Alternative Conceptions

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Abstract
In lieu of an abstract, below is the first paragraph of the paper.

Today's student may be very different from the students who came through schools many years ago; however there is one thing that unites them all, alternative conceptions. In every subject there are false ideas that are believed to be true. Why? Human nature. It is our nature as human beings to understand how everything fits into place. These understandings will consist of whatever makes sense to us. Everyone on this planet makes assumptions about the way the world works; these assumptions are a way to ease the frustrations of living in a complex world. We must remember that assumptions are assumptions, and nothing more than someone inventing an idea that attempts to explain misunderstandings. These alternative conceptions often lead to inaccurate concepts that can prevent further learning on the subject.

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Today's student may be very different from the students who came through schools many years ago; however there is one thing that unites them all, alternative conceptions. In every subject there are false ideas that are believed to be true. Why? Human nature. It is our nature as human beings to understand how everything fits into place. These understandings will consist of whatever makes sense to us. Everyone on this planet makes assumptions about the way the world works; these assumptions are a way to ease the frustrations of living in a complex world. We must remember that assumptions are assumptions, and nothing more than someone inventing an idea that attempts to explain misunderstandings. These alternative conceptions often lead to inaccurate concepts that can prevent further learning on the subject.

Children enter the scientific world long before they enter a classroom; every kid in the backyard digging a hole is entering the world of science, whether they know it or not. Engaging in this activity alone raises many questions about how the world works. Questions such as: What makes it rain? What is dirt made out of? How do plants grow? Etc. Many times the child will go to his or her immediate answer for everything. The parents. Sometimes the parents know the answer to these 'basic' science topics, many times they do not. This is where assumptions and guesses are introduced. Assumptions that are logical and reasonable to the learner are explored and explained in a manner that make sense, and then understood as the truth. These assumptions quickly become beliefs, and in turn alternative conceptions. “If misconceptions are learned early on, a stable but incorrect view of the world may result” (Nelson 1992).

“Assumptions, even assumptions that seem logical and reasonable, can make it difficult or impossible for people to understand scientific concepts” (Eaton 1984). The child digging the hole in the back yard begins to understand that it rains when dark clouds arise, this in turn gives him the idea that when dark clouds come, the rain falls through holes in the clouds. He assumes that the clouds are supposed to hold water in, but when they get holes in them it falls to earth. This belief is held closely, and for the moment it explains why it rains and brings relief to the child in a confusing world. Because the child will not be introduced to a scientific explanation until high school science, this explanation will most likely be his understanding until then. This describes one possibility on why children's conceptions about the world are sometimes quite different from scientific conceptions.

Children hold on to massive amounts of alternative conceptions in school, Science is no exception. Some of these alternative conceptions are as old as the theory of spontaneous generation, while others arise every day with new studies. Mr. Michael Bonadonna of Brighton High School reports a finding of a dozen or so alternative conceptions that he repeatedly sees from year to year, (Bonadonna 2009). The most common alternative conceptions found in a high school science classroom involve evolution, astrology, and changes of matter. A frequent alternative conception that is often overlooked includes the concepts involved in the water cycle. These ideas are often introduced in elementary science, yet the assumptions are not completely erased and the child does not learn what is scientifically accepted.

Literature Review

Today's instruction methods are having a strong push towards a constructivism approach. “Students should construct their own knowledge” is being reverentially chanted throughout the halls of many schools these days” (Duffy 1996). Constructivism urges that students create their own understandings, based on the interaction of what they already know, and the ideas that they come into contact with (Richardson 1997). Constructive learning allows for deep understanding of topics, because it allows for students to dip back into previous knowledge and build on it. The role of students' pre-instructional conceptions is important in learning (Duit 1995).

Science learning is often referred to as a memorization topic, while factual knowledge is easy to learn for an examination, it is much more difficult to understand these facts (Duit 1995). “Students might be able to provide the names of animals and plants ... or to provide key examples when presented with formulas. However, there very often is no deep understanding behind the façade of stored factual knowledge” (Duit 1995). Teachers often describe students as “they had memorized everything, but they didn't know what anything meant” (Feynman 1985). Constructivism allows students to build upon prior knowledge, but what if that prior knowledge is
an alternative conception? Since the early work of Piaget researchers have been aware that children's ideas of how the world works are very different from the scientifically accepted concepts. These explanations are based on experience and common sense (Eaton 1984). Misconceptions provide quick and superficially reasonable explanations (Nelson 1992). “At all ages students hold conceptions about many phenomena and concepts before these are presented in science classes ... However, these conceptions are not in accord with science concepts” (Duit 1995). Two explanations for this are expressed: first, students are satisfied with their own conceptions and see no value in learning another idea, and second, a new concept is seen through the old understanding, and because it does not correlate, the new concept is not understood (Duit 1995). The first explanation, which describes students not wanting to learn a new concept, can be correlated with psychological description of people’s beliefs.

