'Prospecting for metacognition' in a science museum: A metaphor reflecting hermeneutic inquiry

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Studying metacognition brings with it many challenges. The challenge of researching metacognition is exacerbated when research, (a) moves from clinical or highly structured settings, those associated with much research in this field, to more naturalistic contexts with less structure, and (b) begins in previously unexplored settings and social contexts with little, if any, existing literature related its study within such settings. We use the metaphor of 'prospecting' to characterise a qualitative methodology that employed a hermeneutic dialectic process to explore the metacognition of parents and their children as they interacted in the naturalistic setting of a science museum. We explore and explain the dialectic hermeneutic questioning and decision making processes we employed and how the research proceeded over 4 days and 14 cases as part of our detailed methodological reflection. Our aim is to inform future research in metacognition, or other under-researched learning phenomenon, using interpretive methods in such settings, and to provide examples of the decisions and thinking that shaped our study's progress.

Background to the methodological reflection

This paper draws from a larger project entitled *Metacognition and Reflective Inquiry: Investigating learning across the contexts (MRI),* the outcomes of which have been previously reported (c.f. Anderson & Nashon, 2007; Anderson, Nashon & Thomas, 2009; Anderson, Thomas & Nashon, 2009; Thomas, Anderson & Nashon, 2008; Nielsen, Nashon & Anderson, 2009; Ballantyne, Anderson & Packer, 2010; Thomas & Anderson, 2013). In this series of studies, the term metacognition, refers to individuals' conscious knowledge, control and awareness of their thinking and learning processes and those of others including how and when to employ these elements (Flavell, 1976; 1987; Brown, 1978; Paris & Winograd, 1990; White; 1998). The MRI's broad objectives aimed at understanding how metacognition manifests naturalistically in informal science education settings, such as individuals' visits to and experiences of aquariums, nature centres and science museums. Such investigations into metacognition are at best rare, but hold rich potential to understand non-experimental, non-contrived, natural manifestations of metacognition that can further enrich our understandings of metacognition and the learning experiences in such settings.

In this paper, we draw from a sub-study of the MRI that focused on a not previously investigated examination of metacognition manifest in parent-child interactions during their engagement at an interactive exhibit at the Science Museum of Minnesota. The focus of this paper is the systematic review and reflection on our own hermeneutic questioning techniques and research processes we employed to explore the metacognition of parents

and their children as they interacted in the naturalistic setting. We seek to stimulate further discussion regarding how metacognition research in science museums, and in naturalistic settings in general, might be conducted. Furthermore, we also seek to provide a model metaphor of qualitative research and thinking about such matters, particularly as it relates to the evolution of lines of questioning throughout the course of study.

This is important because much reported research on metacognition understates the methodological considerations and decision-making processes that inform and are inherent in the research enactments, and often implicit and not visible in research publications. This can be said of studies from across paradigmatic orientations. Maximum word lengths for manuscripts can reduce the opportunity for elaboration of qualitative methodologies, and for reflection on and critique of those methodologies. Hence, the capacity to justify employing such methodologies is diminished. Indeed, the understanding of validity and reliability attributed to quantitative research reports is most often tacit and 'taken for granted' and challenging such momentum within the scholarly community requires an opportunity to explicate new approaches and highlight their potential value. Finally, the metacognition research community's predominant interest in findings rather than how the findings were arrived at also downplays discussion of the value and appropriateness of approaches that might not reflect dominant, hegemonic practices within that community.

It is to address these concerns regarding the place and practice of qualitative, interpretivist, and hermeneutic inquiry in relation to metacognition research in complex naturalistic settings, such as science museums, that we sculpt this paper. Details of the findings regarding the participants' metacognition are not the focus of this paper. However, Thomas and Anderson (2013) report two strongly supported assertions from this particular study within the MRI, namely:

- Assertion 1: Parents reported metacognitive knowledge regarding theirs and their children's thinking and learning processes and this knowledge influenced their interactions with their children.
- Assertion 2: Parents were aware that this metacognitive knowledge influenced their interactions with their children, seeing this as appropriate pedagogical action for them within the science museum context, and for the child involved.

These assertions were principally derived from question 'tools' that we describe and explain in this paper. We consider that these findings (assertions) could not have been arrived at if not for our dialectic hermeneutic approach which characterises this research.

Purpose and overview of this paper

As previously stated, the focus of this paper is the systematic review and reflection on our own hermeneutic questioning techniques and research processes we employed to explore the metacognition of parents and their children as they interacted in the naturalistic setting. In what follows we articulate and explain the process and rationale for our

methodological frame employing dialectic hermeneutic enquiry and the researcher attributes we propose that are necessary for such enquiry. We then outline the exhibit selection and participant recruitment procedures we employed, including a description of the interview organisation. Further, we address how we attended to reinforcing the quality of our methodology, analyses and categorised the questions we asked, and demonstrate how and why these questions changed over the course of the data collection period. Finally, we then introduce and explain the 'prospecting for metacognition' metaphor as a means of characterising our approach to question revision and evolution.

