International Journal of Educational Research 64 (2014) 184–198

Contents lists available at ScienceDirect

International Journal of Educational Research

journal homepage: www.elsevier.com/locate/ijedures

Productive disciplinary engagement as a recursive process: Initial engagement in a scientific investigation as a resource for deeper engagement in the scientific discipline☆

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ARTICLE INFO

Article history:
Received 5 July 2013
Accepted 17 July 2013
Available online 19 August 2013

Keywords:
Multicultural
Inquiry
Science

ABSTRACT

Engle and Conant (2002) show how productive disciplinary engagement (PDE) for students can be attained through learning environments structured to support problematizing subject matter, give students authority to address content problems, hold students accountable to others and disciplinary norms, and provide students with resources. This paper considers how one classroom's involvement in a scientific investigation embodied and extended the PDE framework. In this U.S. based classroom, 5th grade non-native and English language learning students engaged in scientific inquiry and contributed their findings to a greater scientific community. This paper proposes that these students experienced PDE at both initial and deeper levels, where students' initial PDE in scientific activities served as a resource for PDE at a more discipline-specific level.

1. Introduction

Engle and Conant (2002) describe how structuring learning environments to promote student problematizing of subject matter, authority to address content problems, and accountability to others responsive to shared disciplinary norms, together with making resources available to students, may foster productive disciplinary engagement (PDE).

As Engle (2011) further elaborates and explains, PDE entails students actively engaging in activities related to a discipline, and being productive, or in other words, make progress – and while PDE refers to the in-the-moment attentiveness to students' disciplinary activities, the framework for PDE refers to the kind of learning environments that need to be established by educators to foster PDE. The guiding principles of this framework include that educators promote student problematization of subject matter, give students authority to address content problems, hold students accountable to others and to shared classroom and disciplinary norms – and provide students with the necessary resources to continue learning. Though a variety of different pedagogical approaches may foster PDE, this paper considers what PDE may look like in the case of an inquiry-based investigation, where students participate in addressing an actual scientific research question in collaboration with practicing scientists.

The movement toward inquiry-based instruction seeks to reform didactic and lecture-based approaches to science instruction where teachers teach *about* science rather than engaging students in *doing* science through involvement in scientific practices (National Research Council (NRC), 2000, 2012). In inquiry-based classrooms, students learn science through the context of participating in scientific activities, where scientific content is embedded into scientific practices,

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http://dx.doi.org/10.1016/j.ijer.2013.07.002

which are ideally made explicit to students. Though there has been dispute of what, exactly, counts as inquiry (e.g. Berland & Reiser, 2009), the NRC (2000) describes one North American influential vision of what student involvement in classroom-based scientific inquiry would entail. This description includes the restructuring of classroom learning environments to: (a) engage students in scientifically oriented questions, (b) provide opportunities for students to give priority to evidence in responding to questions, (c) encourage students to formulate explanations from evidence, (d) have students connect explanations to scientific knowledge, and (e) encourage students to communicate and justify their findings in a scientific manner (NRC, 2000, p. 29). More recently, the NRC (2012) specified that in addition to participating in inquiry, student involvement in scientific practices entails practices such as students asking their own questions, planning and carrying out investigations, analyzing and interpreting data, and engaging in argument from evidence. Though the implementation of inquiry, or student involvement in scientific practices, remains on a continuum, with more or less emphasis of the various aspects of scientific practice, Berland and Reiser (2009) delineate three essential goals to scientific inquiry: sensemaking, articulating, and persuading. Consistent with the recommendations of the new framework for science learning (NRC, 2012), these goals suggest that a learning environment structured for inquiry would provide students with opportunities to make sense of data, share their findings, and convince others about what they find.

