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Evolution of Research Methods for Probing and Understanding Metacognition

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Abstract This paper reports on the development, self-critique and evolution of research methods for interpreting and understanding students' metacognition that were developed through the Metacognition and Reflective Inquiry (MRI) collaborative study. The MRI collaborative was a multi-year, multi-case, research study that investigated the elusive nature and character of high school students' metacognition across formal and informal science learning contexts. The study's research design comprised a series of integrated, layered, interpretive case studies which were conducted in a hermeneutic fashion over a 3 year period. The implementation of each case study provided an opportunity for the researchers to reflect critically on the research methods used to elucidate metacognition and hence refine the individual and collective capacity, responsiveness and fruitfulness of the methods used. This paper discusses the evolution of these methods and the lessons that the entire study provides for the conceptualization of other qualitative-interpretivist studies.

Keywords Research methods · Metacognition · Qualitative research · Research design

Nature and Definition of Metacognition

Metacognition is a construct that is often considered to have a core focus on the improvement of students' learning processes and outcomes. Flavell's seminal work (Flavell 1976, 1979) has generated continued interest in and research regarding how educators can develop, enhance, and measure students' metacognition. However, there appears to be no uniform definition of metacognition in the literature (Larkin 2006). Veenman et al. (2006) highlighted the ongoing concern raised by Wellman (1985) that metacognition is a fuzzy

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concept that lacks coherence and that means many things to many people often varying as a function of the researchers' personal subscriptions or identifications with a given research paradigm and/or view of the world. They note that, "...while there is consistent acknowledgement of the importance of metacognition, inconsistency marks the conceptualization of the construct" (p. 4). This issue is evident within the science education literature where metacognition has been defined as, for example, knowledge, control and awareness of learning processes (Baird 1986; Baird and White 1996; Thomas and McRobbie 2001) and the ability to think about one's thinking (Gilbert 2005). In addition to the challenges of variations in definition of the construct, metacognition is an elusive and difficult to discern cognitive phenomenon, and hence, revealing metacognition and elucidating its nature and character is a highly challenging task for researchers (Veenman et al. 2006; Wellman 1985). Moreover, Scraw and Impara (2000) assert that there is a discrepancy between metacognitive measurement and practice, and considerable debate regarding the relative pros and cons of different assessment methods aimed at understanding the nature and character of metacognition.

Common Methodological Approaches to Probing and Understanding Metacognition

Historically, approaches employed by those who investigate metacognition can be understood as a function of the research paradigm with which they are aligned and their definition of metacognition. Although there are many ways in which conceptualizations of research in this area might be stratified, our review of the field leads us to view research studies as broadly falling into two categories—*positivist-decontextualist* and *revelativist-contextualist* paradigms (Brewer and Collins 1981; Nott and Wellington 1993).

The *positivist-decontextualist* studies of metacognition are characterized by research that has been conducted by way of elaborate designs and complex statistical analyses (Nelson and Narens 1990; Gunstone et al. 1988), and an approach to research that seeks simple answers to the complex world of the learner and classroom by creating a simpler, but artificial, world (White 1992, 1998a, b). Important learner and context variables, for example, the motives of students and teachers, the nature of the subject matter, processing demands of tasks, time constraints for completion of tasks, and the effects of the intervention itself on the functioning of the classroom have most often been considered unwanted errors, a nuisance, and of little research interest at all (Gunstone et al. 1988; Petersen and Swing 1983; White 1998a, b). Researchers subscribing to this paradigm have also typically sought to design experiments that use experimental controls with the aim of eliminating self-directed processes (Nelson and Narens 1990). Such approaches seek to eliminate contextual factors and any resultant ambiguities (Popkewitz 1984) and often use one method within the research design with which to reveal and/or understand metacognition. By 'methods' we refer to specific strategies, instruments and procedures employed in the procurement, analysis and reporting of data within a research methodology. By 'methodology' we refer to the research design, including its foundations, assumptions, limitations, and characteristic procedures and outcomes.

