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WHAT ROLE SHOULD BIG IDEAS PLAY IN SCIENCE CURRICULA?

Abstract:

This paper tells the story of the development of a science unit from a unique epistemological perspective—termed "realist constructivism." The teacher in the realist constructivist approach is not expected to relinquish his or her expert status. Instead, that person adopts a stance, described in recent writings by one of the researchers as a "sage on the side" role that is mid-way between the traditional "sage on the stage" role and that of the inquiry-oriented "guide on the side" (Prawat, 2003). As this metaphor suggests, teachers in this approach play a more direct role than they do in the typical constructivist-oriented approach in science, social studies, and other disciplines. Reflecting this role, the approach can best be described as an "ideas first/inquiry second" variant on active teaching and learning. Data from implementation studies are presented that support this novel approach to science curricula development.

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Education, Science, Technology

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1. Introduction

In the rapidly changing world of the twenty-first century, science literacy is an essential goal for every nation's youth. Through science education, students come to understand the natural world and "see" scientific regularity in many phenomena encountered in their daily lives. Science is one of the two content domains where cutting edge technology can play a key role in helping student grasp difficult to teach but nevertheless powerful ideas at the middle school level. The goal we have set in this preliminary project for middle school science education is to begin to examine the role of content and process from a novel perspective. Instead of viewing content as being in service of process ("hands on" or inductive learning), or as the two being equal partners, this study views process as being entirely in service of content.

An example of this type of reasoning might be the following: A youngster observes the surprisingly fact that plants, although they have no way to go out and get food the way animals do, nevertheless are living things and require nourishment. The youngster, perhaps encouraged by a teacher who suggests that the student think of plants as "food factories," reasons that, if plants were food producers, than the problem associated with the inability to gather food would be resolved. Therefore, the student continues, plants must have a food producing capacity.

Like the other two approaches, the one examined here views the process of scientific discovery as an imaginative, metaphoric process known as abduction. This view, also defined as "inference to the best explanation," is the brain-child of a philosopher and scientist named Charles Sanders Pierce, a man whose work dates from the second half of the nineteenth century but who is increasingly being seen by highly respected scholars like Susan Haack (1998) and A. I. Miller (1987, 2000) as having a great deal to say in the current debate involving epistemologists and historians about the nature of disciplinary knowledge: The role of knowledge, in this view, is to open our eyes to important regularities in the world which enables us, among other things, to be more fully "in" that world (Prawat, 2003).

An example from the science unit developed in this study might be helpful. The process unfolds, as it relates to one big idea in weather, in the following way: (1) A surprising fact, C, is observed (e.g., midnight is not, apparently, the coldest time of day; sunrise is); (2) but if H were true, C would be a matter of course (e.g., if the earth, especially the oceans and the Great Lakes, stores up energy which slowly dissipates over the night hours, then sunrise would be the coldest time of day); (3) hence, there is reason to suspect that H is true.

Items number two and three above, the second and third part of the process, the truly abductive part, requires the presentation of a "lens" in the form of a metaphor in order for students to begin to see the real regularity that will

reconcile the seeming discordant fact(s) presented in step number one; it also requires their recognition of the fact that the regularity accounts for the discrepancy experience in the first phase of the process.
Following step number three, we then introduce the “deductive” phase of the abductive inquiry process as follows, continuing the numbering process: (4) Here students are asked to determine what things would be like if the hypothesis were true (e.g., one thing students might be able to deduce in the example, with some scaffolding from the teacher, is that, if water stores energy more readily than land, the oceans might stay warmer longer during the seasonal change in both northern and southern hemispheres from fall to winter); (5) students next must decide which of the outcomes is most germane to the hypothesis and then examine data that addresses the predicted outcome. Working in groups, they must explain how the data does or does not support the deduction. The final step (6) involves trying to induce other implications from the now tested hypothesis (e.g., the notion that the oceans and lakes play an important role in the “energy disequilibrium” effect which [hopefully] would be presented earlier in the hypothetical unit).

2. Model Curriculum Design Based on Abduction

In the approach being pilot tested in this paper, the science educator starts with an important real world phenomenon. The authors decided that weather would be a good example of such a phenomenon. Once this has been identified, the curriculum development process focuses on the regularities or laws (as ideas) that “open up” or “unpack” the phenomenon. One example of this is the notion of disequilibrium as it relates to energy from the sun. As the term “disequilibrium” suggests, energy from the sun is distributed unequally on earth, a notion that is apparent when one examines temperatures at different times (e.g., at noon and midnight) in the same place, or at the same time in different locations on the earth’s surface (e.g., at the poles versus the equator). The unequal build up of energy, to continue with the big idea “story line,” creates disequilibrium that results in the movement of energy that we call “weather.” Two additional notions that help explain the unequal distribution of energy on earth relate to the fact that (1) the earth stores and slowly releases energy, and (2) the angle of the sun’s rays hitting the earth varies according to the curvature of the earth and the tilt of the earth in relation to the sun position (i.e., with or at right angles to the earth).

Identifying and sequencing the ideas sets the stage for the development of the three key features of realist constructivist teaching: First, the curriculum developer must figure out how to concretize or instantiate the ideas through the use of metaphor, visualization, and/or physical enactment; second, assuming that the metaphor or physical enactment enables students to “see” the regularity in the phenomenon, the curriculum developer must figure out how to scaffold students in the process of formulating a coherent--and testable--explanation of it; and, third, the curriculum developer must present options for students to ponder

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and discuss, one of which represents a legitimate test of the students' explanation against scientific “fact.”

