Data Evaluation: An Integral Part of Learning Science

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Significance of the study

Inquiry based learning simulates, at least to an extent, the way scientific knowledge develops and at the heart of any inquiry project is evidence-based reasoning. The process of drawing inferences from observation involves sifting through data, formulating evidence, and coordinating theory with evidence; although this process is at the heart of scientific reasoning ability, and have received attention in cognitive science, a detailed examination of its components, as they are adopted by individuals in content-rich and school-based contexts, is rare (Greeno & Goldman, 1998; Koslowski, 1996; Kuhn, 1993, 1999; Kuhn, Garcia-Mila, Zohar, & Anderson, 1995; Kuhn, Schauble, Garcia-Mila, 1992; Siegler, 1996). While there have been some studies done on scientific reasoning, transferring research to classrooms and school contexts has it own challenges (Klahr, Chen, & Toth, 2001; Toth, Klahr, & Chen, 2000; Toth, Suthers, & Lesgold, 2002). Klahr et al. (2001) describe the challenges of implementing research-based strategies in classroom settings and those who are closely connected with classrooms are well aware of these complexities. This implies that there needs to be exploration of student reasoning situated in school contexts. Such experiences are crucial for teachers as well because they need to learn to develop reasoning skills in the context of messy and real data so that they can guide their students through the process effectively.

Underlying theoretical framework

Data science inquiry projects of any kind, be they guided or open-ended, often involve some ambiguity due to imperfections at various levels and as a result its interpretation can be difficult for beginners. Whether the data is "messy" or not its interpretation constitutes an essential aspect of scientific reasoning process. There would be hardly any debate about the claim that as a result of learning science, students should be able to reason and be able to understand the implications of evidence. However, researchers have shown that individuals have difficulty interpreting anomalous data unless they have the metacognitive ability to reflect on their own strategies and theories (Kuhn et al.1992; Kuhn et al., 1995). While some individuals might be able to develop these reasoning skills on their own as cognitive research has shown, educators can not leave it to

chance and need to make the effort to transport them to instructional contexts to help all students develop strategies for examining data and drawing conclusions.

In this regard another aspect of general instructional environment needs attention; that is, writing reports or expressing the reasoning through writing, since this form of communication plays an important part in a typical school context. Writing reports played an important role in the studies included in this paper. The influence of writing on learning science has been receiving attention from researchers in science education in recent years (Keys, 1999; Keys, Hand, Prain, & Collins, 1999; Hand, Hoehnshell, Prain, 2004). Some of these studies show the importance of writing in helping students learn science but we need details about how students make sense of data, how, when, and why they discount information, what they count as evidence, and other facets of the reasoning processes that are demonstrated in student reports. With this as the basic premise, this study examined the written reports of students at different academic levels, such as middle school and freshman year, in the context of a variety of inquiry projects. The purpose of the study was to gain an understanding of the ways reasoning is used by students in making sense of data during various inquiry projects. The research questions for this study are:

Do students draw inferences from data? What kind of justifications do they provide?

Research design and procedure

This is a part of a larger study involving students in middle grades in an urban school and undergraduate students enrolled in a physical science course for preservice teachers. This wide range of participants was based on the dual purpose of providing future teachers with experiences similar to their students and to study teachers' reasoning process as well. In this way, the study could provide two levels of information: one, about students' ways of reasoning; two, how the future teachers handle this kind of science teaching. In this report, the results from a part of the data corpus are presented to provide a sense of the preliminary findings from these projects.

Three tasks – two brief and one long-term project – carried out by the sixth grade students and a two-week long weather project carried out by the preservice teachers constituted the source of data for this study. The sixth graders carried out a pH scales and Acid-base activity; they also planned and carried out an Acid rain project over several weeks.

pH scales: In this activity, students tested various household substances for their pH levels and then classified them as acid, base, or neutral.

Acid-base activity: In this activity, students used universal indicator to examine the neutralization of acid and base.