Studies embedded in and reflecting a *relativist-contextualist* paradigm regard such factors as being influential in relation to the development of metacognition. They consider the natural ecology of the learning environment in which the learner is embedded as holding a vitally important set of parameters with which to understand the learner and his or her metacognition. Moreover, studies aligned with this paradigm are typically qualitative and interpretivist in nature. Successful attempts to study metacognition that reflect this

paradigm include Baird and Mitchell (1987) and Baird and Northfield (1992)—the PEEL Project; Baird (1986); Thomas and McRobbie (2001); and Anderson and Nashon (2007). Central to the research methodology employed in these studies is an acknowledgment that the complexity of the learning environment must be recognized and accounted for as much as possible, and that teachers should play an active role in developing metacognition and cognitive strategies while at the same time respecting students' intellectual integrity and autonomy. In addition, these studies utilized multiple data forms that emanated from the use of a variety of research methods in the research design to help to better interpret and understand the nature of metacognition, to triangulate data and to point the way to credible conclusions. Researchers immersed in this paradigm see a need to understand students' metacognition in the context of natural, purposeful activity so that ecologically valid solutions (Bronfenbrenner 1979), can be found to the real-life, educational problems of teachers and students. It is our view that the kinds of research questions that can more fruitfully assist educators to improve students' learning processes and outcomes are embedded with this paradigm. Moreover, a renewed and on-going scrutiny of methods for collecting and analysing empirical data gathered in a naturalistic manner is needed to fulfil the objective of seeking deeper understanding of metacognition, its development, and its effect on student learning.

Numerous methods have been used in research into metacognition, for example, questionnaires (Pintrich and de Groot 1990; Thomas 2003), interviews (Zimmerman and Martinez-Pons 1990), the analysis of thinking-aloud protocols (Afflerbach 2000; Veenman et al. 1993), stimulated recall (Van Hout-Wolters 2000; Thomas and McRobbie 2001). The methods employed are chosen according to the methodology and the research paradigms in which the study is embedded. Hence, it should be pointed out that each of these methods have inherent pros and cons and, moreover, their strengths and weaknesses are a function of the research paradigm in which they are imbedded. According to Veenam et al. (2006), questionnaires, for example, can be easy to administer to large groups, whereas thinking-aloud protocols are suitable for individual assessments. Further, some of the assessment methods, such as face to face interviews, may be more intrusive than others. Veenam et al. (2006) further posit that it is important to determine more precisely what metacognitive knowledge or skill component can be assessed successfully with which methods. In other words, it appears that each metacognitive skill might require different assessment methods, which depend on the character of that skill. Studies have for instance shown that questionnaires can be used to assess metacognitive activity or strategy, the scores on these questionnaires may not always correspond to actual student behavioral measures during task performance (Veenman 2005; Veenman et al. 2003). This background into previously used and critiqued methods motivated us to develop an innovative, more comprehensive design of a study incorporating multi-methods that aimed at investigating students' metacognition cross-contextually within a qualitative-interpretivist paradigm.

The Metacognition and Reflective Inquiry Study

The Collaborative for Metacognition and Reflective Inquiry: Understanding learning across environments – [Metacognition and Reflective Inquiry (MRI) Collaborative], was a multi-year, multi-site study established in 2003 and concluded in 2007, constituted by the collaborative endeavours of several institutions – University of British Columbia, Vancouver, Canada (the lead institution); Hong Kong Institute of Education, Hong Kong, China; the Minnesota Science Center, Minneapolis, USA; Iwate University, Morioka,

Japan, and the University of Queensland, Brisbane, Australia (see Anderson and Nashon 2007; Anderson et al. 2007; Hisasaka et al. 2004; and Thomas et al. In Press). The MRI Collaborative existed for the purpose of investigating the experiences of metacognition through reflective inquiry across "learning environments" and "contexts". The partner institutions in the MRI Collaborative investigated the same core research questions in addition to other specific research questions that are relevant to their particular settings of investigative research. Core research questions included:

1. What is the nature of metacognition evident among students situationally interpreted across the learners' context?
2. How does students' metacognition change as their learning from field trip experiences is recontextualized in and beyond the classroom?