In this paper, we will illustrate how the realist constructivist approach works by focusing on the second big idea (energy storage and release) and the third big idea (the angularity issue) mentioned above. The account provided below, it should be emphasized, is based on preliminary work we have done as a way to think through this model. Apropos idea number two, we predicted that middle school students would identify midnight as the coldest time of day. Accordingly, the lesson relating to big idea two began by asking students the question, “What time of day is the coldest?” Students, working in pairs at wireless laptop stations, were asked to talk among themselves before formulating their response to the question. As predicted, the largest majority of the students (approximately 75%) responded with the predictable answer that, “It is coldest at midnight.”

3. Intervention

The intervention began with the teacher, as instructed, ignoring for the moment a “At the end of the night” response that was offered by one of the more science savvy groups. The groups were asked to explain why they thought midnight was the correct response. Six of the 12 groups of pairs gave slightly different versions of the explanation “because that is the middle of the night.”

At this point, the teacher illustrated using her own laptop how to access the idea tool titled “Day/Night Simulation.” This idea exploration tool depicted a small globe with a tiny red figure located somewhere in the Midwestern US. The globe had no tilt to simplify matters and the sun’s rays were depicted as emanating from the right. The students could rotate the globe by using their mouse from noon (where the tiny figure was profiled against the dark black sky, atmosphere being another complication that was eliminated in this simulation), around to sunset (where the figure was lost from view), to midnight (where the figure reemerged on the opposite side from the sun, another departure from reality in the interest of students grasping the idea), to, finally, sunrise (where the figure had barely emerged from the darkness). Associated with each rotation was a factually correct average temperature for the vernal equinox in the Midwest. What students saw, of course, was that it was coldest at sunrise. Our use of technology to present a surprising fact was the first step in the technology-mediated abductive process described earlier. The teacher, again as instructed, let the groups discuss this surprising result for a few minutes and then showed them how to access a second important “tool” on their computer.

This second tool, as indicated, involved the use of a powerful metaphor to trigger the process of abduction. The purpose here was to provide a “lens” which allowed the students to see the regularity that, once grasped, allowed them to convert what was a surprising fact--in this case, the counterintuitive notion that sunrise and not midnight is the coldest time of day--into one that was viewed as a

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natural consequence associated with the hitherto unimagined regularity. The regularity that we want students to abduct, of course, is the notion that the earth, especially the oceans and the Great Lakes, slowly releases energy built up during the day over the night time hours.

To this end, students were presented in side by side boxes with two possible metaphoric "explanations" for the surprising fact that had been called to their attention: On the right there was a light switch which they can manipulate in an on/off position; in the off position, the box immediately darkens. On the left, there was a realistic representation of a pot of water on a gas stove in the process of coming to a boil. When they turned the knob beneath the pot, they turned off the flame beneath the pot. The pot contained a thermometer that showed the temperature slowly dropping when they stopped the source of heat. The question related to this metaphoric visualization tool which they were asked to respond on paper provided to each group was, "Which of these two images do you think fits best with what you have discovered about the coldest time of day? Why?"
The teacher, following instructions, spent a considerable amount of time (10 to 15 minutes) going over student responses with the class. She identified one or two of the most promising explanations, which the two-member groups were asked to incorporate into a revised answer to the question under consideration.

4. Results

Comparison of pre- and post-test achievement scores in the pilot tests provided compelling data that the realist constructivist approach was a viable way to get essential weather content across to students--and in a way that, it appears, combine comprehensiveness of content coverage typically obtained using traditional, text-book based instruction with the depth of understanding one associates with more progressive (and labor intense) project- or inquiry-based instruction. This statement necessitates some further elaboration of the kind of data collected in the pre- and post-testing phase of the week and a half long version of the weather unit discussed in this paper. As indicated, we used a middle school grade classroom for the purpose of testing the approach used here.

In the pilot testing, we were able to do a 10-week follow up to see how well students retained content to which they had been relatively briefly exposed (e.g., 30 minutes or less). Students fared well even on items that they had great difficulty with on the pre-test: The question, "Where on earth does nature best store the sun's energy?" is an example. This item relates to a key idea in weather (not the one highlighted earlier): Namely, that water holds the sun's energy longer than land. Seventy-three percent of the students selected "deserts" on the pre-test; the percent opting for this on the post-test was 33% but this percent dropped even lower on the 10 week follow up test. Only 20% chose this option while fully 72% selected the correct choice, "oceans and lakes." The remainder stuck with the third option, "mountains."

We obtained a similar pattern for other important test items, including the item that directly assessed the efficacy of the intervention described above . The answer to our “When is it coldest?” question is another example of remarkable retention for such a young group: Sixty-seven percent chose the most obvious choice, “midnight,” on the pretest (see below), while 75% and 68% answered correctly (“sunrise”) on the posttest and on the 10- week follow-up, respectively. Another example of remarkable retention over the ten-week interval was for the item “How does a blizzard form?” On the pretest, 81% of the fifth graders selected “two cold air masses collide” as the answer. Again, after relatively brief exposure to this content, 76% responded to the correct answer: “Warm, moist air from the Gulf of Mexico collides with cold, dry air from Canada.” Fifty-seven percent of the students got this answer right on the follow up test (the third foil was as wordy as the correct one so that apparently was not the determining factor).

5. Conclusion

The pilot results reported above suggest that the Realist Constructivist approach examined in this study--which involves teaching big ideas in science through the use of concrete, technology-mediated metaphors, represents a promising alternative to the “hands on,” discovery approach favored by many reform-oriented science educators. It is fair to say at this point that additional research testing the more direct but still inference-based model of science discovery advocated here (e.g., “abduction” vs. “induction”) is in order.

6. References

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