Eighth Grade Students' Understandings of Groundwater

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ABSTRACT

According to national standards, eighth graders should possess appropriate understandings regarding groundwater and its role in the hydrologic cycle. This study identifies what types of ideas eighth graders actually possess, providing invaluable information for high school and post-secondary science teachers in addressing students' prior conceptions. Students completed surveys composed of one multiple-choice item and one drawing prompt. The multiple-choice items were scored using a rubric and each drawing was analyzed for evidence of understanding of groundwater formation, movement, and storage. Class discussions regarding a groundwater model were videotaped, transcribed, and coded. Results indicate students hold naive conceptions concerning groundwater, however, the natures of those conceptions are not easily recognized due to students' conflicting use of vernacular and scientific language. Additionally, students' spatial reasoning plays a significant role in the development of their conceptions of groundwater as they construct mental models of materials and environments directly unobservable with the naked eye.

Students' understandings of complex scientific concepts often involve notions that drastically diverge from those held by the scientific community. Eliminating conceptual disparity between the public's understandings and those of scientists is a constant challenge for science educators. Groundwater and its related concepts serve as a good example of an area where teachers struggle to assist students in constructing understandings that more closely resemble those held by scientists (Meyer, 1987).

According to the National Science Education Standards (NSES) eighth graders should possess appropriate understandings regarding groundwater and its role in the hydrologic cycle (National Research Council, 1996). Most state standards are modeled after the NSES and textbook companies make financially conscious efforts to incorporate content that adheres to those standards. Consequently, most school systems provide formal instruction on the concept of groundwater by the eighth grade. In North Carolina students are required to obtain an earth/environmental science credit for graduation from high school. So what types of ideas do eighth graders take with them to high school and perhaps beyond?

Background

Few science education studies, involving K-12 students deal explicitly with students' understandings of groundwater formation and movement. One potential reason involves the historic focus of K-12 science education on Biology, Chemistry, and Physics (Kusnick, 2002). Studies that include groundwater have generally done so in the context of the water cycle or surface freshwater concepts (Bar, 1989; Mattingly, 1987), and then only as an minor, ambiguous component of these other systems.

Those teaching hydrology courses in post-secondary contexts usually provide the literature that exists on student groundwater conceptions. Many of these educators view teaching groundwater related concepts to introductory geoscience students as a difficult proposition (Trop, 2000; Rimal, 2000). The difficulty may be due, in part, to the typically didactic, theoretical-based approach employed in instruction, an approach typified by a wealth of mathematical equations and few opportunities for practical exploration or visualization (Lee, 1998). However, efforts are continually being made to develop instructional strategies and tools to better assist students in understanding groundwater concepts (Luft, 2001; Rich, 1997; Rose, 1997; Renshaw, 1998; Carlson, 1999; Nicholl, 2000; McKay, 1999; Gates, 1996).

Deeply held naive conceptions also interfere with groundwater instruction. Such conceptions develop from formal instruction and emerge from errors or misleading representations in texts, lectures, and inappropriate or misapplied practical experiences throughout the student's history. Wampler (1996, 1997, 1998, 1999, 2000) illustrates this point by regularly publishing articles that illuminate subtle naïve conceptions about groundwater found in popular textbooks. Science teachers unfortunately demonstrate the ability of lectures and laboratories to give birth to these conceptions by conveying misinformation or unconnected pieces of appropriate information (National Research Council, 1997). Newspapers, movies, discourse with friends and family, and personal experiences, all provide additional sources of naive conceptions. Embedded in both of these formal and informal learning environments is a cadre of words and phrases used at times as metaphors and other times as actual descriptors. Meyer (1987) notes several such words including: "pools", "lakes", "rivers", "streams", and "veins". These words used as descriptors rather than metaphors usually imply the idea of groundwater as a contiguous body, a notion many of us encounter regularly in our instruction.

Students construct understandings of groundwater from different sources, many of which potentially fuel naive conceptions. Science educators must assist students in addressing their inappropriate and incomplete understandings. As such, the need to identify how students think about groundwater becomes critical to providing effective instruction.