We emphasise at this point, that our considering and writing about the process of this research into parent and child metacognition in a museum setting is itself a consequence of us reflecting metacognitively. We were metacognitive about the thinking processes we ourselves used to contemplate the nature and value of the questions we designed and employed. We did not enter the research cognizant of this metaphor for the process we were about to experience. Our use of metaphor – defined as a conceptual tool for implicitly comparing the conceptual structures between two domains – follows a long tradition of the use of metaphors in science education for a range of learning and meaning-making purposes (e.g. Aubusson, Harrison and Ritchie, 2006; Duit, 1991; Thomas & McRobbie, 2001; Tobin, 1990). Interestingly, Aubusson et al's review of the use of metaphor in science education does not contain reference to its use as a means of conceptualising methodological research processes in science education. However, we see that it has high utility in both conceptually understanding and reflecting on methodological issues.

Metacognition: Researcher paradigms and methodological deliberations

In the field of metacognition research, debate continues regarding which researcher paradigms, methodologies, and data collection methods best provides confirming and disconfirming evidence for the existence and quality of individuals' metacognition. Because metacognition is a mental activity, "its presence can be inferred, but not observed directly" (White, 1998, p. 1211). Therefore, all measures of metacognition involve varying degrees of inference. The extent to which scholars accept or otherwise differ about degrees of inference in relation to data collected and its analysis and interpretation, is a source of contention (Thomas, 2009). Hence, in the spirit of being transparent about these matters, we lay bare the paradigm and methodological position we adopted during the course of MRI studies and this particular sub-study.

Researcher paradigms

Anderson, Thomas and Nashon (2009) and Anderson and Ellenbogen (2012) suggested that researchers' approaches to investigating metacognition and learning phenomenon are influenced, at least partly, by the research paradigm to which they predominantly subscribe. Research orientations reflecting a positivist-decontextualist paradigm, most often evident in metacognition studies, are characterised by a minimisation of the

influence of learner and/or context variables, such as participants' motives, the nature of the subject matter under consideration, and the physical and psychosocial environments within which the individuals and the research are located. They seek to "eliminate" contextual factors, including those related to the researchers, and any ambiguities arising from acknowledging such factors. The view of those subscribing to this orientation is that such factors are, at best, unwanted errors and of little if any interest. Hence they tend to be largely ignored and little attention is paid to the physical and/or temporal contexts within which data is collected.

Conversely, researchers more aligned with a relativist-contextualist paradigm regard contextual factors as highly relevant to considering individual's metacognition and its development and enhancement. They acknowledge the importance of the psychosocial nature of individuals' environments for influencing metacognition and see the ecology of the environment within which metacognition is embedded as vitally important. Studies reflecting this paradigm are typically interpretivist in nature and most often employ qualitative or mixed methods. Critics of such an orientation, e.g., Dunlosky, Bottiroli, and Hartwig (2009) propose that such a position can be problematic for helping develop a generalisable theory of metacognition. Yet, even those authors acknowledge the importance of environment when suggesting that, "to obtain generalizability across environments, education researchers should begin by describing the environment to which they want their outcomes and conclusions to generalize" (Dunlosky et al., p. 436).

Our orientation within the MRI was consistent with a relativist-contextualist paradigm which regards factors such as visitors' agendas, self-efficacy, motivations, prior knowledge and socio-cultural identities as highly influential and important in relation to their metacognition. We consider the natural ecology of the learning environment within which the research participants are embedded (i.e., a science museum setting) as vitally important for framing the learner and his or her metacognition. Our MRI studies have departed from the tradition of "lawlike theories of social behaviour" (Popkewitz, 1984, p. 36) that declares that there exists a single, objective reality that can be uncovered by stripping away "possible contaminating influences" in "searching for the way things really are" (Guba & Lincoln, 1989, p. 84). Instead, we explored metacognition through the lens of social constructivism. Consequently, we aligned our methodological approaches to be predominantly qualitative and interpretivist. In the MRI studies we regarded such an approach to be more fruitful for constructing assertions to assist science educators and museum staff to improve learning outcomes within informal learning contexts.

Methods

What has also emerged from the debate regarding methodology and the varying paradigmatic orientations in metacognition research is a polarisation of opinions as to whether the use of 'off-line' or 'on-line' methods (Veenman, Van Hout Wolters, & Afflerbach, 2006) are most appropriate. Off-line methods are those presented either before or after task performance, while on-line methods (e.g., think aloud protocols and studies of eye movements) are conducted concurrently during task performance. Researchers' choices of which to employ seem strongly related to their academic

background and their consequent dispositions to particular paradigm/s, rather than any choice determined by the research context, the nature of the question asked, and/or the ecological validity of the methods themselves (Thomas, 2012). Our investigations of metacognition in the MRI relied greatly on self-reports on the individual's interpretation of the questions asked as well as their interpretations of their thoughts, actions, social interactions and other experiences. This occurred both during the participant's task discourse (on-line) and after the task (off-line) as part of face-to-face interview with the parents and children.