The MRI research design comprised a series of integrated, layered interpretive case studies (Gallagher and Tobin 1991; Merriam 1998; Stake 1995) which were conducted in a hermeneutic fashion (Guba and Lincoln 1989) over a 3 year period, from which conceptual generalizations were derived that elucidated the common and developing experiences of science students' metacognition. Highly descriptive accounts of the richness of individual's (and later group-level) metacognition were progressively captured. Interpretive strategies are appropriate for this type of investigation since, 1) the holistic, cross contextual nature of metacognition is not well understood; 2) the strategies employed were for the greater part congruous with the researchers' epistemological views of learning and metacognition and 3) the research questions of this study required a series of hermeneutic cycles of data gathering, analysis and interpretation, each informing and shaping the next.

The MRI study considered metacognition to be the active monitoring, conscious control, and regulation of learning processes (Baird and White 1996; Baird 1986; Flavell 1987; Gunstone 1994; Larkin 2006; Thomas 1999a; Thomas and McRobbie 2001; White 1993, 1998a, b). The investigators' view of metacognition was framed on the basis of ontological and epistemological underpinnings that view learning as occurring holistically and not just in isolated contexts only (Ausubel 1963; Bruner 1996), and metacognition as being dynamic and not the domain of any one single context or experience (Flavell 1979). Additionally, learning and metacognition were viewed as processes that manifest cross-contextually, and hence can be examined across both formal and informal contexts. Moreover, learners' personal conceptions of themselves as learners, their self-awareness and control of their learning processes were considered both empowering and limiting factors in ways they construct knowledge. These considerations further informed the research design, methods and interpretation of data over the period of the research.

The General Methodological Procedures of the MRI

The participants of the MRI studies were all Year 11 high-school science students, whose metacognition was investigated through the local contexts (see Table 1) mediated by either their school physics or biology curriculum. The initial procedural scripts for investigating and interpreting metacognition varied slightly among the various case contexts of the MRI (see Table 1) but all involved three general stages which were largely common to all.

Stage 1 Participants took part in experiences designed to cognitively engage them within small groups in both informal and formal settings. These experiences were video recorded and, as in most studies investigating metacognition, they were important to provide students

Table 1 Staggered phasing of stage one, two, & three method as a function of case

Research site	Case context	Case classes	Case group	2004						2005			2006				
Vancouver Canada	Amusement Park Physics	Class 1	Group A	1	2	3											
			Group B	1	2	3											
		Class 2	Group C		1	2											
			Group D		1	2	3										
Morioka Japan	Amusement Park Physics	Class 3	Group E			1	2	3									
		Class 4	Group F			1	2	3									
Vancouver Canada	Environmental Nature Centre	Class 5	Group G							1	2	3					
			Group H							1	2	3					
			Group I							1	2	3					
Brisbane Australia	Environmental Nature Centre	Class 6	Group J										1	2	3		
			Group K										1	2	3		
			Group L										1	2	3		
Vancouver Canada	Marine Science Centre	Class 7	Group M											1	2	3	
			Group N											1	2	3	
			Group O											1	2	3	
			Group P											1	2	3	

with opportunities for personal engagement in metacognition and to establish rich personal episodes with which participants could later discuss their own knowledge, self awareness, monitoring, evaluation and control of their knowledge construction and cognitive processes. The group format was intended to enhance participant engagement and increase opportunities for argumentation and higher order cognition (Driver et al. 1997; Duschl and Osborne 2002). In the case of the MRI studies, these experiences were holistic in nature in that they were not solely micro-learning and/or classroom-based experiences but, rather, they were contextually embedded (real science in real world field settings), cross contextual (field settings and classroom) extended learning episodes. This conception of the cognitively engaging experience is in itself an evolution given that many previous science education studies of metacognition have tended to consider micro-learning, classroom-based experiences such as solving math or chemistry problems.

Stage 2 Personal stimulated recall of the experiences in order to permit self-reflection of the participants' own learning and metacognition. This involved the capturing of the audio of individual participant's conversations, during the first stage, by means of personal digital audio recorders which were transferred to compact discs to which participants listened. This provided a mechanism beyond simple memory recall of stage one, and a supportive experiential opportunity for participants to listen to themselves and reflect on their own metacognition and learning processes and their interactions with others.

