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An Argument for Arguments in Science Classes

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Abstract

[...] in science education, where researchers have argued strongly for a conception of science as a process of collecting evidence, critically evaluating, and constructing explanations (Driver, Newton, and Osborne 2000), the argument for incorporating more argumentation in school science has grown. An important finding in this research is that students who have been able to explore why the wrong idea is wrong have a more secure and deeper understanding of why the right idea is right (Alverman, Qian, and Hynd 1995). [...] when teaching the explanation for day and night, there is as much educational value in considering why the arguments for the geocentric explanation for day and night are fallacious (that the sun moves; if you jumped up you would not land in the same spot; at the speed of over 1,000 mph at the equator, you would be flung off) as in considering the evidence for the heliocentric view (which, ironically, the evidence for which very few teachers of science appear to know).

Full Text

Science education has a problem. Science is deemed so important that all students must study the subject for many years and, in most states, schools are evaluated in part on their students' science achievement. Across the globe, sustaining the scientific and technological base of advanced economies is now of such concern that it has generated a succession of reports about how to address students' lack of interest in science. An increasing body of evidence suggests that curricula that are defined by a long list of standards combined with examinations that test their recall of a broad body of knowledge are undermining students' interest in science (Osborne, Simon, and Collins 2003; Sjøberg and Schreiner 2005; Au 2007). Of particular concern is a finding from a recent study involving over 20 countries showing a negative correlation between quantitative measures of how advanced a society is and students' interest in the further study of science and scientific careers (Sjoberg and Schreiner 2005).

Science curricula are predominantly framed by scientists and their needs, and their dominant requirement is the need to educate the next generation of scientists (Millar and Osborne

1998). Too often, the outcome is science curricula based on state standards that are written as a list of separate and detailed concepts and lack an overarching narrative that might provide coherence. The result is that students often experience science as a miscellany of facts. This conception of the subject is reinforced by an assessment system that tests students' ability to recall elements of atomized knowledge and by a teaching style that emphasizes recall over higher-order thinking. The result is a lack of emphasis on the ability to reason or argue in a scientific context. Rarely are students able to explore how we know what we know, how such knowledge came to be, or why it matters.

The irony in this state of affairs is twofold. First, science, more than any discipline, has allowed us to transcend the shackles of received wisdom; yet it is taught in a manner that is the antithesis of the spirit of open inquiry and invention that it has fostered. Second, the ability to synthesize knowledge from different domains and engage in critical and analytical thinking is the very skill needed to enhance a nation's economic competitiveness (National Research Council 2008; Hill 2008). This concern is driving many countries to implement standards-based curricula even though there is evidence that such an approach engenders negative attitudes toward science (Sjoberg and Schreiner 2005; Osborne and Dillon 2008). In addition, this approach minimizes opportunities for critical thinking. How, then, can science education foster both the knowledge and the skills required by society?

An Argument for Argument

Giving students opportunities to construct arguments and counter- arguments can be an effective strategy for both developing students' ability to reason and enhancing their conceptual understanding. A body of research suggests, however, that the skills of reasoning and argumentation are domain specific, that is, students who can argue successfully in history may not argue successfully in science. Hence, in science education, where researchers have argued strongly for a conception of science as a process of collecting evidence, critically evaluating, and constructing explanations (Driver, Newton, and Osborne 2000), the argument for incorporating more argumentation in school science has grown. Indeed, the argument for reasoning and critical thinking in science education is central in the recent NRC volume, Taking Science to School: Learning and Teaching Grades K-8 (Duschl, Schweingruber, and Shouse 2006). Consequently, a growing body of research on how to incorporate argumentation in school science has emerged.

An important finding in this research is that students who have been able to explore why the wrong idea is wrong have a more secure and deeper understanding of why the right idea is right (Alverman, Qian, and Hynd 1995). Thus, when teaching the explanation for day and night, there is as much educational value in considering why the arguments for the geocentric explanation for day and night are fallacious (that the sun moves; if you jumped up you would not land in the same spot; at the speed of over 1,000 mph at the equator, you would be flung off) as in considering the evidence for the heliocentric view (which, ironically, the evidence for which very few teachers of science appear to know).

Giving students opportunities to consider common scientific misconceptions, however, contradicts common assumptions about what it means to teach science. For instance, science teachers typically want to persuade students of the validity of the scientific worldview; considering alternative perspectives, therefore, simply seems illogical. It also requires a shift in the perception of what matters in science, placing more emphasis on its explanatory theories - the creative ideas that scientists have dreamt up, for example, that all stable matter consists of only 92 atoms or that the universe started with a big bang. Judging which theory is best, assessing the significance of experimental evidence, or simply determining which data and how much to collect are critically dependent on argument.

Argumentation in the Classroom

Inevitably, asking students to engage in argumentation in science generates many questions. Are young students really capable of such a discursive activity, particularly if they lack the necessary content knowledge? How can teachers initiate and support argumentation in a manner that is meaningful to students and relevant to the curriculum? Colleagues and I have learned from our research in U.K. classrooms that it's possible to do this and also possible to develop organizational structures that teachers can use to support such activities (Osborne, Erduran, and Simon 2004). Our work demonstrates that teachers can use argumentation to encourage more dialogue about science and improve students' ability to reason.