Methodology

This paper reports on one aspect of a larger research study conducted to examine spatial visualization of earth science concepts by middle school students. Eighteen eighth grade students enrolled in a nine-week elective course on mapping and related earth science concepts taught by the Science Education faculty and graduate students from North Carolina State University. The participants reflected the demographic composition of the school in areas of race, socioeconomic status, and gender, and held grade point averages of a B or higher.

In the eighth grade class, we focused explicitly on groundwater in only one fifty-minute class period

Item	If a person drilled a well to get groundwater, from where would this water come? (choose all that apply) A. river B. sand layer C. underground pool D. water tower E. soil F. spigot or faucet G. solid/fractured rock H. underground stream I. lake J. city water supply	
Score	**Definition of Level**	**Classification of Level**
2	Approaching a scientifically appropriate understanding of groundwater	Answer only includes one or more of the following: B, G, and/or E
1	Understands that groundwater occurs beneath the surface of the earth, but does not understand how groundwater functions	Answer may, but does not have to include any of the following: B, G, E AND Must include one or both of the following: C, H
0	Does not understand that groundwater resides beneath the surface of the earth or in what medium	Any combination of not listed above

Table 1. Multiple-Choice Item and Rubric.

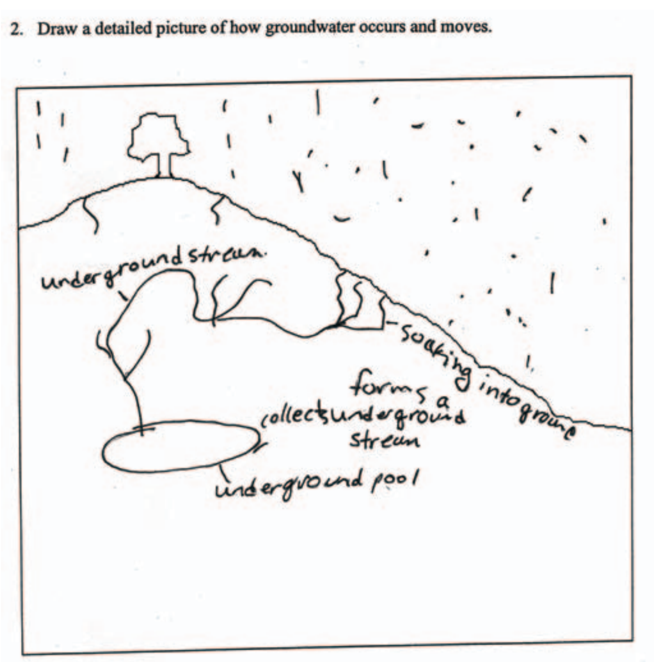

Figure 1. Use of "Underground Stream" and "Underground Pool".

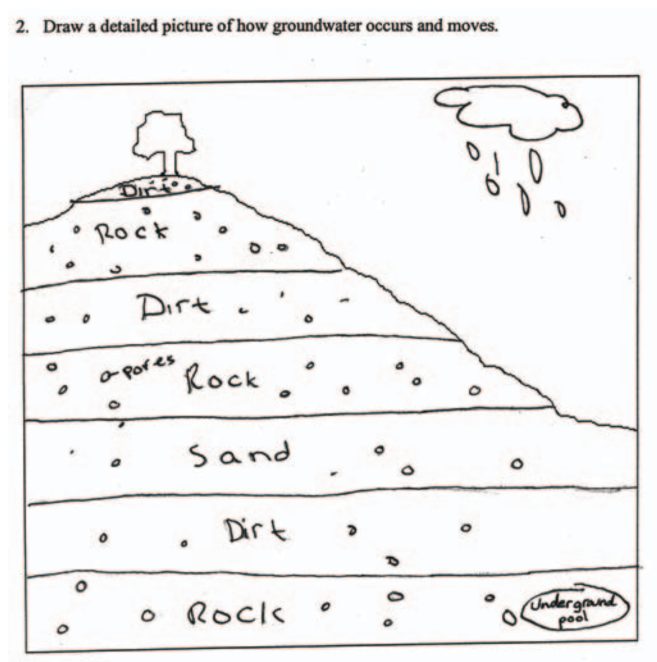

Figure 2. Disconnected Scientific Terms.