Stage 3 Face-to-face interviews with group members incorporating the use of a semi-structured interview protocol. The protocol (See Appendix) permitted and facilitated focused yet open-ended discussion concerning the participants' experience of stages one and two. In addition, video excerpts of whole group interactions from stage one were shown during the interviews, a practice that provided an additional rich and highly qualitative means of stimulated recall to elucidate and understand the nature of the metacognition manifest among the participants and groups within which they were situated. Table 1 illustrates the staggered phasing of stages one, two and three as a function of case.

Based on the focus of our study, interpreting metacognition and learning cross-contextually, the students worked collaboratively in small groups as a means of revealing their metacognitive skills. The focus of this paper is to discuss the methods and their evolution as they developed iteratively as part of an interpretive study that sought a fine resolution of the phenomena under investigation in situ.

Our Evolution of Methods

As with any well designed research study, the conceptualization of research methods requires careful thought and development. Methods are designed and crafted in keeping with the researchers' epistemology and in a manner which supports the overall research design of a study which in turn support the best practicable approach to answer a study's research questions given the constraints inherent in the research context, i.e., time, budget, limitations of participants, and so on. In the context of the MRI study, the methods were constituted with these principles in mind in keeping with the research team's knowledge of contemporary research practices derived primarily from the literature. But, because the study was multi-faceted, comprising several repeated years of data collection with multiple cases in multiple sites, the research team was afforded the benefit of itself learning and hence developing and refining the study's methodological practices. Changes in method were in response to concerns discerned through the research team's collective critical reflection and scrutiny of the effectiveness of the methods in probing and elucidating metacognition. These issues which drove change were not immediately apparent without a broader contextual appreciation and perspective about the nature of metacognition and its enactment in the real world that developed as the study progressed. We contend that what might appear to some as only minor changes in methods were in fact substantive leaps forward in the evolution of methods to more fruitfully understand the contextual nature of metacognition. The following sections discuss four key evolutions in methods embedded in stages one, two and three, that were designed to stimulate and probe metacognition.

Researcher Selected to Participant Selected Incidents of Whole Group Interactions

Consistent with many of the methodological practices surrounding the use of stimulated recall, the MRI methods dictated that the research team first identified and selected several incidents (or small episodes) from the video data of participants' engagement in activities and later posed these to the participants for discussion and probing as part of a follow up interview. This process required the research teams' collective viewing of the students' engagement in activities, the transcripts of the students' conversations, and personal field notes derived from stage one. The researchers' rationale and justification for section of incidents was based on three criteria. Firstly, incidents were selected that appeared indicative of the deployment of metacognitive strategies by a group member or the entire group, for example, evaluation of self knowledge, self-selection of learning strategy and/or evaluation of that strategy. Secondly, incidents were chosen that were indicative of cognitive struggle or impasses which, in the eyes of the researchers, were often episodes that required group members to reflect deeply on their knowledge and problem solving strategies and that were fertile ground for deeper levels of metacognition to manifest. Thirdly, incidents that were considered indicative of individuals' engagement of higher order thinking skills, and which were again believed to be indicators of recent engagement of metacognition were selected. With these criteria in mind, a set of 5 or 6 incidents was

short-listed for each group. Team discussion and negotiation regarding the capacity of these incidents to engage participants and generate self-awareness and elaborative discussion regarding various aspects of their own metacognition then led to a ranking and identification of three incidents to be used in an interview.

In stage three, the participants were asked a variety of questions pertaining to their experiences in stage one, viewed the researcher-selected critical incidents and were asked to reflect on the specifics of these incidents, and finally were asked to discuss the experiences of listening and self-reflecting on the experiences of stage two. The following sections report on the challenges and the subsequent evolution of the researcher-selected critical incidents method. Issues regarding efficacy or otherwise and subsequent evolution of the methods of stimulated recall are reported in the next section.

