A Study of Grade Six Students Generating Questions and Plans for Open-Ended Science Investigations

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Abstract

The purpose of this study was to investigate the reasoning strategies of urban Year 6 students involved in creating their own questions and plans for scientific investigations. The study focused on how the students generated ideas for their investigations, characteristics of their questions, cognitive tasks involved in designing investigations, the management of variables and the emerging roles of the teachers who mediated investigative activities. The instruction was based on the generative model of teaching primary science (Harlen & Osborne, 1985), which includes stages for exploration, investigation and reflection. The interpretive study was based on videotaped data of students' discussions during investigation planning, the students' written documents and field notes. The results indicated that students pursued two major avenues for question generation, varying the teacher directed exploration activity and inventing questions from their own imaginations. Students designed investigations that were both experimental and descriptive in nature. Cognitive tasks for the students centred around transforming abstract ideas into physical objects and events, especially with regard to defining, choosing, and measuring variables. Main roles for the teachers were identified as encouraging group collaboration, and evaluating and influencing variable selection.

The current wave of science education reform literature emphasises learning science as inquiry. For example, in the United States, authors of the National Science Education Standards assert that “Inquiry into authentic questions generated from student experience is the central strategy for teaching science” (National Research Council (NRC), 1996, p. 31). The content standards for science inquiry at years 5-8 include the following: “Identify questions that can be answered through scientific investigations,” “Design and conduct a scientific investigation,” and “Develop descriptions, explanations, predictions, and models using evidence” (NRC, 1996, p. 145). These statements reflect the view of a majority of science educators, who believe that students should build on their own knowledge, explore questions that are of interest to them, and learn to use inquiry strategies to build conceptual understandings. However, there is relatively little classroom research on the how young students respond when they are asked to pose their own questions and design investigations to answer those questions.

The purpose of this study was to examine the reasoning strategies of Year 6 students who had the freedom to generate their own questions for investigation in an everyday classroom setting. A naturalistic approach was used. Year 6 was chosen because it represents a transitional age between the more concrete thinking of the elementary child and the more abstract thinking of the secondary child. Four research questions guided the study: (1) How did the children generate questions for their investigations and what were characteristics of their questions? (2) What were the most important cognitive activities of the children during investigation planning? (3) How did students who designed experiments manage the manipulation of variables? (4) What major roles emerged for the teachers in the study in regard to mediating students investigation questions and plans?

While reformers urge the development of curriculum in which children pose inquiry questions and design investigations to answer those questions, literature on the feasibility of such activities and their potential learning outcomes remains inconclusive. In a 1995 review article,
Metz outlined a compelling argument that research to date provided no support for the theory that young children are not developmentally able to perform investigations, especially in scaffolded instructional environments. Metz advocates involving young children in abstract problems that go beyond seriation, classification, and observation to promote understandings of the nature of science, practice with scientific processes in a meaningful context, and increased motivation (Metz, 1995). Yet several studies have indicated that children do not think like scientists when confronted with experimental tasks. Clinical research on the development of scientific reasoning in pre- and early adolescents (Carey & Smith, 1993; Dunbar & Klahr, 1989; Kuhn, 1993; Kuhn, Amsel, & O’Loughlin, 1988; Kuhn, Schaub, & Garcia-Mila, 1992; Schaub, Klopfer, & Raghavan, 1991) indicated that elementary children tend to remain attached to their personal theories, so that they have difficulty: a) producing causal hypotheses from their ideas; b) deducing possible consequences from the hypotheses; and c) effectively evaluating the meaning of experimental data. Kuhn and her colleagues (Kuhn et al., 1992) concluded that both primitive and sophisticated strategies for making inferences from data are simultaneously present in a child’s repertoire and compete with one another.

Some recent classroom studies of experimental design in children aged 11-13 years (Duggan, Johnson, & Gott, 1996; Germann, Aram, & Burke, 1996; Gott & Duggan, 1995) indicated that most 11 year olds were able to design clear experiments when given only one independent and one dependent variable, but had difficulty with cognitive tasks such as manipulating two independent variables, conceptualising data as continuous, quantifying data, graphing, and evaluating the validity of data. DeTure, Fraser, Giddings and Doran (1995) found that Year 5 students were fairly proficient at observing, describing, and measuring, but their processes of hypothesising, concluding, and explaining were generally weak. Duggan et al. (1996, p. 472) suggest that children’s failure to “keep the whole task in mind,” including their lack of understanding about the purpose and ultimate goal of data collection may be a barrier to rigorous experimental design and analysis. Thus, there is substantial evidence that children do have difficulty mentally processing the investigation problems put to them by adults, even when they appear to be actively engaged in these investigations. Rath and Brown (1995) report that children approach inquiry from motivational frames that differ significantly from the intentions of adults, including performance, fantasy, pet care, exploration and engineering.

Operating from the theoretical perspective that school science should be primarily based upon children’s present interaction with their world, rather than concerns for future learning, pioneering researchers in the Learning in Science Project in New Zealand worked extensively with children on generating questions of authentic interest (Biddulph & McMinn, 1983; Biddulph & Osborne, 1982; Biddulph & Roger, 1983; Biddulph, Symington, & Osborne, 1986; Symington, Osborne, Biddulph, & Freyburg, 1982). In contrast to the studies described above, they posited that children should be able to investigate their own questions, whether or not they lead to productive hands-on investigations. This program of research resulted in some extremely interesting findings, based on classroom interactions with Year 3 and 4 students. The children reacted very positively to instruction that encouraged them to ask questions and brainstorm possible answers, but their ability to evaluate the reasonableness of potential answers was weak, due to their lack of experience with research skills. Although they achieved some degree of success synthesising information from reading and interviewing, the children were unable to design and conduct any meaningful practical investigations that responded to their questions. The authors attribute this weak performance to the children’s lack of prior knowledge and processing strategies (Biddulph & McMinn, 1983). Recently, guides and planning documents have become available to scaffold both teachers and students in the process of developing meaningful investigations (Hackling & Fairbrother, 1996), yet again, these plans are predicated upon the teacher posing the question for investigation, rather than the students inventing their own questions.