Hermeneutic enquiry

Our adoption of an interpretive and naturalistic inquiry lead us to value the power of hermeneutic enquiry to explore to naturalistic phenomenon in a new, previously unexplored settings and social contexts. At the heart of hermeneutics is the process of interpretation or making meaning from the stance of the interpreter. Hence, repeated logical argumentation (dialectic) amongst one's own interpretation of meaning (hermeneutic) has the capacity for arriving at deeper meaning. A core presumption of such an approach is that the research structure should provide and prepare for multiple stages of data collection and hermeneutic interpretation over the investigation. Additionally, such approaches require that opportunities be built-in the researchers to dialectically reflect between the successive stages of the research to critically examine their epistemological stances concerning the phenomenon under investigation, in our case parent-child metacognition. Such dialectic reflection facilitates critique and possible modification of the research methods (tools) over successive stages of data collection. These modifications, in turn, have the potential to enable honing and refinement of the interpretation of the phenomenon. Hence, this approach facilitates a synergistic and parallel refinement of the capacity of tools and, with that, the understanding of the phenomenon (Anderson, 2012).

Within such interpretivist approaches, research methods should, where practicable, not be rigidly fixed, but rather be dynamically responsive to (a) a study's research objectives, (b) the progressively developing understandings of the researchers in relation to the phenomenon being studied, and (c) any evolution of the epistemologies of the researcher(s). On this latter point, several pre-conditions are required of researchers. Firstly, they need to be critically cognisant their own epistemological stances and the views they hold about the learning phenomenon under investigation. Secondly, they should consider that their approaches regarding their investigation of phenomena should be flexible and should have the capacity to shift approaches in response to changes in their understandings of the world(s) in which these approaches are contextualised and/or changes to their understandings of the learning phenomenon they are investigating. Thirdly, the researchers should possess a willingness to allow their approaches (i.e., interview questioning tools) and the values they hold about their positions, even as they emerge from their interactions with the data, to be challenged along with the progressively developing understandings of the phenomenon being studied (c.f. Guba & Lincoln, 1989, p. 149; Guba & Lincoln 1997). Indeed, the position held across the MRI studies was that

progressive change and the development of one's epistemological stances in this paradigm are both necessary and virtuous.

Our case context: Parent-child metacognition

In the museum and visitor studies literature, several authors suggest the need for research on parents and their children's metacognition within museum settings (Anderson, Thomas & Ellenbogen, 2003; Loomis, 1996, National Research Council, 2009). Investigations of family learning and children's learning have received extensive attention in the museum, science education, and developmental psychology literature (c.f., Anderson, Piscitelli & Everett, 2008; Anderson, Piscitelli, Weier, Everett & Tayler, 2002; Piscitelli & Anderson, 2001; Blud, 1990; Borun, Chambers & Cleghorn, 1996; Diamond, 1986; Ellenbogen, 2002; Dierking & Falk, 1994). These studies demonstrate that family groups and children do learn science in museum settings and that the nature of learning from these settings is diverse and complex. Most studies also suggest that the complexity of learning in informal settings makes investigation of phenomenon extremely challenging. There are no known studies (apart from our own) about parent-child metacognition in such contexts.

Given our appreciations of the nature of experiences that afford rich manifestations of metacognition, we sought an exhibit as the context for exploring visitors' metacognition that met several criteria. Firstly, the exhibit needed to be rich; meaning that its features could be manipulated in multiple ways and have multiple starting points of engagement and multiple outcomes as a function of participants' manipulation and starting points. Secondly, the exhibit needed to be predominately non-didactic in orientation. It could not simply consist of a prescribed and largely inflexible set of possible events or activities. Rather, it needed to enable diversity of possible experiences that had potential to result in cognitive challenge and higher-order learning. Thirdly, the exhibit needed to be both intelligible and engaging so that visitors could understand and comprehend the aim of the experience, and also maintain an intrinsic willingness to persist. Finally, the exhibit needed to present visitors with experiences that initiated a cognitive load that maximised the stimulus for them to become self-aware of their own learning and cognitive challenges as they arose.

We selected the "Math Tracks" exhibit at the Science Museum of Minnesota in Saint Paul, Minnesota, which we deemed met these criteria (Figure 1) (See a more extensive description at http://www.smm.org/static/explorations/calculus.pdf pp. 10-12). Math Tracks is part of the Handling Calculus exhibition. It is comprised of two parallel tracks upon which carts travel. Each cart can carry a miniature tin silhouette of a familiar character that could be selected by the participants (i.e., Little Red Riding Hood, the post man delivering mail). Visitors could enact scripted stories, like Little Red Riding Hood's trip to Grandma's house, or generate their own scripts and play them to generate graphs, and in so doing potentially link their experience with some prior knowledge. The overall aim of the exhibit was to develop an understanding between slope and motion, the derivative and motion, and the visual connections between a graph and its derivative. The exhibit could be manipulated in several ways. For example, the carts could be physically

moved along the track as part of a story rich in movement and mathematics (e.g., the wolf ran to the woods while Little Red Riding Hood meandered up the path). The motions would then be electronically recorded and displayed as displacement, velocity and acceleration versus time graphs. Alternatively, displacement, velocity and acceleration verse time graphs could be manipulated by means of a mouse and then played, illustrating the resultant movement of the physical carts along the track.