The critique In the cases and sub-studies of the MRI, participants who were interviewed and shown researcher selected critical incidents of themselves were interested to see their personal and group interaction in the group activities. However, the success of this strategy in revealing and elucidating metacognition had several limitations. Firstly, in every instance, the viewing of self was a highly novel experience that in many ways distracted the participants from being able to focus on the issues which were of interest to the researchers. Secondly, the participants were, for the first time, being asked to see and hear critical incidents of the whole group that they had not been instructed to reflect upon until that moment during the interview and hence they were often not able to recall or appreciate readily the meaning or significance of an incident for their learning and metacognition. To this end, participants' conversations and discussions in relation to what we considered to be critical incidents were sometimes not as informative as hoped for despite intensive probing. Thirdly, and consequently, the research team was at times perplexed by the lack of participant response to incidents strongly judged by the team to be appropriate for stimulating reflection and eliciting insightful responses and discussion that would attend to the research objectives. Our sense of puzzlement was fueled by comparing what was being stated by the students in the interviews in the earlier stages of the MRI to the type of statements from students that are evident in the literature, e.g. Baird and Mitchell (1987); Baird and Northfield (1992); Thomas and Au (2005); Thomas and McRobbie (2001). Students' often offered brief responses such as, "I don't know," and, "I'm not sure" to open-ended questions such as "How would you describe your role in this group?" and, in relation to students interacting with each other, "What were you thinking at that time as you were looking at these two (other group members) having a conversation?" Such statements were not informative in relation to understanding students' knowledge, control and awareness of their thinking and learning processes. We contemplated that such a lack of explication might be a consequence of, (a) the novelty of the stimulated recall interview itself for participants and, (b) their lack of familiarity and sense of association with the episodes selected, and that we needed to consider means to address these matters.

Our reflections on these matters led us to several conclusions which we considered required us to make changes to our methods. Firstly, we considered that participants probably needed time to become familiar with the novel experience of viewing a video of them individually and of their group's interactions. We believed that providing such opportunities might have a moderating effect on the overall novelty of these experiences and permit more focused engagement and self-reflection in relation to learning and metacognition. Secondly, because it was apparent that the participants were for the first time being asked to see and hear a critical incident of the whole group that they had not

necessarily ever reflected upon, we posited that opportunities to preview critical incidents prior to interview could afford opportunities for more meaningful reflection and insights. This is consistent with our general epistemological view that repeated dialectic reflection aids in deeper self insights about one's own learning and metacognition (Nashon and Anderson 2004). Finally, we began to speculate that what is of importance, significance and relevance to the researchers' view of the participants' experiences was not always congruous with that which was important, significant or relevant to the participants' perspectives of their own learning experiences. This speculation was, in part, based on previous research, e.g. Anderson and Lee (1997), Baird and Mitchell (1987); McRobbie and Tobin (1997); and Thomas (1999b), which demonstrated that student perspectives of what is important in a learning environment may vary from those of teachers and researchers and that students should be given some voice in the research process. Therefore, we asked ourselves, "Why not ask and encourage the students to select episodes that they considered might best reflect their thinking and interactions during their field visits?" To this end, opportunities for participants to self identify and self-select their own critical incidents that they wished to discuss with the researchers were considered potentially advantageous and worthy of providing.

The Evolution As a consequence of our reflections we modified our approach to one where we provided an opportunity for the participants to self-select a set of incidents and to use the set as the basis for stimulated recall and discussion during later enactments of stage three throughout the latter MRI studies. Several days prior to the enactment of stage three, the participants were provided with a video of their group interactions which they viewed. On the basis of their viewing they collectively negotiated three incidents in keeping with our rationale and justification criteria. This approach satisfied the three reflections on the challenges to the original methodology. We also used a smaller set of researcher-selected critical incidents because we held a view that there were some incidents not identified by the participants that we ultimately wanted to probe. Ultimately, we suggest that both be considered important.

Individual Audio Stimulated Recall to Whole Group Video Stimulated Recall

Several studies have previously established benefits of the use of stimulated recall as a method to elucidate metacognition (Marland 1984; Edwards and Marland 1982, 1984; O'Brien 1993). The reliability and validity of stimulated recall as a method are bounded by the participants' ability to remember the experiences under investigation (Rowe 1991). Our initial method involved the capturing of the audio of individual participant conversations during stage one. This was achieved by means of individual lapel microphones connected to small personal digital audio recorders which each participant wore as they were engaged in group activity. At the conclusion of each activity the audio data were transferred to individual compact discs, which were in turn given to each participant so they could listen to the recording of their own conversations and engagement. As previously mentioned, this provided a mechanism beyond simple memory recall and an additional experience which was itself a metacognitive activity that enabled the participants to reflect on their metacognition and learning processes. During stage three of the methodology, the participants were probed about the experience of listening to themselves and the insights they had gained about their learning and metacognition.

