Part I – The Research

Much research has been conducted on student-held misconceptions in science education, focusing on identifying both specific misconceptions and the sources of these misconceptions. Research has found that these misconceptions can be derived informally, from experience and interaction with one’s environment and family members or peers, or formally, from instruction (Guzetti et al, 1993). According to Zwiep (2005), in science education, misconceptions are those “private understandings [which] differ from the accepted scientific theory on the phenomenon” (p. 19). These misconceptions often create barriers, causing a student to have difficulty in, or to be unwilling or unable to learn and comprehend scientific instruction. As a result, many methods and theories have been developed to address these misconceptions and lead to conceptual change in students. (Allen & Coole, 2012).

In order to engage in conceptual change, the students must first accept that they hold misconceptions and become dissatisfied with them. This, however, is a difficult process (Watson & Konicek, 1990). According to Watson and Konicek (1990), there are four barriers that inhibit students from addressing their misconceptions and engaging in the process of conceptual change. These barriers
are: (a) stubbornness, (b) language and vocabulary, (c) perception, and (d) developmental level. A stubborn student refuses to admit their theory might be wrong and may often adhere to a certain confirmation bias viewpoint when analyzing experiments or scientific data, thus creating a barrier to his learning and acceptance of science. Furthermore, scientific terms and vocabulary may be too difficult, causing a student to be unable to simultaneously learn both the new language and new concepts. Additionally, a student brings his own experiences into the classroom. His perception may have reinforced his misconceptions, leading him to believe that what he has seen and felt must be correct, and ignoring the inconsistencies and incompatibilities of these beliefs with science. Finally, the student may not be at a developmental level appropriate to the concepts and information being taught. For example, he may still be in the sensory or concrete levels of development and is not able to reason in an abstract manner (p. 682-3). Therefore, it is suggested that instruction must always begin with concepts appropriate to a student’s developmental level (Zwiep, 2005).

Misconceptions established through observation are generally the most difficult to eradicate because they have been, essentially, proven to the observer to be true. Watson and Konicek (1990) found that the personal experiences that students bring to learning situations have a profound affect on their “willingness and ability to accept other, more scientifically grounded, explanations of how the world works” (p. 682). It is important that teachers keep in mind that based on a student’s experience, developmental level, and cognitive processing, these views
seem valid because they have enabled the student to make sense of the world (Zwiep, 2005).

After identifying students’ misconceptions (through questionnaires, interviews, or informal assessment, etc.), a teacher must address these misconceptions in a constructive way (Zwiep, 2005). How teachers address their students’ misconceptions is incredibly important, because, “although students may recognize a mistake once they are corrected, students may not understand or even accept why their misconception is an incorrect view” (Zwiep, 2005, p. 19). Students may prefer to hold on to their misconceptions and reinterpret the meaning of instruction to fit their ideas (Zwiep, 2005). Furthermore, students may simply regurgitate the correct response in order to please their teacher, but continue to place value in their inaccurate beliefs (Watson & Konicek, 1990).

In response to the prevalence of scientific misconceptions, researchers and educators have established methods of instruction in which to enable conceptual change. One such method is the Conceptual Change Model. In the six stages of the Conceptual Change Model, students: (a) become aware of their own conceptions in the beginning of the instruction by thinking and making predictions before activity begins; (b) expose their views by sharing them in small groups; (c) confront their views by checking and discussing them in groups; (d) work to resolve conflicts between their ideas and their observations in order to accommodate the new concept; (e) extend the concept by trying to make connections between the concept learned in the class-room and other situations, including their daily lives; and (f) are encouraged to go ahead, pursuing extra questions and problems related to the
concept (Costu et al., 2007, p. 525). In the Conceptual Change Model “the learner is an active participant in the learning context, rather than an empty cup to be filled” (p. 525).

Another method of conceptual change is The Learning Cycle (Guzetti et al., 1993) of concept acquisition. The Learning Cycle is composed of three phases: (a) exploration, (b) term introduction, and (c) concept application. In the first phase, exploration, students learn, with little direct instruction, by experimenting and manipulating new materials and ideas, coming up with their own questions that cannot be answered by their established knowledge base. In the second phase, term introduction, with intervention and guidance from the teacher, students organize the data they have discovered, learn terms and definitions, interpret learned information, and link new and old concepts. Finally, in the third phase, concept application, students reflect on what they’ve learned, extend and apply new concepts and ideas, relate new concepts to their own experiences, and explore further applications and situations (p. 145-6).

There are many methods for conceptual change instruction, but the main themes, as exemplified with the Learning Cycle and the Conceptual Change Model, are to place the students in a situation in which their misconceptions are challenged, to give them opportunity to explore the scientific concept, to present the content in an accessible way that satisfies their need for an answer, and encourage them to pursue and apply the concept in ways relevant to their lives. While teaching new concepts and encouraging their students throughout the process of conceptual change, teachers must accept their students’ misconceptions as viewpoints that are
based upon their observation of the world and have held valid for the students thus far. And, finally, in order to successfully engage their students in the process of conceptual change, teachers must teach to their students’ developmental level. Taken together, all of these components allow for comprehensive education, developed understanding of scientific concepts, and the disassembling of misconceptions.
Bibliography


Part II – The Interview

The student I interviewed, Student S, is in 3rd grade. His teacher identified him as a student of average performance. The class was just beginning a unit on the states of matter and changes in matter. I chose to interview the student on these topics for several reasons: First, because they are sometimes abstract concepts that students have difficulty with. Second, because they were concepts that were already on his mind. And third, because the students had only a few days of experimentation thus far and explicit instruction in these topics had not yet begun.