Figure 1: Manipulating the Maths Track exhibit

Procedures and participants

Data collection took place over the course of four continuous days at the Science Museum. Participants in the study were 14 parent-child groups [1] who were casual visitors to the museum and who consented voluntarily to participate in the study. Parents with their children aged 8 to 15 years of age were approached in the gallery and given a brief explanation about the study. Those agreeing to participate were then taken to the Math Tracks and given a brief two to three minute introduction regarding the nature of the exhibit. They were then permitted to engage freely with each other and the exhibit for up to 15 minutes. At the end of this time, the dyad was provided a specific task challenge. This challenge required participants to design a displacement time graph that would make one of the carts travel half-way down the track, pause, and then return to the origin. Participants were then allowed 10 minutes, to attempt this challenge before being interviewed together about their experiences and the thinking they engaged in. During the groups' interactions with each other and the exhibit, the research team unobtrusively observed the participants interactions and engagement from three to five metres behind and noted aspects of the engagement to be investigated during the interviews.

The semi-structured interviews were conducted in a relaxed, friendly manner. The research team members sat around the exhibit with the participants and began by asking

them to describe their experiences with the exhibit. This was followed by a series of questions regarding aspects of their own knowledge and understanding of conceptual science they had become aware, as well as new insights, if any, they had gained. Additional questions followed, that probed their awareness of individual and collective knowledge about strategies they employed during their engagement in the activity, the fruitfulness of those strategies, and their mutual understanding of one another as learners. All interactions with the exhibit and the face-to-face interviews were video recorded for later analysis.

With each successive interview we allowed our questioning to evolve and adapt in concert with our emerging understandings of the phenomenon. This practice was in keeping with our hermeneutic dialectic epistemology. Hence, following each interview we paused and reflected deeply on participants' own interpretation of metacognition and the capacity of our interview questions to yield deeper understandings of that. Further rounds of reflection occurred at the conclusion of each day of data collection which sometimes led to adding and/or deleting questions and/or changes in questioning approaches the next day. Interviews were conducted over four days; cases 1 and 2 on day 1, cases 3 to 6 on day 2, cases 7 to 10 on day 3, and cases 11 to 14 on day 4. The evolution of the questions that we asked participants about their learning and metacognition from group 1 to group 14 could not have occurred without us engaging in ongoing hermeneutic dialectic reflection regarding what we were learning about metacognition, and also what we were learning about the effectiveness or otherwise of the questioning tools we were using.

Analysis of questioning processes

For this paper, the primary data we analysed were the questions we asked participants during interviews and our description of the process we followed. Type-written transcripts of all 14 participant dyad interviews were generated and each transcript was reviewed individually and then collectively by members of the research team in sequential order in the following manner. Firstly, the questions posed were highlighted and compiled according to which members of the interview team asked the question. Secondly, a coding scheme was developed to categorise the kinds of questions being posed to participants in terms of specific aspects of metacognition and metacognitive activity being investigated. This occurred for the first interview and for each interview that followed. Thirdly, with each successive interview analysed, we refined the coding scheme and the previously analysed interview coding of questions was revisited and modified as necessary to ensure ongoing consistency of interpretation regarding the classification of questions. Finally, upon completion of the analysis and classification of the 14th interview, the entire question coding scheme was collectively reviewed by the team for consistency. The coding scheme is represented in Appendix A.

Important matters about parent-child metacognition influencing questioning

There are important matters that must be acknowledged in relation to the investigation of metacognition using a dialectic hermeneutic approach in the science museum context. Although we argue that it is true that this approach permits a synergistic and parallel

refinement of the questioning tools, and with that an increasing potential to understanding a phenomenon, we ought not expect a regular and linear increase in refinement with each successive case interview. Rather, we might expect changes in question sophistication but, once again, not necessarily in any regular pattern.

The reasons for this are several. Firstly, there is no reason to expect that the metacognition and/or learning processes or behaviours of one individual or dyad should be identical across individuals and/or groups. Rather, we should expect that some participants would be more and/or less and differently metacognitive than others. Therefore, the potential of each case to yield further understandings of metacognition and, as a consequence, influence the refinement of questioning tools, should not be expected to progress at equal time intervals or to the same extent for each case. Secondly, we should not expect that all participants will have identical capabilities to effectively articulate their metacognition in an interview, especially one that was not part of their expectations as a museum visitor. Indeed, it is extremely difficult for most people to express or elaborate on their own metacognition given that they are very rarely asked to consider such issues and are unfamiliar with the language they might use to make their metacognition evident and open to scrutiny. Thirdly, the relationships and status of relationships that exist between parents and their children vary, as does their personal knowledge of each other's cognition and metacognition. As such, particular kinds of questions may be deemed by the researchers to be inappropriate to ask on the basis of what was observed by the researcher during the participant/s' interaction with the exhibit, and/or on the basis of what emerged during the interview itself. This is especially the case when at the time of questioning, researchers discern that it may be ethically inappropriate to ask questions that might compromise the parent-child relation or create tension between the researcher and these participant volunteers who have no vested interest in the research outcomes.