The critique The reaction of participants in the MRI sub-studies to the stage two experiences was only moderately fruitful towards the objective of revealing insights about the nature of participants learning and metacognition. Both the extent and depth of the critical self reflection were limited to several common themes. First, personal self-deprecations concerning the limits of their contributions to the group, such as "I didn't realize how much/or little I talked" or "I didn't realize how often I interrupted". Second, personal realizations about roles adopted within the group, for example, "I thought I was the idea giver" or "I was the one bringing the group back on task". Third, occasional surface level revelations about themselves as learners, for example, "I realized that I sometimes use others' ideas" or "I was adding to ideas and connecting with others' answers". The participants were for the most part not able to discuss at length or in detail the personal revelations gained surrounding themselves as learners. We considered this situation less than optimal for the purposes of our research.

Our reflections on these matters led us to propose that there were several limitations associated with this method. Firstly, we considered that exposure and practice to the process of listening to oneself was beneficial for facilitating overall reduction of novelty so as to better enable the participants to critically self reflect. Secondly, the listening to personal audio conversations of oneself constitutes a limited representation of the overall discourse and behavioral interactions that occurred within groups in stage one. The lapel microphones and personal digital recorders captured reasonable representations of individual conversations, but were poor at capturing the entire group conservations of which the individual was a part. Thus, this method of capturing individual discourse often suffered from the absence of the wider group discourse. Additionally, audio data represents only one part of a larger behavioral discourse and interactions of the individual embedded within the group. There were often very many things communicated non-verbally through group interactions that were not captured by the personal audio recorder. Finally, we considered that individual critical reflection did not allow us access to any potential benefit that might be derived from a group or collective critical reflection which would inherently contain multiple voices and perspectives.

The Evolution We modified our approach to one where we provided participants with copies of the DVD video recordings of their whole group interactions from stage one instead of individual audio recordings. Stage two was thus modified to provide participants with the opportunity to meet together in their original groups several days after stage one to view their DVDs of their stage one engagement. The modified method built in time for participants to reduce the deleterious novelty effects associated with viewing themselves for the first time. Participants were collectively given full autonomy to self-select and negotiate within their groups a set of three critical incidents consistent with the rationale and justification for the selection of incidents previously discussed. This change satisfied the researchers' concerns regarding the original methodology in that it provided opportunity for novelty reduction, for the capturing of a much boarder sample of the group discourse, the behavioral discourse, and an opportunity for the whole student group to reflect critically. Hence, these changes led to opportunities for students to self-select critical incidents that might more fruitfully enable them to reflect critically and discuss the incidents that elucidated their learning and metacognition.

Individual Units of Analysis to Group Units of Analysis

Most science educators and science education research studies have tended to almost exclusively focus on the individual as the unit of analysis when examining learning and

metacognition. The reasons for this are rooted in the historic traditions of science education research. However, the more dominant rationale possibly lies within educational assessment systems in schools that focus on the measurement of individual achievement. Paradoxically, science educators recognize the value of group work for meaningful learning and social constructivists commonly consider the groups as the units of analysis yet, to our knowledge, no studies of metacognition have considered group units of analysis: yet both would seem important to consider. In the initial phases of the MRI studies, the research team's epistemological position was one that sought to understand the nature of metacognition predominantly through the unit of the individual embedded within a group setting. Hence, the focus was in keeping with much of the traditional methods and historic examination of metacognition that considers the individual as the unit of analysis.

The Critique The research team's interpretations of learning and metacognition that manifest in numerous case groups across the MRI and its sub-studies bore testimony to the fact that not only were individuals metacognitive, but that the groups in which individuals were embedded behaved and responded in ways that demonstrated what constitutes collective metacognition. Anderson et al. (In Press) provide a substantive elucidation of this phenomenon. Specifically, this study demonstrated that students are aware of, monitor, evaluate, and control their engagement within the cognitive (learning), task, and social domains. Moreover, these three meta-domains are, for many participants, engaged actively and simultaneously in group activity. Additionally, individual and group engagements were seen to be dominated by meta-social influences which involve, for example, the maintenance of overall group harmony and the social status of individuals within the group. The research team's reflections concerning evidence for collective group metacognition led them to realize that this phenomenon is considerably under-researched and its effects on learning and behavior are highly underappreciated.