Social psychologists have empirically studied people’s tendency to cling to cherished beliefs, even in the face of a mountain of disconfirming evidence, known formally as confirmation bias. Once a belief is established, people will actively seek out information that supports it. If confronted with mixed evidence, people will give greater weight to information that supports their belief while discounting contradictory information (Hanes 2009).

The water cycle holds many alternative conceptions within it. “Water is a commonly used example of the solid, liquid, and gaseous states of matter. The properties, along with the phase changes between them, are complex and easily misunderstood” (Fries-Gaither 2008). Younger students tend to focus on the properties of water, while older students lean more towards functions of water (Henriques 2000). This is a list of some of the most common alternative conceptions involving the water cycle:

- The water cycle involves only freezing and melting water
- Water only gets evaporated from oceans or lakes
- When water boils and bubbles come up the bubbles are air
  - The bubbles are oxygen or hydrogen
  - The bubbles are heat

- The white substance coming from boiling water is smoke
- Steam is hot air
- Hydrogen and oxygen are separated during boiling and recombine to form water in the air
- Water in an open container is absorbed by the container
- Water in an open container changes into air and disappears
- Condensation on the outside of a container is water that seeped through the container
- Condensation is when air turns into a liquid
- (List from Henriques 2000 and Fries-Gaither 2008).

“The science education community generally accepts the idea that students enter the classroom with their own understandings of the world. These understandings are often at odds with the scientifically accepted view of the world,” (Henriques 2000). Teachers must be aware of these misconceptions, and be able to adapt their instruction to fit their teaching style (Fries-Gaither 2008). Existing misconceptions must be eliminated before new concepts can be learned. This is a difficult, sometimes impossible task (Philips 1991). When teachers know what their students are thinking about science, they can implement activities to challenge these false ideas (Henriques 2000).

Methodology

Alternative conceptions in the classroom are not solely present in the science classroom, they arise in every subject. In order to address these false ideas we must first find out what they are. Finding out what exactly students think can be tough due to the distractions in any given environment. In the classroom environment verbal and non-verbal cues can quickly influence the authenticity of children’s responses (Bell and Osbourne 1981). A one on one interview can help avoid some of the distractions that arise in a regular classroom and help get down to what the student truly believes.

Interview may be the wrong term, however. The meeting, as we will call it, must be conducted in a manner that is comfortable for both individuals and depicts a conversation, not an interrogation. “When teachers interact with students individually, they often unconsciously lead them through a series of questions,” (Bell and Osbourne 1981). This
questioning develops into an oral examination of the student’s knowledge, not a conversation. The purpose of the interview must always remain in the interviewer’s mind in order to discover what these alternative conceptions are. It is not the job of the interviewer to teach, but to learn.

In an effort to gain experience with the alternative conceptions involved in the water cycle, a meeting was set up with a local tenth grade high school student, we will name her Caroline. Caroline was picked at random from Wayland-Cohocton Central School, based in Wayland, New York. She had finished Earth Science only one year before the meeting, where these particular concepts are emphasized. Caroline was also sixth in her class, which has an average of 150 students per grade year. Caroline was forewarned of the meeting, but was given no indication of what the meeting would consist of. She was not informed of any information before the meeting; however she was informed of the answers after the meeting.

The questions were broken down into three main sets, each having to do with a situation in where the water cycle is interpreted and asked to be drawn. (These drawings are included in the results) Each situation has its own set of questions; however other situations were introduced when Caroline began to explain situations. Therefore some of these original questions referred to abstract concepts of the water cycle. These allowed us to truly comprehend what Caroline understands about these subjects. The original questions that were taken into the meeting are as follows:

1. Topic one: the basic cycling of water
   a. Do you know what the Water Cycle is?
   b. Can you draw it for me?
      i. Depending on the drawing several other questions can be asked
   c. Can you label the parts of the drawing for me?
      i. Looking for evaporation and condensation
   d. Where in the picture does evaporation and condensation take place?
   e. Where does water evaporate from?
   f. Where does water condensate?

2. When boiling water...
   a. What is the white substance coming out of the water?
   b. What are the bubbles in the water?
      i. What are they composed of?

3. What would happen if you left a cup of water out in a room?
   a. What is happening when you leave a cold drink sitting on a counter top?
   b. Why is there water on the outside of the drink?

As stated before, these were the questions originally taken into the meeting; other questions were raised as interesting topics came into light.