Identifying changes in the question 'tools' across the participant set

The categorisation of the questions asked across cases 1 through 14 (Appendix A) shows the question codes and what each code represents. The frequency with which questions corresponding to the question codes in Appendix A were asked in each interview is represented in Appendix B. It also shows the days on which each group was interviewed. The vertical axis represents the question types asked of participants, while the horizontal axis represents the participant cases in order of their interview and day. Each time a question of a particular code was asked is represented by a dot. This visualisation enables the reader to both numerically and visually-comprehend the frequency and extent of questioning for each question code for each case. Broadly speaking, the chronological sequence of questions asked of each participant group progresses from the top of the vertical axis to the bottom over the course of each of the interviews. However, it is important to note that each interview was a dynamic conversation between researchers and participants. Therefore, the question sequence was not necessarily predetermined, or repeated in the same order for each dyad. Rather it unfolded as a consequence of the progress of the interview.

Our initial question sets, posed in the first few interviews, were informed by, (a) our core research objectives to understand participants' learning processes and their knowledge, control and awareness of their individual and collective knowledge about the strategies they employed with the exhibit, and (b) their mutual understandings of one another as learners. The question sets used in the initial interviews were akin to an orientation phase for us in which we were intent on developing foundational understandings of the 'lay of the land' concerning participants' metacognition. We came to interviews with some pre-existing knowledge about how to explore metacognition based on, (a) our past experiences as researchers of learning and metacognition, (b) the literature on metacognition, and particularly, (c) our experiences in other studies we had collaboratively undertaken within the MRI project. However, we acknowledge that our collective and individual appreciations of parent and child metacognition, situated in the context of shared experiences at an interactive exhibition in a science museum, were limited. This is particularly since we considered that this was the first such study of metacognition with this specific focus and context in mind. Hence, we considered that because of this context and focus that the study was ideally suited to the application of a dialectic hermeneutic approach (Johnson & Onwuegbuzie, 2004), where we were (a) studying a limited number of cases in depth, (b) attempting to describe complex phenomena, and (c) attempting to describe metacognition in rich detail, as it was situated and situated in a social context.

Our process of inquiry and questioning tool re/design, emergence and development: The "prospecting for metacognition" metaphor

In seeking to explain our research process, we consider that "prospecting for metacognition" is a metaphor illustrating the probing and interrogative procedures we employed. Like olden-day gold prospectors (http://en.wikipedia.org/wiki/Gold_mining) whose tools were various types of picks and shovels, we explored the 'subterranean labyrinths' of participants' metacognition, seeking to locate seams of 'metacognitive gold' which could be further explored with the hope of a rich bounty. Prospectors are known to have laboured in the dark not seeing readily the gold they sought except through them peeling back layers of rock and earth. We too started in the dark with only our prior experiences and knowledge. Seams of quartz may indeed point the way to a bountiful discovery, but also, rapidly disappear and not lead to anything of substantial value, despite much effort. The prospector would also change tools, a specific pick for specific purposes, in order to expertly access the seams and deposits that lay hidden below the surface. Moreover, experienced prospectors had and developed a connoisseurship of the rock types. The rock 'spoke' to the prospector and could provide telling indications as to whether they were near a potentially productive vein. In like manner, we too sought that which was not immediately evident on the surface; the underlying processes that help inform an understanding of the complexity of science learning.

We employed different forms of questioning tools to locate and 'reveal' the participants' metacognition, although we acknowledge strongly that revelation regarding a phenomenon such as metacognition is heavily shaped by our interpretations as researchers, as is the case in interpretive research. We allowed the participants' responses to guide our efforts, just as rock types speak to prospectors. The tools we required to

uncover metacognition in the metaphorical 'dark' context of the science museum in some cases needed to be created and were often not at our disposal at the commencement of our 'dig.' With our emerging understandings of the context and of the phenomenon itself gained through reflections after each interview and at the conclusion of each day, we re/designed effective questioning tools and modified these over the data collection to excise details regarding the elements of the participants' metacognition.

Within this 'prospecting for metacognition' metaphor, we draw five further mappings (Gentner, 1989; Holyoak and Thagard, 1989) to our dialectic hermeneutic practice as researchers, focusing on our questioning techniques that we employed across the cases in this study through the analysis of Appendix B. We elaborate further on these metaphorical mappings as an exposition of what interpretive researchers – prospectors of metacognitive phenomena – might practically expect in the exploration of new and unfamiliar territory regarding metacognition through the application of dialectic hermeneutic methods. The mappings (a) to (e) that follow are all represented as Table 1 with examples of questions asked. Table 1 is a distillation of the mappings (a) to (e) from data presented in Appendix B, and the purpose of Table 1 is to simplify Appendix B to highlight these specific mappings. As previously explained Appendix A provides the description of codes for all question asked during interviews.