The Evolution We modified our analytical approach to understanding metacognition to consider both the individual and the group as valid and important units of analysis when understanding metacognition. This change in appreciation led to changes in the way participants were permitted to self-select critical incidents in stage two, and also the kind of questions posed in stage three. Specifically, questions were posed to the whole group that were derived from the collective group-selected critical incidents concerning their collective awareness, monitoring and control of the group learning processes in addition to the traditional probing questions intended to interrogate their individual metacognition.

Researcher Driven Interview Discourse to Participant Driven Interview Discourse

Most interpretive studies of metacognition in the field of science education employ some form of interview methods in order to explore participants' metacognitive attributes, states, or changes in state. This method is very often driven by the researcher(s) with the aid of an interview protocol comprising a set of predetermined questions consistent with the research questions or objectives of the study. Semi-structured interviews are a commonly employed approach within this sub-set of methods since they afford the opportunity for the interviewer to dynamically respond to the participants' answers to questions posed, and to capitalize on emergent issues raised that may not often be predictable. In the MRI sub-studies, semi-structured interview protocols were developed for each case site and sub-study as a function of the context of the stage one activities that the participants engaged in. However, each interview protocol

commonly probed the nature of participants' learning and metacognitive experience manifest in stage one. For example, students were commonly asked to self-reflect and discuss incidences where they were aware of specific learning strategies they chose to employ in given situations.

The Critique Perhaps most significant to the critique of this method was the research team's reflections on the extent of participants' reflections on their own thinking that they were prompted to consider during the interviews. In the interview cases of the MRI sub studies, the participants found the experience of being interviewed about their stage one engagement an experience from which they learnt about themselves as learners and how they might alter their strategies, for example:

> I realized that I personally think aloud a lot....if something comes into my head I just say it right away...I get distracted easily, so maybe I should learn to stay more focused, try to spend more time on an answer, keep thinking of more possibilities instead of just writing down something and then going on to the next answer. (Winone)

> I wasn't really contributing what I thought (in the group activity) and I should have done that...to take the initiative to be in the conversation more, to get my ideas out there. I'd like to see their reactions to my ideas, and I'd get input from their answers (Patricia).

The extent to which the interview was itself a metacognitive experience that enabled the research team and participants to gain deeper insights about the nature of metacognition was not fully appreciated or understood by the research team in the planning and initial stages of the MRI. The extent of this realization holds lessons for those conceptualizing research designs aimed at understanding metacognition. Specifically, the tools and methods deployed in collecting information about metacognition inherently hold the capacity to initiate highly metacognitive experiences. In fact, we also see this as also potentially being the case for research methods that are grounded in a positivist paradigm, which largely employ quantitative measures. In other words, even the quantitative measures derived from such methods may have the capacity to influence participants and indeed the dependent variables being measured. This was the case with the self-identification of critical incidents in stage two, and also the case in participant engagement in stage three.

The Evolution Based on the team's collective self reflection on the interview methods, the researcher-driven discourse embodied in the semi-structured interview protocol was modified to better appreciate the power of emergent participant-driven discourse. Specifically, the interview discourse employed the original semi-structured protocol, but special attention was directed to opportunities for the participants' own discourse to become the subject of self reflection and repeated self analysis as was reflected in the manner by which the research team (interview panel) used the participants' own statements made during the interviews to assist in revealing the nature of students' own metacognition.

Discussion and Implications

Our repeated critical dialectic reflections led to various evolutions in methods (discussed within Our Evolution of Methods section) within the MRI study lead us to conclude several