Acid rain project: For this long-term project, the students worked in groups of three or four and designed an experiment to test the effects of spraying coleus plants with acidic, basic, or neutral water for 3 weeks.

Weather project: In this project, (freshman year) students from a physical science course collected data from weather reports on tv pertaining to a research question of their choice. They were asked to incorporate the variables pressure and temperature in their question; aside from that, they were free to investigate the changes according to their interest. They developed explanations for the patterns of changes they observed in the weather variables, discussed their findings with the instructor, received feedback, and submitted reports on their findings.

Data Analysis: The written reports from these projects are analyzed using inferences and the justifications as criteria for coding. These a priori coding criteria are based on the theoretical framework of the study and are guided by the research questions stated earlier in the paper (Miles & Huberman, 1994). Student reports are examined to see if they drew inferences from their observations, if their inferences are correct and supported by appropriate justification or not. The findings are discussed in detail in the following section.

Findings

The simple experimental tasks carried out by the sixth grade students involved making inferences based on observations. The simplicity of the tasks allowed a clear picture of where students used or ignored evidence in their inferences or justifications. It also provided a scope for guiding them toward further developing their thinking skills. For example, in the pH scales task inferences such as the "acids are sour" did not include the anomalous evidence they had from a soft drink, which tasted sweet. As they learned to examine data, in course of the subsequent tasks, the students illustrated a pattern of moving back and forth between valid and invalid inferences and justifications. This is not surprising given that other researchers (Kuhn, 1999; Siegler, 1996; Kuhn et al. 1995;) have found similar instability in inexperienced learners. Feedback on the ways students used evidence and justified their responses or drew conclusions constituted a major facet of this project. It appears that students – both sixth grade and preservice teachers benefited from this experience as their final reports illustrated improvement in two levels: one, they provided justifications for their inferences which was not usually the case at the beginning; two, they considered anomalous data in the process of making inferences.

The sixth grade students were capable of designing their long-term project on acid rain; working in groups of three or four individuals, they identified the independent and control variables to find the effects of acid rain on coleus plants[1]. In this case, they needed some help in operationalizing the dependent variable, specifically, the plant growth. Analyses of the final reports show that while most students could effectively make simple causal connections between variables from their observations, for some the beliefs and attachment to personal data became a barrier to logical inferences and justifications. The outcome of their experiment was contrary to their expected outcome as well as the composite group data, which indicated that the plants did better with plain water and did not do well when sprayed with acidic water. In their case the plant receiving the acidic spray of water grew well whereas the one receiving plain water died and they concluded that the acidic water was better even though they did not expect it. Nevertheless, these students used their own data to support their conclusion, even in the face of anomaly and in spite of the group data indicating a different trend.

This pattern adds a new dimension to Kuhn's (2001) and Kuhn et al.'s (1995) findings since, according them, individuals tend to have more confidence in their beliefs in the face of anomalous data rather than the data itself. In this case, the group believed in their own data even though it showed a pattern opposite to their own belief and to the larger dataset from the rest of the groups.

The reports written by the preservice teachers focused on more complex inquires as they explored the relationships among pressure, temperature, and humidity (this was the most commonly chosen additional variable) as the local weather changed from day to day. In addition to these variables, some students included some other variables in their studies as well. Nonetheless,

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[1] They had learned to design simple experiments in their science class earlier in the year.

overall, there were similar patterns in the development of the data interpretation skills of these students as well. Initially, the conclusions overlooked certain inconsistencies in the data but in course of time they learned to address anomalies, became more adept in drawing inferences based on data, and providing justifications based on evidence.

It was obvious that some of the essential aspects of reasoning processes were rare even in the freshman students' reports at the beginning. In order to learn to reason from "messy" data, students need to explicitly focus on this and instruction needs to guide them in the process; students need to learn a new array of evaluation skills for making sense of data involving complexity and anomaly. The findings further suggest that such skills need to be taught over an extended period of time but unless attention is paid to this aspect of learning science, students are unlikely to learn to make sense of data.

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