Mapping A: A consistently productive seam – A line of questioning employed productively across all dyad cases

With our exploration of the 'lay of the land' in the initial interviews, there were a number of questions which repeatedly yielded interesting and productive insights about participants' learning and metacognition across the cases. These kinds of questioning tools yielded insights early on in the study and were used repeatedly in subsequent cases because they were effective in several ways. Firstly, they often readily enabled participants to discuss and self-report about their learning and metacognition. Secondly, they were fruitful in the insights they elicited about the participants' metacognition. Thirdly, they opened up lines of discussion that led to other new revelations that were interrogated further via subsequent lines of questioning. Such lines of questioning had the potential to lead to deeper insights about the phenomenon. Examples of these include for instance, *MCA-SRB - Metacognitive awareness of social role and behaviour*, and *MCAE-SOE – Metacognitive awareness and evaluation of self and others' expertise.*

Mapping B: A depleted seam – A line of questioning that initially and potentially seems fruitful, but that depletes in value over time

Sometimes a question may initially appear fruitful in two or more successful cases where it is posed, but then cease to be productive in subsequent cases. In such cases the line of questioning became extinct and the metaphorical 'quality' of the vein disappeared. Examples include MCA-PSD Metacognitive awareness of psycho-social dimension of how the others' influence their interactions with that person, and *MCA-CDVI Metacognitive awareness of context dependence of various interactions with others.*

Mapping C: A fruitless seam – A question that is not productive and is discontinued

There are examples of questions that were raised within an interview that did not yield any insights of value and/or were deemed unproductive, and therefore discontinued. For example, *MCA-TRE – Metacognitive awareness of transfer of role, planning or strategy in support of learning, MCA-P Metacognitive of planning,* and *EOLS Evaluation of others' strategies for learning.* These kinds of questions emerged and were put to participants based on indications within the interview (like a seam of quartz) or theoretical assertions within the literature that we considered might reasonably be pursued, especially early in the interview sequence.

Mapping D: A localised seam – A line of questioning that is productive within a single case

These lines of questioning may, or may not, be fruitful and yield interesting insights, depending on the particular case. In other words, once explored, the same line of questioning may be deemed not potentially useful in other cases. To this end, the interesting phenomenon may be considered as solitary revelations isolated to one dyad, and not seen again in other cases. Such examples do not permit confirmation of any hypothesis a researcher may form despite seeking to test them in subsequent cases. Examples included: *A-WILSO – Awareness of when to implement a learning strategy to assist others.*

Mapping E: An emergent productive seam – A subsequent and fruitful line of questioning emergent in later cases

There were certain lines of questioning which proved to be fruitful, but were not, and potentially could not have been, envisioned or foreseen at the outset of the study or from the earlier case interviews. Such questions emerged through the dialectic hermeneutic approach as new hunches about the participants' metacognition emerged from our interpretation of the interviews, and were then explored. Examples of these are *MCA-VLABS – Metacognitive awareness of the variations in learning approaches between siblings,* and *MC-ILASO – Metacognitive awareness that ones' learning approach is the same as another.* These examples, and others in this category, did not emerge as productive tools until after the seventh interview and emerged only after the research team had reflected deeply on both the insights gained about metacognition and the questioning tools employed in the study to that juncture. It was due to this reflection that considerations emerged about what new kinds of questioning tools might effectively be employed to excise and elucidate elements of participants' metacognition not previously noted or explored.

Within qualitative interpretive research, researchers seek both confirming and disconfirming data from the cases in order to construct assertions (Strauss & Corbin, 1998). Generally speaking, the confirmability of assertions is derived from patterns of responses that occur consistently across multiple cases, i.e., in our study (a) A consistently productive seam and (b) An emergent productive seam. The emergence of isolated or

Table 1: Question codes, exemplar metaphor mappings, and frequency of question type asking across interviews

	Day	1		2				3				4			
	Interview no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Metaphor mapping	Question code														
A: Consistently Productive Seam	MCA-SRB	••	•••	••••	•	•••	••••	••	•••	••••	••••	•••	•••	••	••
	Metacognitive Awareness of Social Role & Behaviour: What were participants' views on their roles within the dyad? Eg., *Think about what you did this last ten minutes in terms of both your roles; what you actually do at the exhibit and how did you engaging with each other?*														
B: A Depleted Seam	MCA-PSD	•				•	••		••						
	Metacognitive Awareness of Psycho-Social Dimension: What was the quality and extant of awareness of how the other influenced their interactions with that person Eg., *Do you think about how you might treat each other in terms of what your role might be in relationship to each other?*														
C: A Fruitless Seam	MCA-TRE		••		•										
	Metacognitive Awareness of transfer of role as an expert: Did participants report other contexts within which they also took on the role of expert? Eg., *And when he [dad] helps you with your work that you do for school, is that [the way he helps] the same or different?*														
D: Localised Seam	A-WILSO							•							
	Awareness - When to Implement a Learning Strategy to attempt to assist Others: What awareness is held of when to implement learning strategies for others? Eg., *What's the tell-tale clue for you to know that you've got to implement that strategy with your daughter?*														
E: Emergent Productive Seam	MCA-VLABS							••••			•	•	•••	••	•
	Metacognitive Awareness of Variation in Learning Approaches Between Siblings: Parents' awareness of own cognitive approaches are similar to a specific sibling (identification) Eg., *And do you think your older son does things differently to your daughter? Do you think they have different thinking processes?*														