things regarding the method employed in qualitative-interpretivist studies. First, methods should, where practicable, not be fixed, but rather responsive to a study's research objectives and the evolving epistemologies and the progressively developing understandings of the investigators in relation to the phenomenon and context/s being studied. This was the case with the MRI team in that we had initially constructed what we considered to be the best possible set of complementary methods with which to probe and understand the participants' metacognition. Yet, the opportunity to repeatedly reflect critically at the conclusion of investigating each case context and case group, with the benefit of increased understandings the phenomenon and context, permitted continuing refinement and evolution of the methods and a reciprocal increase in the team's capacity to understand the phenomenon and context. Moreover, the collective evolution of the set of methods resulted in increasing the synergy between the methods and hence further increasing the depth of understanding afforded to the researchers and participants. An example of this synergy is evident in the evolution of, (a) the participant selected incidents of whole group interactions, (b) the participant driven interview discourse and (c) acknowledgement and use of group units of analysis. The methods that provided autonomy for participants to collectively select incidents supported their capacities to reflect and discuss what was meaningful to them, and moreover, revealed insights about the manifestation of group metacognition. Hence, we see the evolution of individual methods resulting in their increased capacity, responsiveness and fruitfulness, but also the collective synergies of the evolved methods was a move forward in maximising their capacities.

Second, researchers need to be aware of the potential of data collection methods, interventions and themselves to profoundly (and substantially) influence participants' metacognition. Traditional conceptions of positivist-decontextualist research designs that often employ an experimental framework (cf. Campbell and Stanley 1963), strive to control threats to validity through the design and administration of methods intended to measure effects from interventions. Yet, with qualitative-interpretivist studies such as the MRI that subscribe to relativist-contextualist paradigms, the notion of impact of method and researcher on the phenomenon can rightly be seen as a virtue. This is particularly the case in the context of with-in subject research designs that are not concerned with comparison outside of the subjects under consideration.

Third, the use of group interaction and engagement and the collective group reflection of learning experiences is a powerful mechanism that reveals metacognition in ways that solitary experiences cannot. From the outset of the MRI the team was aware that collective engagement in stage one would very likely be beneficial towards participant engagement of metacognition because of the increased opportunities for argumentation and other forms of higher order cognition that group work provides. However, it was the hermeneutically orientated cycles of data gathering that permitted us to realize that the extent of benefits embedded in data collection methods that capitalized on group discourse. In particular, the evolution in methods that permitted collective self-reflection of whole-group context, whole-group selection of critical incidents, whole-group interviews, and participant (whole-group) driven interview discourse were all highly beneficial for us in developing better understanding of the phenomenon and context.

Fourth, researcher experience of the use of specific technology to support methods that enhance data collection, participant involvement and reflection is necessary before previously unconsidered uses of the technology can be initiated and better exploited. The experiences of the research team within the MRI attest to this assertion given our evolving appreciations of ways to more effectively modify our methods in reciprocity with increased understanding of the phenomenon and context. Additionally, the use of innovative methods

employing uncommon technologies may result in high levels of novelty for participants that may initially present detrimental reactions which threaten the effectiveness of the methods. It is important to appreciate that participants may need exposure to innovative methods in order for their capacities to be more fully realised and potentially detrimental effects minimised.

Finally, the investigation of metacognition in a qualitative and interpretivist manner can be enhanced by methods that permit increased participant control and autonomy over the metacognitive experience, selection and discussion of what is meaningful and important to them in their reflection of the learning episodes. Moreover, researchers can benefit from being themselves metacognitive (as we were) in relation to their knowledge, control, and awareness of their thinking processes regarding research methods as they use and reflect on the nature and use of those methods. Such knowledge should be considered tentative and subject to ongoing scrutiny and, as necessary, revision. We contend that such scrutiny and reflection is a key to moving research in metacognition and possibly other areas of science education forward.

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Appendix

Group Interview Protocol: Stage 3

1. What key things stick in your mind from your experiences in the group activity?
2. What new understandings did you gain from the experience in the group activity?
3. How did you find the task of listening to yourself and reflecting on what was said?
4. What did you learn about your own thinking from hearing yourself? What did you learn?
5. Have you ever thought about this type of thinking before?
6. Could you identify any incidences where you felt you became aware of your own knowledge (physics knowledge)?
7. Can you recall any incidence where you put your knowledge to work?
8. Were you asking yourself questions? Were you talking to yourself when you were _x_? What were you talking about? What kinds of questions were you asking yourself?
9. Why did you ask yourself these questions?
10. Why did you use that kind of thinking?
11. What do you know about your own thinking?
12. Did you have a plan?
13. VIDEO—Critical Incidents (Stage 2)
14. Were you aware of the other group members' learning? What learning?
15. Can you tell me what the most important thing that you've told me today?

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