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Investigating the Development of Understanding and Scientific Reasoning via Cycles of Guided Inquiry Instruction

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Abstract: Inquiry in the scientific community involves a combination of first-hand investigation of the physical world *and* learning from the work of others (second-hand), which is primarily text-based. Our approach to science instruction (Guided Inquiry supporting Multiple Literacies) features an interplay of first- and second-hand experiences via multiple cycles of investigation in multiple contexts, which provide students with opportunities to use and develop ideas and ways of reasoning iteratively. This poster presents cases of GIsML instruction in 2nd and 4th grade classroom (studying light motion and light respectively) in which we trace – through the study of classroom discourse, student assessments, and artifacts – the development of conceptual understanding and scientific reasoning, including the ability to: a) conduct fair and reliable tests, b) observe specific aspects of the world to determine relationships among the parts, c) represent findings as knowledge claims, and d) evaluate the adequacy of knowledge claims based on the strength of the evidence supporting them. Results show: a) the role of multiple cycles of first- and second- hand investigations in supporting the deepening and refinement of knowledge, and b) the power of employing scientific reasoning *in the service of* building conceptual understanding.

Keywords: science education, elementary school, learning environments, discourse

Introduction

Inquiry is a complex form of thinking that has been developed over thousands of years. From a sociocultural perspective, it is a “cultural tool” of a psychological nature (Wertsch, 1998), an approach to reasoning that others have found useful. The conduct of inquiry in the scientific community typically involves a combination of first-hand investigation of the physical world *and* consultation and learning from the work of others (second-hand), which is primarily text-based. We have been working with a community of elementary school teachers over the past four years to plan, conduct, and study the outcomes of a culturally authentic approach to science instruction that features an interplay of first- and second-hand experiences. This paper describes the theoretical orientation and first principles underlying the instruction, which we illustrate by presenting two cases of learning in classrooms. Both cases feature the development of understanding and scientific reasoning; one case focused on learning about motion at the 2nd grade level, and the other case focused on learning about light at the 4th grade level.

The nature of the substantive knowledge (Schwab, 1964) targeted in each of these topic areas is specified within each case along with a description of the nature of the instruction. The goals relative to the nature of scientific reasoning are similar in each case and include knowledge about and the ability to: a) conduct fair and reliable tests to answer a question, b) observe specific aspects of the world in order to determine relationships among the parts, c) quantify observations to specify precisely the nature of relationships, d) represent findings as knowledge claims to a broader community, and e) evaluate the adequacy of knowledge claims from the community based on the strength of the evidence supporting them.

The Instructional Orientation

Our thinking about instruction follows the work of Shulman and colleagues, who view teachers' knowledge about instruction as rooted in an orientation, which is a set of values and beliefs about subject matter, pedagogy, and context. Our orientation is called Guided Inquiry supporting Multiple Literacies (GIsML). Inquiry in GIsML is assumed to occur through multiple cycles of investigation in multiple contexts, which provide students the opportunity to use and develop ideas and ways of reasoning iteratively. Full enactment of GIsML instruction is characterized by sustained engagement in a program of study situated in a learning community. Complementary use of first and second-hand investigations in a seamless manner results in children’s acquisition of deep understanding (demonstrated by language and action) of both the products and reasoning processes of science. The second-hand investigations utilize a new genre of text we developed that is modeled after a scientist's notebook.

To capture and understand the complexity of this instruction requires the use of multiple methods and data sources. Our methods have included procedures drawn from ethnography (e.g., participant observations and interviews) as well as quasi-experimental research (e.g., pre- and post-instruction paper/pencil assessments). Data sources include: a) transcribed videotape of classroom instruction, b) field notes describing instruction, c) assessments of individual student learning, and d) student artifacts generated during instructional activities.

Case 1: Developing Understanding and Reasoning about Motion (2nd Grade)

This case explores how a second grade teacher and her class negotiated their way through a program of study using balls and ramps that included four cycles of investigation. Two of these cycles were first-hand because the children analyzed data they collected themselves; the others were second-hand because the children interpreted data and conclusions generated by a fictitious scientist (Lesley Park) and represented in text form as a scientist's notebook (see Palincsar & Magnusson, 1999). Conceptually, students were expected to develop an understanding that: a) all objects *fall* at the same speed; i.e., they *fall* through equal distances in equal time, b) the steeper the incline the faster a ball falls, c) when an object in motion hits an object at rest, it can cause the object at rest to move, and d) the momentum of an object is related to its velocity and mass, and influences the motion of what it hits. They were also introduced to: a) modeling (Lesley uses balls of different masses to model the people and she uses an inclined plane to model the hill), b) the need to conduct multiple trials and record keeping via a table; and c) designing additional investigations to address questions arising from initial investigation.

Construction of this case employed data from video records, transcripts of instruction and teacher interviews, student artifacts, and pre- and post-instruction measures of understanding. Results of the analyses indicate: a) meaningful use of the texts occurred because of the interweaving of first-hand and second-hand investigations, b) a wide variety of strategies such as pantomime and careful questioning were used to mediate children's experiences with the texts, c) children's notebook entries were particularly helpful for linking first and second-hand experiences, and d) students appropriated the texts' language and conventions of scientific reasoning.

Case 2: Developing Understanding and Reasoning about Light (4th grade)

This case examined student learning from GIsML science instruction about light. Microgenetic analyses of children's discourse in whole class discussions, and assessments of students' content understandings were used to trace the development of students' understandings and scientific reasoning over an entire program of study. The progression of students' understandings were represented via a series of concept maps that were derived from classroom discourse as it unfolded over seven weeks of instruction. Targeted content goals about light included: a) all objects reflect light, b) light can be reflected, absorbed, or transmitted, c) there is an inverse relationship between the amount of light reflected from and absorbed by an object, and d) the law of reflection.

Results indicate that students' understandings about light surpassed expectations from previous research for this age group. Students' understandings of the nature of scientific reasoning showed improvement in their ability to represent data, their understandings of the general processes of investigation, and to some extent, their use of evidence to support claims. However, their ability to discuss the phases of their investigations at a metacognitive level was limited. The use of texts in the genre of a scientist's notebook afforded opportunities for students to engage in inquiry processes while conducting text-based investigations. Students learned to read and interpret text and graphical representations of data, to critically evaluate a scientist's claims made from her data, and to apply the information in the texts to their own developing understandings. Students held a skeptical view of the information found in the texts, which is authentic to the practice of scientists.

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