unique phenomenon within cases might be valuable to explore and further understand, but the choice to do so must be framed and comprehended within the boundary of the study, the study context, and the time constraints (Stake, 1994). Isolated and atypical data arising from particular questions are not generally employed in the confirmation of more prominent assertions. Further, these questions tended not to be asked again after their value for furthering this research came into question and began to be doubted. In the case of our study mappings (c) A localised seam, (d) A depleted seam, and (e) A fruitless seam typify such categories of unproductive questions. We should add that under different circumstances or in a study with different goals these questions may be more valuable and lead to new insights.

Concluding comments

We have documented one of the very few, to our knowledge, reflections on a hermeneutic dialectic process within the combined fields of metacognition and informal learning. Our purpose has been to engage readers in understanding our thinking and decision making processes as we investigated science learners' metacognition in a naturalistic research context. In this paper, the complexity of the dialectic hermeneutic approach as it plays out in a context where the researchers are attempting to break new ground, to metaphorically go where no 'miner of metacognition' has previously ventured, is evident. Our prior experiences as researchers could only partially prepare us for the uncertainty that challenged us.

Calls for research into children's thinking and metacognition in informal settings have been largely ignored. We posit, in line with considerable literature, that this is largely because of well documented difficulties that present themselves when working with children, and especially in such settings (Piscitettli & Anderson, 2001). However, we propose that with a reasonable and functional understanding of the hermeneutic dialectic approach, such issues can be addressed and overcome. More broadly, under-researched and non-traditional research contexts and research questions can be investigated with some hope and confidence.

The hermeneutic dialectic process requires an iterative interplay between researchers' experience, the researchers' interpretation of emerging assertions and the process by which those assertions emerge. It is potentially further complicated by the diverse nature of human participants, the research context, and the need to ethically balance research agenda with participants' agendas in such settings. In this study, where the participants were children and parents interacting in a science museum setting, these challenges become even more noteworthy.

Traditional research practices most often place virtue on making minor, if any, changes to interview protocols. We argue this constrains the possibility of attending fruitfully to new emerging insights, our metaphorical potentially gold-bearing veins, that may or may not lead to assertions that can be confirmed, and consequently contribute to the production of new knowledge of phenomena. Rather, we argue that qualitative researchers (as miners of phenomena) can break ground with an initial set of tools which then might be refashioned during the 'dig.' We have abstracted and made transparent five 'mining' mappings of the metaphor 'prospecting' to define question categories that arose within and across dyads and that ultimately improved the likelihood of us elucidating and understanding the complex nature of participants' metacognition in the science museum context. We propose that metaphor is useful for considering, contemplating and reporting on the research processes in and across research studies, especially those that, like ours, were investigating a well-mined concept in a new context. Our process is in keeping with those who have used metaphors to make abstract concepts, processes and phenomena understandable (e.g Lakoff & Johnson, 1980; Milne & Taylor, 1995; Munby, 1986; Paris, 1988). It may be that others may consider the prospecting metaphor itself as a useful way to conceptualise their own new or ongoing research.

From another perspective, we have engaged in reflection on our own metacognition as it related to our knowledge, control and awareness of our thinking processes of our research in ways rarely documented and made transparent in published research studies. In doing so, we have tried to address the aforementioned concern we raised regarding the truncation of methodologies in papers related to metacognition research and often in many papers employing qualitative research. As we have earlier alluded to, traditions in our fields of metacognition and informal learning that often tend to emphasise research findings over any critique and reporting of methodologies and their underlying epistemological foundations. The influence of methodology cannot be under estimated in terms of its affordances and constraints with regard to the production of new knowledge. Qualitative research has a valuable role to play in opening up new areas for investigation in metacognition. Through this paper we have sought to demonstrate the type of researcher thinking that might be employed to further such research.

Endnote

[1] The Thomas and Anderson (2013) report's findings about parent-child metacognition considered only 12 of 14 case groups because of the specified age range of the child participants.