One example taken from work that a colleague and I recently conducted is shown here. Students were asked to discuss which graph would best represent the change in temperature of ice as it is heated and ultimately turned to water vapor (Figure 1). This sheet is also accompanied by statements of evidence that students can consider in their discussion, such as "energy is needed to break bonds between particles," "in solids, there are bonds between particles which hold them together in a fixed shape," and others.

This example typifies many of those we developed requiring students to consider plural alternatives. Another framework requires students to examine evidence for how a rock or an organism, such as an animal or plant, should be classified. Students are provided with conflicting evidence - for example, the rock was found at the top of a mountain, it is easy to scratch and contains fossils - and then asked to develop an evidence- bas ed argument for the most appropriate classification. Embedded in such an activity is an opportunity to show students that ambiguity is a normal rather than an exceptional feature of science.

The type of discourse that this kind of activity is capable of generating, taken from a study conducted with 7th graders, is shown beneath. The text captures these students challenging opposing viewpoints, critically evaluating their initial ideas, and considering alternative propositions.

S1:Our counter- argument is [. . .] Someone might argue against our idea by saying that energy does not require so much time to break the bonds, especially since the time is not stated on the graph. . . .

S2: So if someone does not agree with us, we would convince him or her by presenting our evidence and reasons as to why we think that graph B is the correct one.

S1:Like, for example, if someone says that ice can straightaway melt and turn into the liquid state, we would say that energy is being used to break the bonds between the particles. So time is needed to change its state.

S3:The temperature stays constant at 0° C for a while.
S2: Someone could argue that the heat is.... very, very strong, so causing it to melt instantly and its temperature to constantly rise up instead of stopping and pausing for a while.
S1:So how are you going to rebut?
S2:Uhm [...] To rebut that, we'd probably have to carry out an experiment where all the factors are constant and we can try to use a constant heat source in one experiment and another not so constant. . . .
S1:We can use different kinds of flames [of] different intensity to observe. And see what happens.
S3: So we'll show her an experiment.
Interestingly, later the members of this group comment:
S2:This is one of the best experiments I've ever done.
S1:Where we actually think! (Students laughed.)
Our work showed that such activities increased the amount of deliberative discourse commonly observed in school science classrooms from about 5% to 15% to 32%, depending on the context. Thus, encouraging teachers to give students such opportunities offers the potential to include more dialogue and stimulate higher-order thinking. A considerable body of research suggests that such activities lead not only to enhanced reasoning skills (Osborne, Erduran, and Simon 2004) but also to enhanced conceptual understanding (Alverman, Qian, and Hynd 1995; Zohar and Nemet 2002). What is clear is that argumentation activities must be well- structured with clearly defined goals and outcomes. When conducted in this manner, and where teachers are perceived to endorse independent scientific thinking and exploring concepts in depth, students do appear to have a deeper engagement and greater satisfaction with their science learning (Nolen 2003).

What Challenges Are Posed by This Approach?

Typically, science teachers are not trained to engage students in arguments. Consequently, it is not a common feature of their repertoire of instructional strategies. Indeed, research indicates that to embed inquiry-based activities incorporating argumentation into their practice requires an extended period of time with ongoing support Qennings and Mills 2009; Martin and Hand 2009). Therefore, to make this kind of teaching easier, we developed DVD-based materials (the IDEAS pack) that support teaching about ideas, evidence, and argument in science education (Osborne, Erduran, and Simon 2004). Drawing on lessons taught by teachers who were our collaborators , these materials focus on: 1) the main features of argumentation and why argumentation matters in school science; 2) how to manage smallgroup discussion so that it is structured and productive; 3) instructional strategies required to teach argumentation; 4) resources for teachers; 5) how to evaluate argument and distinguish strong arguments from weak arguments; and 6) ways of modeling argument to young people. While these materials are only a beginning, the opportunity to see other teachers using such approaches with a range of students in typical classroom contexts has helped teachers see that such approaches have value and are manageable.

As Au (2007) has shown, NCLB has led to a greater emphasis on teaching to the test, a dominance of teacher-led pedagogy, and greater fragmentation - all features that diminish student engagement. Giving students opportunities to discuss, reason, and deliberate in science seems to offer one way to reverse that trend. If learning to argue is learning to think, then developing students' facility may be the most enduring value of a good education.

Sidebar

The best way to teach science may be to teach students to argue.

R&D appears in each issue of Kappan with the assistance of the Deans' Alliance, which is composed of the deans of the education schools/colleges at the following universities: Harvard University, Michigan State University, Northwestern University, Stanford University, Teachers College Columbia University, University of California Berkeley, University of California Los Angeles. University of Michigan, University of Pennsylvania, and University of Wisconsin.

Sidebar

Rarely are students able to explore how we know what we know, how such knowledge came to be, or why it matters.

Students who have been able to explore why the wrong idea is wrong have a more secure and deeper understanding of why the right idea is right.

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