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Authority and accountability in light of disciplinary practices in science

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ABSTRACT

Our aim is to explicate the importance of students' learning about disciplinary authority and accountability and to anchor our analysis in transcripts from a North American high school biology classroom. Previous analyses of the entire two-day lesson and a qualitative description of an episode from one day showed that the students were able to see errors in their peers' proposals better than they were able to point out the potential errors in their own. Our findings led us to at least one conclusion that differs from earlier formulations of productive disciplinary engagement: that the interpersonal process of construction and critique precedes and fosters its intrapersonal appropriation. The implications for a practice theory of learning are discussed.

1. Introduction

In an article about classrooms that foster productive disciplinary engagement (PDE), Engle and Conant (2002) describe how a group of students in a community of learners' classroom (Brown & Campione, 1994) became passionately involved in arguing with each other. They also traced the ways in which their arguments evolved to become more soundly evidence-based over time. The National Science Education Standards (1996), as well as many science educators (e.g., Bricker & Bell, 2008; Driver, Newton, & Osborne, 2000; Duschl, 2008; Duschl & Osborne, 2002) assert that such productive disciplinary engagement in genuine scientific arguments is crucial for a variety of reasons. In addition to the fact that argumentation is "at the heart of science" (Driver et al., 2000; p. 288), it provides students opportunities to practice critical thinking and to externalize their reasoning (Erduran, Simon, & Osborne, 2004).

One reason why students need to understand scientific content as a product of argument has been highlighted by a contrast with what is more common—namely that students come to understand scientific knowledge as a collection of facts about the world. It has been argued (and we agree) that understanding science as a "rhetoric of conclusions" (Schwab, 1962) or "final form science" (Duschl, 1990) is a fundamental, rather than a peripheral, misunderstanding. This misunderstanding is likely to prevent scientific literacy, that is, to hamper the ability to learn and use scientific ideas effectively, and to distort the formation of well-grounded opinions about socio-scientific issues (Driver et al., 2000).

Engle and Conant (2002) outlined four principles for fostering productive disciplinary engagement (PDE) that included introducing open-ended problems to be solved (that might have multiple solution pathways as well as several solutions); shared authority among teachers and students; accountability to each other and to the discipline; and sufficient material and symbolic resources (including adequate time). They also articulated the meaning of "productive disciplinary engagement." Nevertheless, they did not clearly define what they meant by *disciplinary* engagement or learning, other than it includes

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disciplinary content and that arguments should appeal to evidence (Ford & Forman, 2006). We believe there are important reasoning practices that are specifically characteristic of science that may be neglected in this earlier version of the PDE framework.

Engle (2011) recently expanded upon the earlier version of the PDE framework. There she clarified that the definition of PDE and also the four principles for supporting it were intended to encourage more specific definition and work in this area. Thus, we aim here to further our understanding of the importance of students learning about disciplinary authority and accountability and, like Engle and Conant (2002), to illustrate our argument with transcripts from an instructional example that we believe succeeded in supporting PDE in the practice of argumentation (i.e., the Modeling for Understanding in Science Education or MUSE project described by Stewart, Cartier, and Passmore (2005)).

Our argument focuses on ways in which disciplinary authority and accountability are related in scientific practice as well as the implications of this for fostering PDE. In science, authority for one's claims is achieved when the arguments for these claims succeed in sufficiently *convincing* a community of disciplinary peers of their merit. Claims are sufficiently convincing when the evidence for them addresses and successfully stands up to the critique of disciplinary peers. Because the scientist attempting to achieve authority for her claim must address peer critique, understanding and anticipating disciplinary critique (i.e., disciplinary accountability) is a *logical and developmental precursor* for achieving disciplinary authority. As a result, if we consider scientific practice as an anchor for defining what *disciplinary* means in terms of student engagement, the way authority and accountability unfold is crucial. In what follows, we elaborate on this sketch of how disciplinary accountability underlies disciplinary authority, highlighting how it throws additional light on classroom activity designs that engage students in productive disciplinary work.

In order to make this case, we will first briefly sketch an account of scientific practice, anchored in the science studies literature, highlighting the relationship between authority and accountability.

2. Authority, accountability, and reasoning in scientific practice

Science education scholars have drawn on the work of Deanna Kuhn in order to note specific features of argumentation in science that students should engage. One of Kuhn's important contributions as a developmental psychologist is highlighting two fundamental aspects of scientific reasoning—that scientific ideas each exist within a conceptual ecology of alternative possibilities and that evaluation of these ideas occurs in light of evidence, which must be in some sense, independent of those ideas (e.g., Kuhn, 1991, 2005). These two key features of scientific reasoning have been cited by many science education researchers in their concern to support students' understanding of science's epistemic basis (e.g., Berland & Reiser, 2009; Driver et al., 2000; Duschl & Osborne, 2002; Herrenkohl & Guerra, 1998; Osborne, Erduran, & Simon, 2004). For example, Duschl and Osborne (2002) note that science education standards documents in the United States and United Kingdom emphasize that students learn not only *what* we know from science, in terms of content and ideas, but also *how we know*, that is, its epistemic basis. They highlight that this involves two things: (1) how evidence is used in science and (2) the criteria used to evaluate evidence and relate it to explanations.

A way to highlight how these crucial epistemic features of science relate to scientific dialog is through the basic voices of construction and critique (Ford & Forman, 2006). Ford (2008) drew from philosophy and sociology of science to distill a model of scientific practice in terms of these two diverse roles, or voices (Ford, 2012), within the scientific community. The key idea is that scientific knowledge claims are not only constructed, but also are critiqued, for example during peer review. Because knowledge claims in practice are accepted only when they can address critical points raised by peers, the constructor must take these critical points into account, indeed even anticipate and reason through them when setting up an argument for a claim. As a result, the reasoning of the scientist who is concerned with constructing new knowledge is supported by and even infused with envisioned critique.

From this basic analysis, we can conclude a few things. First, critique is not merely a step that occurs *after* a claim is constructed, which is typically what evaluation means. Rather, it is a central part of the construction process itself. Second, critique can be considered as a search for errors, for something that is not correct about the claim being made or about the evidence (e.g., data) brought to support it. This search for errors can be conceived more specifically as a generation of alternative possibilities and their evaluation relative to the claim and what else is known, for example the evidence being presented and the facts and ideas currently accepted in that field (Ford, 2010, 2012).

Thus, both scientific practice and reasoning can be considered in terms of the dialog between construction and critique. And the way construction and critique play out in scientific fields of inquiry is precisely what makes those fields of inquiry (and the knowledge they produce) scientific in a *disciplinary* sense. Critique is the social and intellectual source of a search for errors and the examination of multiple possibilities. An investigator who is not socialized into science might be convinced of a claim and see no need for questioning it or seeking evidence (or counterevidence). However, because her peers will actively generate alternative possibilities and propose those that may seem more likely, she needs to anticipate and consider these options herself and present independent evidence that makes these alternatives *less* likely. In this way, critique gives evidence its meaning—the skepticism of an audience is the reason why something aside from the claim, independent evidence, is necessary.

In our argument, we appeal to an account of scientific practice in order to be more specific about how the *disciplinary* aspect of PDE should be conceived and supported. From our point of view, practice is holistic, as its components have their sense and rationale in relation to others and the overall goals and norms of the community. Also, learning to participate in a