "objects with air in them float" (ages 8, 6). Throughout the course of this unit, children consistently drew on previous experiences and knowledge to inform their attempts at creating objects that would float. Some interesting examples included a young girl who made a duck out of the clay because she knew that ducks floated and a young boy who made a lifesaver ring because he knew that he had seen the object float in a swimming pool.

Air

The common conceptions associated with air were…"air is for breathing" (age 6), "air can be used to move objects" (ages 8, 7, 6, 5, 4), "if you have more air, you can move heavier objects" (ages 8, 6), "air can be created by blowing" (ages 6, 5, 4), "air is inside a bubble" (ages 7, 6, 5, 4), and "air is invisible" (ages 5, 4). For this particular concept, children again used many connections to their real life to arrive at their conceptions regarding air.

It is important to note that this unit involving air required children to explore paper and plastic bags along with napkin parachutes. Through this exploration, the following misconceptions were revealed: "if a bag is flattened, there is no air in it" (ages 8, 7, 6, 5, 4), "if a bag is puffed up, there is air in it" (ages 8, 7, 6, 5, 4), "air helps the parachute fall slowly" (age

6), “air is inside or on top of a parachute, but not around it” (ages 8, 7, 6), “air is outside and in the sky” (ages 5, 4), and “air is not everywhere…it’s only around when someone/something is blowing” (ages 6, 4). Similar to the conceptions previously listed, children again relied on their prior knowledge and experiences to inform their misconceptions. Additionally however, their prior knowledge was also used in concert with the new experiences they were encountering. For example, when children explored the napkin parachute to determine how air was involved, they used their conception of air being used to move objects to recognize that air did indeed influence the way the parachute fell to the ground. In the same sense, however, the children were unable to recognize that air was also present on the sides of the parachute, as well as inside and on top of the parachute. This example demonstrates another instance where children have a naïve understanding of a concept that informs how they interact with materials and science content

Discussion

“Since the early work of Piaget (1929; 1969) researchers have been aware that children’s conceptions about the world are sometimes quite different from scientific conceptions” (Eaton, Anderson & Smith, 1984, p. 365). These misconceptions subsequently affect they way children learn, understand, and apply scientific concepts, skills, and phenomena. By investigating and understanding the conceptions and misconceptions of young children, educators can better tailor their instruction so that opportunities are provided for children to correct their misconceptions and develop deeper, more sophisticated understandings of science.

The findings of this research are consistent with other research in the area of children’s misconceptions, however this study is unique in that the population researched involved young children. In addition, this study shed further light on the strategies children use to create understandings about science. For example, children used the ‘touch test’ and the categorization of ‘drinkable’ to determine if a substance was a liquid or a solid. Furthermore, when exploring all areas of content involved in this study, children consistently relied on their prior knowledge and experiences to articulate their understandings, which is consistent with previous research associated with misconceptions and conceptual understanding (Ayers, 1999; Blosser, 1987; Committee on Undergraduate Science Education, 1997; Eaton, Anderson, & Smith, 1984; Kyle, Family, & Shymansky, 1989; Ozdemir & Clark 2007; Suping, 2003). This finding further exemplifies the importance of prior knowledge and past experiences in the development of young children’s conceptions and misconceptions associated with science. “Children come to school already holding beliefs about how things happen, and have expectations based on past experiences which enable them to predict future events” (Blosser, 1987, Findings Related to Elementary Science section, para. 1). Teachers must take these experiences and knowledge into account when planning and implementing instruction. If teachers do not connect their units of study to the child’s life and prior experiences, the misconceptions that the children have will never be challenged and will therefore continue to exist.