during the entire nine-week course. During that class period, we introduced a model that provided a common image of groundwater around which a class discussion developed. Several weeks prior to the introduction of the model, students completed surveys concerning their ideas about groundwater concepts. We administered the same survey several weeks after the class discussion of their groundwater model observations. The survey consisted of two questions including one multiple-choice item and one open-response drawing prompt. We scored the multiple-choice item using a rubric (Table 1) and analyzed each drawing for evidence of understanding of groundwater formation, movement, and storage. The class period that focused on groundwater was not intended as an intervention, and we expected little to no change in student responses. We administered the two surveys as part of a separate methodology used in the larger study. The conceptions revealed in both sets of surveys prompted their use in this study. In addition to the surveys, class discussions were videotaped and transcribed. We coded and analyzed the transcriptions and made assertions about students' understandings of groundwater concepts.

Results

Of the sixteen students who completed the multiple-choice item on the first survey administered, two received a score of one and no one received a score of two. In contrast, of the seventeen students who completed the multiple-choice item on the second survey administered, five received scores of one and one received a score of two. The most frequent answers included: river (A), underground pool (C), underground stream (H), and lake (I). All students who completed the multiple-choice item in the first survey included one or more of the answers A, C, H, and/or I. Only one student did not include one or more of the answers, A, C, H, and/or I, in her response on the same item in the second survey.

Students frequently used the phrases "underground stream" and "underground pool" in labeling their drawings Figure 1. Additionally, words and phrases like "porres [porous]", "pores", "water table", "aquifer", "pressure", "force", and "flows" appeared in many of the drawings that contained underground pools or streams. In most cases the vernacular terms like underground streams were disconnected from the typically scientific terms like pores and pressure. For example, in Figure 2 the pores do not appear to connect in any way to the underground pool. The isolation of groundwater concepts commonly occurred in many students' drawings. Only four of eighteen students addressed the second portion of the drawing prompt regarding groundwater movement. Three of the four participants drew arrows indicating a downward movement of water through the cross-section, while one drew water moving upward towards "pipes". Additional in-depth probing would be necessary to determine the nature of the conceptions these drawings represent.

During the class discussion about the groundwater model, some students indicated a metaphorical use of certain words as described in the excerpt below.

Student 1: *Exactly, the little streams and stuff, that's what it's following.*
Teacher: *The streams, where do you see streams?*
Student 1: *It's in there.*
Teacher: *Where? … Does anybody see a stream? Does anybody see a pool?*
Student 2: *Right there.* [points to food coloring plume in model]
Student 3: *I see it.*
Teacher: *…So when you talk about a stream or you talk about a pool, are you talking about a contiguous or a solid body of water?*
Students 1, 2, and 3: *No.*

As the discussion continued, students began to use more scientific terms such as porosity and permeability, yet failed to explain these terms when asked to do so. Students also employed additional metaphors equating rocks with sponges in the context of discussing porosity. While this metaphor is appropriate in some instances, students appeared to apply it in both appropriate and inappropriate contexts. For example, while the class discussed how fluids move through unconsolidated materials such as the sand layers viewed in the model earlier in the lesson, one student said the water not only flowed around, but through the grains.

Student 4: *It's porosity.*
Teacher: *…It's what, hang on, hang on…. So the actual **grains** absorb water?*
Student 4: *Kinda like a sponge.*
Teacher: *Like a sponge?*
Student 4: *Yes.*
Teacher: *…Okay. If I pour water on a rock, is that rock going to soak up that water?*
Student 4: *It depends on what kind of rock it is.*
Teacher: *Okay. If I take a quartz rock* [teacher holds up quartzite sample], *which is what that sand is made out of, quartz, and I pour water on it, is it going to soak up that water?*
Student 4: *A little bit.*
Student 5: *A little bit.*
Student 4: *It could flow through.*
Teacher:*Okay, let's try* [holds sample under the sink tap].
Student 4: *It's not going to soak it up like that. That' s not what I'm talking about.*
Teacher:*Oh, oh, what are you talking about?*
Student 4*: It's like, I'm not talking about like that.*
Teacher: *Okay.*
Student 4: *But I don't know.*
Teacher:*Okay…. You're saying that it soaks it up. So, if you have a quartz grain, a quartz rock, and you pour water on it, you are saying that some of it will be absorbed. Right, is that what you were saying, am I saying it right? [Student 4 nods] Okay. Why do you think that? How many people agree with that? [a few students raise their hands] That if you pour water on a quartz rock that it will soak it up?*
Student 5: *A little bit of it.*
Teacher:*Okay, a little bit of it, how much?*
Student 5: *A tad bit.*