Setting
The meeting took place in the kitchen of Caroline’s home to encourage a relaxed environment. This setting also made it difficult to get a good quiet meeting because of a few outside interruptions, but the information we were looking for was not inhibited by these interruptions.

Results

Question Set 1
Interviewer: Do you know what the water cycle is?
Caroline: Yes
Interviewer: Can you draw it for me?
Caroline: Yes
The drawing is made, complete with descriptions of what is happening (drawings attached)
Interviewer: So where is this water evaporating from?
Caroline: The water
Interviewer: Just the water, not from the tree at all?
Caroline: Maybe
Interviewer: Maybe?
Caroline: I don’t know, I don’t know why it would evaporate from a tree
Interviewer: So would you classify this body of water as a lake?
Caroline: Yes, the water evaporates from the lake up into the cloud
Interviewer: And then what happens?
Caroline: Then it rains, into the lake
Interviewer: Say this was a mud puddle; would the water evaporate from the puddle?
Caroline: Yes
Interviewer: So any flat body of water involves evaporation?
Caroline: Yes
Interviewer: What about a creek or stream?
Caroline: yea (ponder) yea it would
Interviewer: So where does water really evaporate from?
Caroline: Any water
Interviewer: Any water, but not plants?
Caroline: Probably
Interviewer: Ok, do you remember where you learned this?
Caroline: Earth Science

Caroline confidently answered when asked if she knew what the Water Cycle was, and agreed to draw it. Her drawing immediately led into the next question. She was able to label evaporation and precipitation, and also said that water absorbs into land, and drew an arrow to the roots of a tree. However when asked where water evaporates from, she answered the body of water, or a lake. She was not sure whether it evaporated from the tree or plants in general. She answered the question several times with an “I don’t know, probably.”

Caroline was very confident in saying that water evaporates from any standing body of water, and also a stream or creek. She was very sure that water evaporates from any water, yet was uncertain of whether it does from plants. She repeats a “probably” answer but will not answer yes or no. When asked where she learned this, she replied “earth science” which was a course taken only one year prior to the interview.

**Question Set 2**

Caroline is now confident that evaporation takes place from any water, but seems confused on other parts of the cycle. The next set of questions deals with an open glass of water, which leads into a close look at condensation.

A drawing of a glass with water is made for this series

Interviewer: Does water evaporate from this glass?
Caroline: Yes
Interviewer: If I put a real glass of water out on this table right now, what would happen?
Caroline: It would start evaporating
Interviewer: Would it eventually form a cloud in this room, like your previous drawing?
Caroline: No
Interviewer: Why not? Does water precipitate back down?
Caroline: The water precipitates back down on the side of the glass
Interviewer: So if I went and got that glass of water, it would evaporate and precipitate back down on the side of the glass?
Caroline: Not immediately, but yes
Interviewer: Why?
Caroline: I don’t know... I don’t know

Interviewer: But you do know that water does get there?
Caroline: Yes, well water rises up and accumulates at the top of the glass and drips down the side
Interviewer: How did you know this?
Caroline: I thought about it, educated guess

Caroline accurately states that the water in the glass will evaporate, but gets confused when I ask where the water goes. She states that a cloud would not form in the room over the glass, but goes into her own explanation of how water arises on the outside of the glass. She states that “water accumulates on top and drips down the side of the glass.” This statement completely disagrees with her former standpoint, which stated that a cloud does not form on top of the glass. On the drawing you can see faintly the lines drawn which show the water evaporating, rising to the top of the glass, accumulating, and then dripping down the side of the glass.

She now had an “understanding” of how water appears on the outside of an open glass. To have her explain this theory in more depth a new set of questions were raised that would force her to put this theory to the test.

Interviewer: So let’s say you were down at the beach, and you went to a soda machine to get a cold drink, would there be water dripping down on the side of that cold soda?
Caroline: Yea I guess so
Interviewer: well how did that water get there, if there is a cap on the soda?
Caroline: it, must go through, the plastic
Interviewer: It just seeps through the plastic?
Caroline: yea
Interviewer: So in a closed bottle, the water seeps through, but in an open glass it accumulates at the top and drips down?
Caroline: Yes
Interviewer: Did you learn that it Earth Science?
Caroline: no, I just figured it out

Caroline was now very confused, she did not know how to respond when the closed bottle revealed the same water on the outside of the bottle as the open glass did. Her theory fell apart with the cap on the soda bottle. With this contradiction she was forced to introduce a new theory that applied only to bottles with caps. The water in the soda “seeps” through the plastic to the outside of the container. Her theory now states two different
ideas: One that explains open glass water evaporation and condensation, and a new “seeping” action that occurs only in plastic bottles.