Another notable finding associated with his study was the discovery of how the conceptions that children hold can also lead to the misconceptions that they have. For example, children articulated the conception that marbles sink. This understanding informed the misconception children simultaneously held: all glass sinks. This finding was consistent across all content areas and is an important discovery for educators to consider when planning and implementing instruction. “Preconceptions, never having been put on the table, will continue to coexist with a morass of conflicting ideas… and scientific principles that are not addressed, can coexist with ‘what the teacher told us’ and create a mishmash of fact and fiction” (Watson &

Kopnicek, 1990, p. 680). In addition, we also found that children frequently over-generalized their conceptions, which created inadequacies in their scientific understandings. This over-generalization of knowledge is a manifestation of conceptions informing misconceptions.

Implications

Based on the results of this research, the experiences of the researchers as well as prior literature, three areas of implications are specifically addressed. These areas are implications for research, policy, and practice.

Research

There are several research implications targeted for misconceptions and conceptual change. First, further research to identify additional conceptions and misconceptions that young children hold in regard to scientific concepts, skills, and phenomena is warranted. Many research studies address the misconceptions associated with older populations of students, however, little is done in the area of early childhood education. Although this study was successful in providing results associated with young children in the areas of matter, magnetism, density, and air, more research should also be conducted to include other areas of science such as, biological science, physical science, chemistry, Earth science, as well as environmental and ecological sciences.

Second, research to investigate and determine effective instructional methods for identifying misconceptions and promoting conceptual change is also critical. Although research indicates that implementing instructional strategies to help children progress through the four conditions necessary for conceptual change (Posner, Strike, Hewson, & Gertzog, 1982) are promising, specific methods for teaching in such a way are limited. In our research, we found the inquiry process to be effective for identifying the conceptions and misconceptions of young children. Inquiry teaching and learning provided the children with opportunities to discover and begin to address the inconsistencies in their scientific ideas while also providing them the space to enjoy learning about science content, skills, and phenomena.

Once methods of instruction have been identified, it would also be especially useful for researchers to investigate the effectiveness of conceptual change instruction on academic achievement. If the underlying goal of progress made in the area of science education and conceptual change is to have children come to better, more sophisticated understandings of science, it is crucial to investigate the effectiveness of these practices on student achievement.

Finally, we also believe that the misconceptions of preservice and inservice teachers should be investigated. It has been suggested that teachers oftentimes transfer their own misconceptions on to their students, thereby creating additional misconceptions for students that are even more difficult to address (Blosser, 1987; Maria 1997; Watson and Kopnicek, 1990). Therefore, understanding and correcting the misconceptions of preservice and inservice teachers before they begin teaching would be a worthy research endeavor.

Policy

Professional development opportunities and additional preservice and inservice teacher education opportunities are important if we expect teachers to be adequately prepared for teaching conceptual change in early childhood science classrooms. According to the National Research Council (1996), “the process of transforming schools requires that professional development opportunities be clearly and appropriately connected to teachers’ work in the context of schools” (p. 57). Therefore, these opportunities must provide teachers with both the theoretical and practical background knowledge of conceptual change. Specifically, preservice and inservice teachers will need to understand how to identify and address the multitude of misconceptions that children can have in their classrooms. In addition, preservice and inservice teachers will also need to be provided with numerous opportunities and a great deal of support when developing lessons and units designed to create cognitive conflicts which provide children opportunities to confront the inconsistencies in their scientific ideas. Most importantly, if all of these propositions are to take place, preservice and inservice teachers must also have adequate scientific content knowledge in all areas of science. If all of these issues are addressed, educators may then be able to augment their teaching practices to support children in developing accurate and sophisticated understandings of science.

Practice

Both teachers and preservice teachers alike need to understand that children are capable of discovering and constructing scientific understandings, skills, and abilities with deliberate planning of effective instruction. This research provides further evidence to suggest that young children are capable of expressing their ideas associated with science, when they are provided the opportunity to do so. Thus, it is important for preservice and inservice teachers to not underestimate the abilities of their young learners and plan for instruction that addresses conceptual change.