Though engaging classroom-based inquiry may provide learning opportunities for students that more closely models scientific activities, in many cases classroom-based inquiry falls short of modeling the actual work of scientists because of the lack of access to scientists and their guidance in learning about scientific norms (e.g. Chinn & Malhotra, 2002; Schwartz, Lederman, & Crawford, 2004). It is important to note that while classroom-based activities are authentic to the practices of school science (Lave, 1992) and reflect an hybridized culture of pedagogical practices combined with scientific content and practices (Hogan & Corey, 2001), they may not necessarily be representative of what scientists actually do. Involving students in *scientifically authentic* investigations (Bencze & Hodson, 1999; Lederman, 1992), in collaboration with practicing scientists, may provide opportunities for school-based inquiry to extend beyond the classroom and connect to a scientific community of practice (Wenger, 2007). In this way, classroom-based inquiry may become more authentic to the actual work of scientists and students may be provided with opportunities to learn more about scientific practices and norms beyond the classroom environment. In this unique learning environment, a hybrid space may be formed between the classroom and context of the scientific activity and the fusion of disciplinary and school-based norms may occur. This sort of learning environment may also provide a stepping-stone for promoting deeper levels of PDE in science, by first engaging students in more surface-level aspects of the discipline.

In the case of involving students in inquiry, a teacher may guide them toward PDE in science. In a learning environment where a teacher engages students in scientifically oriented questions, students may have the opportunity to problematize content and form their own questions about what they are observing. Problematizing may entail not only students making sense of content from their own perspectives, but also making sense of content using *scientific* terms (Ford, 2008). Students involved in actual scientific investigations may also have access to resources, such as authentic scientific questions and the scientists who ask them. As students are provided with opportunities to formulate explanations from evidence and communicate their findings, they may begin to practice authoring their own ideas. Student authorship with respect to inquiry-based practices also presupposes that students have access to resources, such as data to work with and an audience who is interested in and responsive to their findings. As students give priority to evidence and learn to justify their findings – as well as connect their learning to prior scientific knowledge, they may begin to demonstrate accountability to disciplinary norms. That students are able to do so would involve students having access to data and to scientific knowledge and guidance to learn scientific disciplinary norms, again in this case, a resource. Thus, through PDE in scientific practices, students are also introduced to the scientific discipline.

While the idea of establishing collaborative relationships between science classrooms and practicing scientists is gaining momentum (e.g. Cakmakci et al., 2011; Rennie & Howitt, 2009; van Eijck & Roth, 2009; van Eijck, Hsu, & Roth, 2009), more research is needed to consider the impact of student engagement in actual scientific practices in school settings may be. This paper claims the hybrid context formed by the infusion of scientific practices into a classroom setting, with the teacher both structuring this learning environment and serving as a broker between classroom and scientific practices, provided students with the opportunity to engage in PDE at both initial and deeper levels. This paper further proposes that student PDE in actual scientific practices may *itself* serve to foster students gaining, or appropriating, disciplinary aspects of scientific problematizing, authority and accountability, in effect creating a positive feedback loop between these principles and fostering PDE at a deeper, in this case scientific, disciplinary level.

To theoretically illustrate the recursive process through which student initial PDE led to deeper PDE in this hybrid classroom setting, this paper makes use of a case of student involvement in the Fossil Finders project, an investigation conceptualized by geologists using fossils to research environmental changes during the Devonian period. This case study provides a compelling example of the trajectory of PDE in a classroom of underrepresented, where students' initial PDE in classroom activities prepared them and became a resource for deeper levels of engagement in the actual practices of geological research. This project was implemented with a 5th grade classroom in an underresourced urban school in the eastern part of the United States, a setting in which innovative approaches to science instruction and PDE may be unlikely to occur (Settlage & Meadows, 2002). The focus classroom served underrepresented and non-native language speakers, many of whom were recent immigrants. The goal of engaging these particular students in scientific activities was to provide them with *opportunities* to engage in and experience scientific practice. The intention of the curriculum was not to transform these students into scientists, but rather, to illustrate what participating in science could be like. The collaboration between the