When Caroline was asked how she knew this, her reply was “I thought about it,” and “it was an educated guess.”

Question Set 3
A drawing of a boiling pot is made for this series

Interviewer: When you boil water, what happens?
Caroline: When the water boils, it evaporates, and then at the top of the counter above it, it accumulates, and drips down
Interviewer: Ok, can you explain what is going on down here (pointing to the bottom of the pan) where the bubbles arise?
Caroline: There are air molecules, and the collect to bubble up
Interviewer: The air molecules come up?
Caroline: yes
Interviewer: ok, we know that water is made up of two H’s and one O right?
Caroline: yea
Interviewer: and is a liquid, so in chemistry terms what is happening?
Caroline: The oxygen pops up
Interviewer: well what happens to the hydrogen?
Caroline: They bind, to other stuff
Interviewer: They bind to what?
Caroline: I don’t know
Interviewer: well what happens to the oxygen?
Caroline: they bubble out, I mean I’m sure the hydrogen come out too, I just don’t know how
Interviewer: so hypothetically, someone could breathe in the steam of boiling water and live on it alone?
Caroline: Well, yea I guess
Interviewer: Did you learn this in Earth Science?
Caroline: Probably

At this point Caroline is inventing ideas to explain what is happening, she is confident in saying that she learned this the previous year, but either does not remember, or did not properly understand the information enough to recall it. She now feels that she must have a ‘complete’ water cycle in every instance. The beginning explanation of boiling water included a counter top that allows for the steam to drip back down. This is possibly due to personal experience, but also possibly from the previous explanations involving both evaporation and condensation of water.

Caroline described the bubbles in the boiling water as “air molecules.” When prompted what is in the “air” she responded oxygen. Caroline did not have a reasonable explanation for the disappearance of hydrogen, though. She said that the hydrogen “probably come out too” but could not explain any process. This raised another abstract question, “could someone breathe in the steam of the boiling water and live on it?” She responded with a yes, but did show a confused on her face. Caroline does not understand the process of boiling water.

After the interview Caroline was very confused. When the camera was turned off she said that she was “embarrassed” because she felt as though she should have known these answers. The concepts were then explained to her and she said that she felt “dumb.” Caroline commented “I thought I knew what the water cycle was, but instead I just knew the idea of the cycle. The different components of it make sense now, but in the meeting I felt as though I should have known them, but didn’t.”

Analysis
The alternative conceptions that arose from this meeting are very common in classrooms throughout the country. From the twelve conceptions earlier listed in this paper, Caroline accurately stated six of them, these included:

- Water only gets evaporated from oceans or lakes
- When water boils and bubbles come up the bubbles are air
- The bubbles are oxygen or hydrogen
- Hydrogen and oxygen are separated during boiling and recombine to form water in the air
- Water in an open container changes into air and disappears
- Condensation on the outside of a container is water that seeped through the container

These answers correctly acknowledge some of the misunderstandings high school students have about the Water Cycle. While Caroline immediately responded that she knew what was involved in the cycle, she did not know specifics. She did know that the cycle involves Evaporation and Condensation, the two main points of the cycle. However the unknowns were subject to assumptions and reasonable conclusions, all of which were false.
Caroline understood that water evaporates from a glass left out on the table, probably because she has witnessed this happen in real life. How this happens though she does not really understand. She took previous knowledge, which is that the water cycle involves evaporation and condensation, because we were having a meeting on the water cycle she included those words and pieced together what made sense to her. This is a list of her probable construction of an answer to this question:

**Interviewer: What happens to the water in the glass?**

**Caroline's predicted train of thought:**

**What I Know**

1. Water evaporates from standing water
2. Water is found on the outside of glasses most times
3. Water condenses in clouds and falls down

**What I Predict**

*Caroline:* Water precipitates back down the side of the glass after evaporating.

Caroline took what she knew about the subject and made the best explanation possible, sounds very familiar to a learning concept addressed earlier: Constructivism. Learning is the process of converting previous knowledge into further knowledge. Assumptions are made based upon what people already know, and whatever else makes sense to them. When Caroline did not know an answer she took what was already addressed and believed to be the truth and built on it in order for the problem to work out for her to understand.

It is said that people will only understand what they believe, and for students this is no exception. If a student does not "buy into a topic" he or she most likely will not understand it in the end. The child in the back yard will already have an understanding of how the world works and it will make sense to him, teachers must have a plan to approach this. It is necessary for teachers to be able to explain topics in several ways so that every student understands the logical science behind them. It is the job of the teacher to leave the student with all the tools necessary to construct knowledge. In order to do this, teachers must understand how students learn, the alternative conceptions students hold before they enter the classroom, and why these alternative conceptions are understood.

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**References**