Specifically, preservice and inservice teachers must provide opportunities for children to inquire into the world of science while connecting their prior knowledge with the new information that is to be acquired. Children must experience the dissatisfaction of erroneous ideas so that they can progress toward finding more accurate ways of knowing that are "intelligible, plausible, and fruitful" (Posner, Strike, Hewson, & Gertzog, 1982, p. 214). Teaching science through inquiry may be one potentially valuable avenue for assisting children in moving from misconceptions to accurate scientific understandings. In doing so, preservice and inservice teachers will thereby be employing strategies that support accommodation. In addition to instructional practices, preservice and inservice teachers also need to develop more appropriate evaluation techniques that take into consideration the process of conceptual change.

While making these adaptations to instruction, it is important for preservice and inservice teachers to recognize that "…changes can be strenuous and potentially threatening, particularly when the individual is firmly committed to prior assumptions" (Posner, Strike, Hewson, & Gertzog, 1982, p. 223). Although teaching for conceptual change will take time, it is a worthy pursuit that will indeed assist in achieving scientific literacy for all children (NRC, 1996).

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Appendix

Unit Information

It is important to note that throughout all of the lessons, the researchers were careful not to confirm or deny participant ideas. The goal of this research was to uncover the conceptions and misconceptions held by young children, *not* to teach them scientific content. In addition, within each of the lessons, the research asked the students to justify their thoughts, decisions and responses by giving priority to evidence.

Matter

To begin the lesson, the researchers provided each participant with a variety of rocks and had them describe the rocks to us (i.e. what do they look like, feel like, etc). After listening to student responses, we introduced the word ‘solid’ to the students and told them that the rocks were examples of solids and then asked the participants to provide other examples of solids. Next, we provided the participants with the opportunity to explore a variety of objects that were also solids (i.e Shoe box, brick with holes, solid brick, bucket, water bottle, baskets with holes, foam noodle, marbles, coins, keys, paperclips, sorting bears, crayon, teddy bear, blocks, rubber eraser or dog toy, paper, cloth), however, we didn’t tell then that these objects were solids. Instead, we asked the children to talk about the objects and discuss whether or not they thought they were solids. After listening to student discussions, we then asked the students to create a definition of solid and provide additional examples of solids.

To extend the idea of matter to liquids, the researchers provided the participants with a shallow bowl of water. Children were allowed to explore the water and describe what they were feeling and/or noticing. After listening to student ideas, we then asked the students if this water was a solid and asked follow up questions, which required students to justify their thoughts based on their previous experiences. Next, we introduced the idea of a liquid and told students that water is an example of a liquid. Based on this idea, we then asked students to provide other examples of liquids. We then provided the participants with the opportunity to explore a variety of substances that were also liquids, but again, did not tell them that they were examples of liquids (i.e. Water, milk, half and half, ginger ale, cool aid, oil, syrup, vinegar, soy sauce, juice, etc.). Similar to the solids exploration, we asked students to classify the substances as either 'liquid' or 'not liquid' and then asked the students to create a definition of liquid and provide additional examples.

To conclude the lesson and to determine if students would be able to differentiate between solids and liquids, the researchers provided the participants with a large piece of construction paper with the labels of 'solid' and 'liquid' at the top of the paper. Using this organizer, we asked students to classify a variety of solids and liquids into the appropriate categories. While categorizing the materials, the researchers asked the students to justify their decisions with evidence and attention to the properties of solids and liquids previously discussed.

Magnetism

To begin the lesson, the researchers threw a stuffed animal (with magnetic limbs) onto a magnetic surface so that it would stick. The researchers then asked the students why they thought the animal was able to stick to the surfaces. The participants were allow the opportunity to manipulate the stuffed animal and based on evidence, adjust their ideas if necessary. Te researchers then introduced the idea of magnets to the children and asked them to discuss what they knew about magnets (i.e purposes, appearance, etc). Participants were then asked to discuss what magnets stick to and make predictions about objects around the room that would stick to magnets. Students were then provided with the opportunity to test their predictions by traveling throughout the classroom to determine which objects the magnets would stick to. After children had time to explore, we came back together to discuss findings as a group. During this time, the researchers were sure to have students discuss the things that did stick as well as those that did not. Next, the researchers extended this idea of ‘stick’ and ‘not stick’ typically used by the children and introduced the vocabulary of attract and repel.