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Appendix A: Question codes, titles and descriptions for questions asked during interviews

Question Code: Title	Description
E-SR: Elicitation: Stimulated Recall	What did participants report about their thinking, learning or experience with the exhibit as a consequence of stimulated recall during the interview?
MCA-LE: Metacognitive Awareness of Learning Episodes	When, if at all, during the activity did participants become aware of learning 'x'?
MCA-SMK: Metacognitive Awareness of Self Meta-Cognitive Knowledge	What General Declarative and Procedural metacognitive knowledge did participants report?
MCA-CMK: Metacognitive Awareness of Conditional Metacognitive Knowledge	What, if anything, did participants report about how, if at all, their thinking/cognition was exhibit/context specific?
MCA-CLPOG: Metacognitive Awareness of Cognitive and Learning Processes of others in General	Did participants report meta-knowledge of how the other thought and learnt in a general (i.e. in an everyday sense)?
MCA-OLD: Metacognitive Awareness of others' Learning Dispositions	What were participants' view/s of the/any preferences and tendencies of others that they are reported being aware of?
MCA-CDVI: Metacognitive Awareness of Context dependence of interactions with others	Are participants aware that they change their interactions with others as a function of the context?
EOLS: Evaluation of others strategies for learning	What were participants' evaluations of the other's learning strategies?

MCA-CP Self-in-situ: Metacognitive Awareness of Cognitive Processes-Self In-Situ	How were the participants thinking (in-situ) when they engaged with the activity?
MCA-CP-Others-in-situ: Metacognitive Awareness of Others' Cognitive Processes - In Situ	What did participants report in situ that they know about the others' cognitive processes and thinking when they were engaging with the activity?
MCA-SRB: Metacognitive Awareness of Social Role & Behaviour	What were participants' views on their roles within the dyad?
MCAE-SOE: Metacognitive Awareness & Evaluation of other's and self expertise	What did participants consider were their own and the other's level of expertise in relation to the task?
MCA-PSD: Metacognitive Awareness of Psycho-Social Dimension	What was the quality and extant of awareness of how the other influenced their interactions with that person
SE: Self Efficacy	What was the participants' self-rated level of confidence or expertize in relation to the task and setting?
MCA-TRPS: Metacognitive Awareness of Transfer of Role, Planning or Strategy in support of others learning	Did the participants report that they engaged in a similar role with the other outside the exhibit context so as to support the other's learning?
MCA-TRE: Metacognitive Awareness of transfer of role as an expert	Did participants report other contexts within which they also took on the role of expert?
MCA-P: Metacognitive Awareness of Planning	Did participants have a plan or approach to the activity (or the other) in mind?
MCA-ISLA on Planning Metacognitive Awareness and Influence of one's own Learning Approaches on Planning and Strategy to support of others learning	Did participants report that their knowledge and awareness of their own learning approaches influenced their planning and strategies to support others' learning?
MCA-IOLA on Planning: Metacognitive Awareness and Influence of Others' Learning Approaches on Planning and Strategy to support of others learning	Did participants report that their K & A of other learning approaches influenced their planning and strategy to support others' learning?
A-OBAEL; Awareness of how the other's behaviour assisted engagement and learning?	Did participants' report an awareness of how the other's behaviour assisted their own engagement and learning?
A-WILSO	Awareness of when to implement a learning strategy to attempt to assist others
ERC: Evaluation of relative contribution of the other to task completion	What did participants report was the relative contribution of the other to task completion?
EOS: Evaluation of Other Success	The evaluation of other dyad members' success at the task given the consciously employed behavioural and social role of self.
MCA-VLABS: Metacognitive Awareness of Variation in Learning Approaches Between Siblings	Are parent participants aware that they employ or scaffold different learning approaches between siblings?
MCA-ILASO: Metacognitive Awareness that one's Learning Approach is the Same as an Other	Awareness of the child participant that their own cognitive approaches are similar to a specific sibling (identification)

Appendix B: Frequency of questions of particular types being asked over the period of data collection

Day	1		2				3				4			
Interview no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Question code														
E-SR	••	•				••		•	•••		•			
MCA-LE	•		•		•								•••	
MCA-SMK	•	••	••••			••		•		•••	•••	••	•••	••
MCA-CMK	••		•	•					•			•••		
MCA-CLPOG:	•	•	•	••	•	•		•	•	•	•	•••	•	•
MCA-OLD	•••			•										
MCA-CDVI							•	•	••	•			••	
EOLS		•												
MCA-CP (S)	•••••	•••	•••••	••	•	•	•••	••	•••••	•	••	•••••		•••
	•••		••••						••			••		
MCA-CP (O)	•	•••	•••••	••	••		••	•		••				
MCA-SRB	••	•••	••••	•	•••	••••	••	•••	••••	••••	•••	•••	••	••
MCAE-SOE	•			•••••	•••	••••	•	•		••	•	•••	••••	••
MCA-PSD	•				•	••		••						
SE				•	•			•••	•	•			••	
MCA-TRPS		•	•••			•	••	••	•	•		•	••	
MCA-TRE		••		•										
MCA-P								•						
MCA-ISLA		•				••••			•		•	•		
MCA-IOLA		•	•				••	•	••	•	•••	•	••	••
A-OBAEL		••	••		•				••	•		•		
A-WILSO							•							
ERC		•		•										
EOS											•			
MCA-VLABS							••••			•	•	•••	••	•
MCA-ILASO			•				•			••	•	•		

Key: • represents one instance of a particular question type being asked

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