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Primary students' scientific reasoning and discourse during cooperative inquiry-based science activities

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ABSTRACT

Teaching children to ask and answer questions is critically important if they are to learn to talk and reason effectively together, particularly during inquiry-based science where they are required to investigate topics, consider alternative propositions and hypotheses, and problem-solve together to propose answers, explanations, and prediction to problems at hand. This study involved 108 students (53 boys and 55 girls) from seven, Year 7 teachers' classrooms in five primary schools in Brisbane, Australia. Teachers were randomly allocated by school to one of two conditions: the metacognitive questioning condition (Trained condition) or the prescriptive questioning condition (Untrained condition). Data on students' discourse and reasoning and problem-solving (RP-S) were collected across Times 1 and 2. The results showed that while there were significant differences in the discourse categories of the students in the two conditions at Time 1, the only significant difference was in questioning behaviour at Time 2 with the students in the trained condition continuing to ask more questions than their untrained peers. Given that these students had been taught to specifically ask 'thinking' questions that probed and interrogated information, these results are not surprising. A follow-up examination of students' discourse during their small group discussions illustrated how these students interacted with each other to probe and interrogate information by providing explanations and reasons to make their thinking explicit and by using analogies to verbally represent concepts they were trying to express. Results on the follow-up reasoning and problem-solving (RP-S) tasks indicated that students in the Trained and Untrained conditions improved their scores from Time 1 to Time 2 although the change was not significantly different between conditions.

1. Introduction: importance of dialogic talk

Attention in recent years has focused on teacher–student dialogue, commonly referred to as 'dialogic talk' and the effect it has on students' capacities to use talk as a tool to promote reasoning, problem-solving and learning (Mercer, 2008a; Wegerif, Littleton, Dawes, Mercer, & Rowe, 2004). The key role that social interaction plays in the development of children's thinking has been documented in studies that have, for example, examined how exploratory talk, an approach that teaches students how to engage in critical but constructive dialogues with each other, can be used to promote thinking and reasoning (Rojas-Drummond, Perez, Velez, Gomez, & Mendoza, 2003; Wegerif et al., 2004) while others such as Anderson et al. (2001b) have shown how children develop argument stratagems from collaborative reasoning experiences when they dialogue together.

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Topping and Trickey (2007) and Trickey and Topping (2006) used a 'thinking skills' intervention called Collaborative Philosophical Enquiry based on Lipman's (1988) Philosophy for Children (P4C). Here children are taught through teacher scaffolding to engage in reciprocal dialogues designed to promote deeper understandings on issues under discussion and found that the students demonstrated cognitive and social gains and these gains were not only maintained two years later but also transferred across school contexts. Similarly, Gillies (2004) and Gillies and Haynes (2011) focused on teaching teachers specific communication strategies designed to promote thinking and learning in their students and reported how, this training, in turn, promoted more elaborative discussions among students and higher scores on follow-up reasoning and problem-solving tasks. In short, Mercer et al., Wegerif et al., Anderson et al., Topping et al., and Gillies and Haynes (2011), highlight the importance of teaching students how to dialogue together to promote thinking, problem-solving and reasoning.

1.1. The role of questioning

Teaching children to ask and answer questions is critically important if they are to learn to talk and reason effectively together, particularly during inquiry-based science where children are required to investigate topics, consider alternative propositions and hypotheses, and problem-solve together to arrive at an agreed solution (Gillies, 2011; Gillies, Nichols, Burgh, & Haynes, 2012). While children's curiosity is widely considered to be a natural resource for classroom inquiry, it is well recognized that children do not spontaneously ask and pursue questions about their own learning (Meloth and Deering, 1999; Zuckerman, Chudinova, & Khavkin, 1998). They generally do not ask thought-provoking questions, and do not spontaneously use and activate their prior knowledge unless specifically guided to do so; however, when they did, it predicted the learning that occurred (King, 1999).

Sadly though, many teachers often do not model how to ask and answer thought-provoking questions, preferring to engage in initiation–response–feedback (IRF) interactions where children are only expected to provide low-level thinking responses to the teacher's questions (Herbal-Eisenmann & Breyfogle, 2005). In a study of the interaction patterns of teachers and students in elementary mathematics classrooms, Wimer, Ridenour, Thomas, and Place (2001) found that only approximately 15% of teachers' questions were higher-order questions or questions that required children to think critically about the topic under discussion. Galton, Hargreves, Comber, Wall, and Pell (1999), in a study of teachers' questioning behaviour in primary schools, also noted that children are rarely asked cognitively challenging questions where they are required to think critically about the issues and justify their responses. This creates a conundrum because Webb et al. (2008) found that when question–answer sequences resemble IRF interactions, teachers model the role of the "teacher" as an active problem-solver and the role of the student as a "passive" recipient of the teacher's instruction. Unfortunately, when this type of interaction pattern occurs, students mirror this interaction style in their small groups with students often providing help that is low-level and giving answers rather than explanations while students who receive the help act as passive recipients of this help. In most instances, students rarely share their thinking or problem-solving strategies or probe each other's thinking. Interestingly though, when teachers do ask high-level questions that challenge students' thinking, students do provide more detailed help and assistance to their peers and this has a positive effect on their learning (Gillies, 2004; Gillies & Khan, 2008; Webb, 2009).

1.2. Questioning in inquiry science

There is no doubt that asking high-level questions challenges students to consider their current understandings in the light of possible alternative explanations so they learn to engage with more than just facts but, rather, determine "how" and "why" they know something (Scott, Mortimer, & Aguiar, 2006). Van Zee, Iwasky, Kurose, Simpson, and Wild (2001) found that when teachers set up discourse structures that explicitly elicit student questions (i.e., student-generated inquiry science discussions), engage them in conversations about familiar contexts (i.e., tap prior knowledge and experiences), and create comfortable discourse environments to help students understand one another's thinking, students, in turn, are more likely to demonstrate abilities to converse thoughtfully by explaining their ideas and asking questions of one another. In so doing, they are more likely to reflect on their assumptions, claims, and warrants in constructing scientific arguments.

In an investigation of teacher questioning and interaction patterns in classrooms employing different levels of constructivist teaching practices during inquiry science, Erdogan and Campbell (2008) found that teachers facilitating classrooms with high levels of constructivist teaching practices, or classrooms where students are engaged in active investigations with their peers, asked significantly more questions and they asked a significantly greater number of open-ended questions or questions designed to facilitate knowledge construction than teachers facilitating classrooms with low levels of constructivist teaching practices or classrooms where teacher instruction appeared to be the dominant form of interaction.

However, despite the over-whelming evidence that asking higher-level, open-ended questions have the potential to promote students' higher-level reasoning and problem-solving, teachers still struggle to use these types of questions when interacting with their students. Reinsvold and Cochran (2011), for example, in their study of the power dynamics and questioning of one elementary teacher during inquiry science noted that the observed classroom discourse tended to be controlled by the teacher with limited student subject matter discourse that seemed dependent on closed-questioning. The authors concluded that the implementation of inquiry teaching to enhance student higher-level reasoning may be much less common or straightforward than expected even though the teacher in this case was using inquiry materials and processes