Next, the idea of magnetism was further investigated by having the participants discuss if magnets would attract through other things. After a discussion, students were again provided the opportunity to explore this idea within the classroom using, cloth, paper, wood, glass, water, plastic, etc. After children had time to explore this idea, we again discussed findings with attention to the materials that magnets did attract through as well as those they did not attract through.

To uncover the conceptions and misconceptions associated with the poles of a magnet, each participant was provided with two bar magnets. Then were then asked to make observations about their magnets and encouraged to predict what the ‘N’ and ‘S’ on either side of the magnet represented. Next, to assist students in articulating these ideas, we asked questions regarding which poles would attract to each other and prompted students to explore this question with their magnets. After exploring, the students then discussed their findings with the researchers and were asked to explain what they have learned, being sure to give priority to evidence.

Finally, to ascertain if the learning from the exploration could be applied to a new situation, the researchers showed students a demonstration of magnets suspended on a rod. The researchers asked the students what they thought was happening and why. To conclude the lesson, the researchers had the students share their new understandings about magnets as well as their new wonderings.

Density

To begin this lesson, the researchers showed the participants a cork and marble and allowed them to hold and explore the objects. Next, the researchers asked the participants to predict what would happen if we put them both in a bucket of water. After listening to responses, the researchers placed one of the objects in the water and had the students make observations and discuss what happened. Next, the researchers introduced the vocabulary of sink or float and had students use the vocabulary accurately to describe what happened to the object. The participants were also asked to explain why they thought the object sank or floated. This same procedure was followed for the second object then the participants were asked to articulate the difference between the two objects when they were placed in the water. The goal of this conversation was to elicit from students their ideas about why one object floated and one sank, and to determine if the participants noticed any differences between the two objects.

To offer participants an opportunity to apply their ideas associated with density, they were presented with a variety of objects, one at a time, and asked to predict if the object would sink or float. Again, students were asked to justify their thoughts. Following the prediction, participants were then asked to place their object in the bucket of water to determine the accuracy of their predictions. In light of this exploration, the researchers again discussed the results with the participants and required them to provide explanations for what they were observing giving priority to evidence and drawing relationships between and among the objects.

Expanding on these basic ideas, the researchers then provided the participants with another exploration with density cubes and clay. First, the density cubes are cubes that have the same volume but different weights. To begin, the participants were presented with the cubes and provided the opportunity to manipulate the cubes to observe their properties. Similar to the previous explorations, students were instructed to discuss their predictions regarding how the cubes would behave when placed into the water. Next, the students placed the cubes (one at a time) in the water, made observations and discussed happenings. Again, the researchers discussed the results with the participants and required them to provide explanations for what they were observing giving priority to evidence and drawing relationships between and among the objects.

During the clay exploration the researchers provided the participants with a ball of clay and asked them to predict if the clay would sink or float. Similar to the above procedures, these predictions were discussed. Next, the students placed the clay in the water, made observations, evaluated the accuracy of their initial predictions, and discussed happenings. Again, the researchers discussed the results with the participants and required them to provide explanations for what they were observing giving priority to evidence and drawing relationships between and among the objects. The participants were then asked if they thought there might be a way they could make the clay float and were then provided time to explore this question. When students finished molding the clay, they were then asked to place it in the water. The students then discussed their observations with the researchers and were allowed additional time for alternative designs of the clay if needed. After all children were able to successfully float their clay in the water, the researchers asked the participants why the clay was floating if we didn't change the original amount of clay. Within this discussion, students were encouraged to justify their thoughts and to make connections to the previous investigations (i.e. density cubes). Using this connection, the participants were then asked to discuss how the heaviest density could possibly be manipulated to float.

