A discourse-based analysis of student inquiry in elementary science

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Abstract: Our purpose in this case study is to describe elementary student inquiry in science related to four elements: mechanistic reasoning, analogical reasoning, argumentation and scientific explanations. Findings show that prior to instruction the students were able to use different components of these four elements of student inquiry, at various levels of sophistication, suggesting that it may be more productive to help students to develop reliable access to those abilities.

Theoretical framework

Despite decades of calls for promoting inquiry in elementary science, the agenda has yet to establish in instructional practice (Hawkins, 1974; NSES, 1996; Minstrell & van Zee, 2000) for a number of reasons. First, while there is a consensus for the importance of inquiry in science learning, that consensus does not extend to the definition of what scientific inquiry looks like in the science classroom. Answers have varied from Hawkins's (1974) general appeal for "messing about" to more specific targets of developing "concrete" abilities of observation and controlling variables in experiments (Metz, 1995). To offer a working definition, we take inquiry to mean the pursuit of causal, coherent explanations of natural phenomena (Hammer, 2004), and suggest that it includes a number of different elements such as abilities for argumentation (Louca & Hammer, 2007), mechanistic reasoning (Russ, 2006), analogical reasoning (May et al., 2006), and scientific explanations (Zacharia, 2005). Second, there are differences with respect to the development of abilities for scientific inquiry. One view has taken a developmental perspective, suggesting that abilities increase with the subjects' age, as part of general cognitive development (e.g., Kuhn & Udell, 2003). A second view has argued that developmental perspectives have systematically underestimated children's abilities, and that differences in findings reflect the contexts of the interviews and framing of the questions (Metz, 1995). A third approach has argued that abilities can and should be explicitly taught as early as in elementary school, and has motivated the development of pedagogical practices that specifically support different elements of scientific inquiry (e.g., Erduran et al., 2004). Our purpose in this paper is to describe pre-instructional abilities of student reasoning.

Methodology

The study involved two groups of students (a total number of nine fifth and 11 sixth graders) in two metropolitan elementary schools. In each school, we set up an afternoon science club, and students volunteered to participate in the study. Students in both schools met with the same teacher and the first author once a week for 90 minutes for a total of 7 months. In these clubs students studied a number of physical phenomena following modeling-based learning practices. For this paper, we used transcripts of videotaped student conversations as our primary data source. We purposefully selected a total of six cases (three per club - a total of 490 minutes of student conversations were analyzed) during which students studied accelerated motion, relative motion and diffusion. From transcripts, we identified episodes of scientific inquiry, and the first two authors coded them independently, looking for different aspects of the aforementioned four elements of scientific inquiry that students used in the conversations. For this purpose, we adopted four analytical frameworks from recent research in science education that call attention to four different elements of student inquiry: argumentation (Louca & Hammer, 2007), analogical reasoning (May et al., 2006) and mechanistic reasoning (Russ, 2006), and scientific explanations (Zacharia, 2005). Our inter-coder agreement was 89%. Disagreements were resolved through discussion. Students had no prior formal instruction about any of the four elements of student inquiry that we investigated.

Findings

Figure 1 presents the study's findings based on the 4 elements of student inquiry we investigated. Each subsequent category represents more sophisticated reasoning from the previous one. For mechanistic reasoning we identified 943 student contributions that we coded for mechanistic reasoning. Students were able to describe the target phenomenon both as a whole (category 1.1; 36.3%) and in small conceptual entities (category 1.3; 10.4%) and its set-up conditions (category 1.2; 12,3%). They talked about those entities properties (category 1.5; 10.9%) and their organization (category 1.6; 4.1%), and the activities of these entities that produce change in the phenomenon (category1.4; 20.1%), showing sophisticated abilities for mechanistic reasoning. Category 1.1 was observed one third of the times, whereas categories 1.1-1.5 represent the 53.7% of coded student contributions.

Although not absent, the two most sophisticated categories (1.6 & 1.7: reason about a particular stage of a mechanism based on what is known about its other stages) represent only 6.3% of the coded student contributions in the conversation. Out of a total 344 utterances that we coded for analogies, in 25.3% of coded utterances students generated analogies (category 2.1), 70% validated and evaluated analogies (category 2.2), and 4,7% used analogies to create new knowledge (category 2.3). However, we were unable to locate any use of analogies for communicating ideas in science, which according to the coding scheme is the most sophisticated component of analogical reasoning (category 2.4). In terms of argumentation, we coded a total of 1535 arguments. Although 72.1% of coded arguments felt into the first level of sophistication (category 3.1, in which arguments consisted only of a simple claim), 16.4% of the arguments were supported with some grounds (category 3.2) and, 8.2% were counter-claims (that is responding on another claim with a weak rebuttal, category 3.3) and 2.9% felt into the most sophisticated level of argumentation: arguments consisted of a counter-claim and a clearly identifiable rebuttal (category 3.4). Lastly, out of 899 coded utterances coded for scientific explanations, 9.6% felt under the everyday explanations level (category 4.1), over half of the explanations were of descriptive nature (category 4.2, 54.4%) and 34,7% were clearly identifiable causal explanations of the phenomena under study (category 4.3). Lastly, only 1.3% were formal scientific explanations (category 4.4).

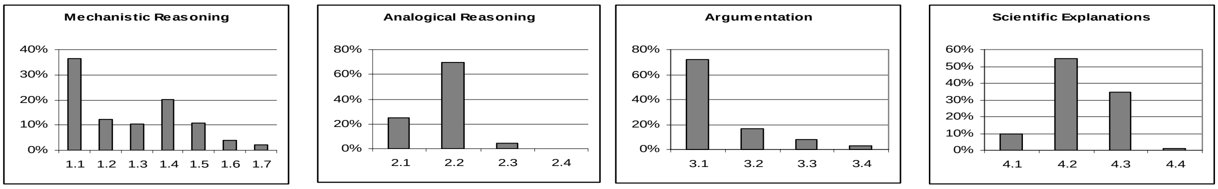

Figure 1. Findings for the four elements of student inquiry.

Discussion & Conclusions

Although we do not claim that our analysis covers the complete spectrum of classroom-based student inquiry, findings from this and other studies (Feldman, 1994; Karmiloff-Smith, 1992; Koslowski, 1996; Louca & Hammer, 2007; Metz, 1995), contend that students come in the classroom already "having" some abilities for mechanistic reasoning, analogical reasoning, argumentation and scientific explanations. The students of this study appeared to be able to use a number of different components of the four elements of student inquiry, some more sophisticated than others, thus, indicating that they have the beginnings of abilities for mechanistic reasoning, analogical reasoning, argumentation and scientific explanations. With ambiguities regarding productive student inquiry (Minstrell & van Zee, 2000), findings such these ones could potentially provide insights to the challenge of defining what student inquiry can look like in the classroom and what teachers should expect to see, especially in early grades. From all these, we suggest that the emphasis of instruction should be on identifying the beginnings of abilities for scientific inquiry in children, focusing on abilities that they already have and possibly use in different contexts.

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