E.M.: Can you tell me what matter is?
Student S: Stuff.
E.M.: Tell me more.
Student S: I think it’s everything.
E.M.: There are three states of matter. Can you tell me what those are?
Student S: Liquid, solid, and plasma.
E.M.: Can you give me some examples of one of the states of matter?
Student S: Water is an example.
E.M.: Which state of matter is water?
Student S: Liquid.
E.M.: As a liquid, what are some of the properties of water?
Student S: It can be snow or sleet or hail.
E.M.: OK. Think of properties as being the same as characteristics. Can you tell me more about the properties of water?
Student S: You can drink it or wash stuff with it. Animals drink water.
E.M.: You said water can be hail. Is hail a liquid?

Student S: No. I think it's a solid.

E.M.: How can a liquid like water become a solid?

Student S: With really cold temperatures. It can freeze.

E.M.: OK. Now, I know you've talked a little bit about evaporation in class. Can you tell me what happens to water when it evaporates?

Student S: It goes up into a cloud.

E.M.: Does it remain a liquid?

Student S: I think so.

E.M.: Can you explain?

Student S: No.

E.M.: Are clouds liquid or solid?

Student S: Clouds are made of matter.

E.M.: What about the planet earth? Would you say our planet is liquid or solid?

Student S: The earth is solid and liquid.

E.M.: Tell me more about that.

Student S: Well, dirt can be hard, but mud is not. There is also water on the planet. But mountains are hard.

E.M.: Would you say that being hard is a property of a solid?

Student S: Yes.

E.M.: Can you tell me any other properties of solids?

Student S: You can hold it in your hands. Not like water.
E.M.: Has anything you’ve learned about matter really surprised you?

Student S: Air bubbles can form inside water while it evaporates.

E.M.: Do you know what creates those air bubbles?

Student S: No.

Based on this interview, I learned that Student S has some understanding of the states of matter as well as of its ability to change states. Many of the gaps in his knowledge will be filled in as the class progresses through the unit. I know the class covered the three states of matter, but his response “liquid, solid, and plasma,” was not entirely correct. I do not think of this as a misconception about matter, but rather an inaccuracy in recall. However, the concept of gases, specifically with water vapor, is a very abstract and difficult to grasp concept for 3rd graders. Students can’t see it or hold it, so how can they understand it?

When asked about the properties of liquids, using the example of water, Student S gave examples of water in its solid state, “snow, sleet, and hail.” However, based on a follow-up question, I know that (a) he understood water in its frozen state is a solid, and (b) water in its liquid state can be imbibed. As far as his understandings of the properties of liquids and solids, that will become clearer as it is covered in classroom instruction.

In an attempt to juxtapose the make-up of a cloud with that of the earth, I asked an ill-formed question, “is the earth solid?” Student S's response, however, showed an understanding of the earth and that both solids and liquids are found on earth’s surface. Furthermore, while Student S failed to produce one of the three states of matter studied (gases), he did mention plasma, which is included as a
fourth state of matter in later explorations of matter, but is not usually discussed that the early elementary level.

I found no major misconceptions in Student S’s understanding of the states of matter and phase change, only gaps in his knowledge that I believe can be filled with direct instruction, experimentation, and observation.

Resources:

C-Mapp, Grade 3 Science Course Guide

http://www.onlineschools.org/library/kidsmatter/

http://www.grc.nasa.gov/WWW/K-12/airplane/state.html

http://www.helium.com/items/1956264-misconceptions-about-matter

Part III – The Application

For students at the elementary level, it is difficult to conceptualize vapors and gases, even while students understand the concept of liquids and can begin to differentiate between different types of solids. For this reason, instruction on matter must begin at a very concrete level and keep pace with the students’ developmental levels (Zwiep, 2005). The subject of states of matter is one that is revisited throughout the grade levels at both the elementary and the secondary level. It is necessary to provide a foundation for future exploration of the states of matter and instruct in accordance to students’ developmental levels and concept readiness.

First and foremost, experimentation and exploration are great ways to start the instruction of matter. Because water is a readily available resource and can take a solid, liquid, or gas form, it is often used in examples of the different states of matter as well as of phase change. Student S had inconsistencies and gaps in his knowledge when it came to the states of matter. In order to address these inconsistencies and knowledge gaps, while designing an instructional plan, I would make sure to couple direct instruction with frequent observation, interaction, and experimentation with the various states of matter and phases of change.

I could manage this at first with water by freezing it and showing it in its solid state; allowing it to melt and return to it’s liquid state; and boiling it to show its change of phase into water vapor. While discussion of matter at the molecular level is explored in more depth at the secondary level, these experiments would allow me to have a discussion with my students about the temperature and density of the water and how that relates to the state it takes.
I found the discussion of students’ developmental levels to be insightful when it comes to misconceptions and the flexibility to undergo conceptual change. According to Piaget’s theory of cognitive constructivism, it is not until the formal operational level, at approximately 11-years-old, that a child can begin to think logically about abstract concepts (Atherton). In consideration of this developmental model, I must be sure to present my students with dynamic instruction that engages their senses and presents knowledge and science in a concrete way.

At the 3rd grade level, evaporation and condensation are two concepts that are adjunct to the discussion of phase change in states of matter. Student misconceptions about these concepts are common. In observing condensation form on a glass in which ice is melting, students commonly believe that the water has spilled over the side or is leaking through the cup. One way to address this misconception is to put dye in the glass and observe how the water on the inside of the glass is colored, while the condensation is not colored (C-Mapp, Grade 3 Science Course Guide).

By basing instructional design on the developmental level of the students, the material will be accessible and comprehensible to the students. Therefore, if ample time for students to explore the properties of states of matter is allowed, and direct instruction coupled with experimentation and observation is supplied, and lessons are always followed up with productive questioning and discussion, students should have the support they need in order to be able to comprehend the topic area of the states of matter.
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