To conclude the lesson, the participants were shown a picture of an aquarium with objects that were floating and sinking and were asked to discuss their observations of the aquarium. Participants were encouraged to discuss why some objects were sinking and others were floating. To elaborate on this idea, participants were then asked to explain how we could get the objects that were floating to sink. Participants discussed their thoughts with the researchers while giving priority to evidence and then were asked how the objects that were sinking could be made to float. Again, the participants discussed their thoughts and related their ideas to evidence from previous explorations.

Air

To engage students in the air lesson, the researchers showed students a paper bag full of random items and told them that we were going to investigate the objects and materials inside the bag. Students were then asked to predict what might be inside of the bag. One by one, the items from the bag were removed and identified. When the bag was "empty" the researchers asked the students if there was anything else in the bag and required them to justify their thoughts. When the students arrived at the idea that there was only air left in the bag, we then discussed with the students how they are able t tell if air is inside of a bag or another container. To uncover the answer to this question the participants were provided with experiences to investigate air on their own.

The first of these investigations involved providing the participants with a zipper seal bag and a straw and were encouraged to see what they could discover about air. Specifically, participants were instructed to blow into their baggies and observe what happens. Throughout the exploration, participants were encouraged to discuss and describe what they were doing and how air was being used. After participants completed their investigations, the researchers revisited the initial question: How can you tell when air is in a bag or another container? Participants were required to use evidence from their explorations as a way to justify their thoughts. To conclude this portion of the lesson participants were asked where else they have seen or felt air.

Next, the students explored air through the use of parachutes. To begin, the participants were asked what a parachute was, if they had ever seen one, and if so, where. Participants were then asked how they thought a parachute worked. To encourage students to elaborate, the researchers, when necessary, asked the participants how air was involved in moving a parachute. To extend this idea, the participants were provided with parachutes and were asked to release them and observe how they move. After investigating the parachutes, the participants then explained and discussed what was happening and why they thought it happened. The researcher then posed another question to the participants: what do you think will happen if we add a 'passenger' to the parachute? Again, a brief discussion about the associated predictions took place and the participants were once again provided the opportunity to explore this question. After all investigations had concluded, the researchers conducted a discussion with the students to discover how they thought the 'passenger' impacted the way the parachute worked.

To conclude this portion of the lesson, the researchers discussed with the participants what made the parachute fall slowly and asked them to compare the differences between flying one and two 'passengers.' Within this discussion, the researchers were attempting to ascertain where the students recognized the presence of air. Finally, the participants were asked to predict what would happen if we took the parachutes outside or home and a discussion was conducted around the following questions: Would the parachutes move differently? What role would air play in making the parachute move outside or at home? Where can air be found?

The next portion of this lesson centered around the use, production, and movement of bubbles. To begin, participants were shown a bottle of bubbles. They were then asked what they thought it was and how they might use it. The researcher then blew a bubble and asked: What is inside a bubble? Can you see it? What is outside a bubble? Can you see it? What moves a bubble around? The researchers then explained to participants that, although they cannot see the air, they could use bubbles to see where the air is moving. In light of this idea, the participants were then asked to explain how they thought air was moving in the classroom. To assist them in their ideas, the researchers blew more bubbles, required the students to make observations and then asked students to elaborate on their thoughts using evidence. To extend this idea, the researcher provided time for the participants to investigate the following questions: How can you use bubbles to show if air moves around corners? How can you use bubbles to show where the air moves fastest? How can you use bubbles to show where the air moves slowest? How can you use bubbles to show how air moves in a doorway? The participants then discussed their findings and provided justification using evidence from their investigations. To conclude, the researchers asked the participants what bubbles had to do with air and what bubbles could tell you about air. Additionally the participants discussed what they had learned about air and then drew a picture to illustrate their learning.

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