Student 4 correctly recognized a connection between porosity and rock type, however the student's explanation of how rocks act as porous materials was inappropriate. The student made no distinction between a quartz sand grain and a quartz sandstone in terms of fluid movement. Additional probing is necessary, but it is quite possible that the student simply considered both cases to involve a fluid moving through a solid. Since they are similar materials, it may seem reasonable to that student to assume that the water would permeate each in a similar way because they both appear solid and consist of quartz. The failure to recognize the difference between the non-porous sand grain and a porous sandstone may reflect, in part, the student's inability to construct a mental model of the internal structure of each material.

CONCLUSIONS AND IMPLICATIONS

Eighth grade students hold naive conceptions concerning groundwater, although the natures of those conceptions are not easily recognized because of the extensive use of both scientific vocabulary and vernacular used in explanations of groundwater concepts. For example, words and phrases typically associated with naive conceptions like "underground pools and streams" do not always represent an inappropriate understanding. Some of the students plainly indicated that they did not think of groundwater as a solid body of water although they called it a "pool" or "stream". In contrast, words and phrases typically associated with an accepted scientific explanation like "porosity" and "permeability" do not always represent an appropriate understanding. Many students used those words in their drawings and discourse; yet when asked to appropriately explain the terms they used could not do so. Instead, explanations revealed notions of minerals and crystalline rock absorbing water like a sponge at the earth's surface. Such explanations combined with drawings that fail to connect concepts like "pores" and "pools", illustrate gaps in students' understandings of fundamental groundwater concepts. As evidenced by students' regular use of scientific terms, it appears they know that porosity and permeability have something to do with groundwater and may know that some bedrock can contain fluids and gases in pore space. However, the idea that a rock should "soak up water like a sponge", at least in part because of porosity, appears grossly incomplete upon further probing. The students questioned did not know what types of rock and under what conditions the "sponge-like" effect would occur. They apparently combined what they see in their environment with what they hear from perceived authoritative sources to attempt to form rational explanations when questioned. The gap that develops between students' incomplete understandings of the scientific terms and their conceptual visualization of the associated concept provides ample space for naive conceptions to move in and flourish.

One way to address students' inappropriate conceptions involves sustained and comprehensive instruction regarding groundwater concepts. More comprehensive instruction would require teachers themselves, in many cases, to acquire more complete understandings of groundwater. Consequently, a need for quality teacher education programs focused on the scientific content related to groundwater becomes apparent. Another option is assisting students in better visualizing groundwater concepts through appropriate physical models, computer software, and fieldwork experiences, a strategy that is an important component in constructing complete understandings of geologic concepts (Piburn, 2002; Hudak, 1999). Because of the potential for generating misunderstandings, the development of models and graphics requires very careful attention. Instructional tools that use concrete representations of concepts as abstract as groundwater must remain as complete and accurate as possible in order to serve a useful purpose. Oversimplified or carelessly prepared models or graphics may prompt students to develop disconnected, isolated notions of groundwater concepts that yield an incomplete and inaccurate mental image.

Among the first steps in addressing the problems in understanding the concept of groundwater is the recognition by science educators and the scientific community that this is a particularly troublesome area. Second, groundwater is an essential resource whose conservation and protection may rest on the degree of understanding held by the public. Third, the concept itself is a difficult one to relate, requiring careful attention to the use of instructional materials and strategies that effectively enable students to develop accurate ideas. Thus, scientists who are in positions to educate teachers and citizens in the community can contribute enormously by examining their own instructional roles and practices. Perhaps most importantly, science teachers can and should increase their own accurate understandings of the content and exercise great care in choosing appropriate strategies and materials as they prepare to teach.

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