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Parents' Metacognitive Knowledge: Influences on Parent–Child Interactions in a Science Museum Setting

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Abstract Despite science learning in settings such as science museums being recognized as important and given increasing attention in science education circles, the investigation of parents' and their children's metacognition in such settings is still in its infancy. This is despite an individual's metacognition being acknowledged as an important influence on their learning within and across contexts. This research investigated parents' metacognitive procedural and conditional knowledge, a key element of their metacognition, related to (a) what they knew about how they and their children thought and learned, and (b) whether this metacognitive knowledge influenced their interactions with their children during their interaction with a moderately complex simulation in a science museum. Parents reported metacognitive procedural and conditional knowledge regarding their own and their children's thinking and learning processes. Further, parents were aware that this metacognitive knowledge influenced their interactions with their children, seeing this as appropriate pedagogical action for them within the context of the particular exhibit and its task requirements at the science museum, and for the child involved. These findings have implications for exhibit and activity development within science museum settings.

Keywords Metacognition · Science museums · Parents · Children · Interaction

Background to the Study

Aims

This paper brings together two main fields of research: *metacognition* and *learning in informal settings* such as science museums. Both fields have been the focus of considerable

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previous research in science education. To begin to acknowledge the importance of metacognition as a factor influencing parent–child interaction and learning within science museums and the aforementioned call for research in this field, this study investigated (a) what parents knew about how they and their children thought and learned, and (b) whether this metacognitive procedural and conditional knowledge influenced their interactions with their children during a moderately complex simulation in a science museum. In what follows, elements of past scholarship and research relevant to this study are presented and reviewed. As this study bridges both fields, we consider this is necessary to orientate the reader to the need for this research and presage the foci and analytic framework of the study.

Literature Review

Metacognition: Theoretical Framework and the Importance of Metacognitive Knowledge

While it is often acknowledged that metacognition is not an easy concept to define (Veenman et al. 2006) and that a unified framework for metacognition is ultimately necessary (Dunlosky et al. 2009; Schraw 2000), all metacognition research in science education locates itself within one of several commonly used theoretical frameworks (Thomas 2009, Thomas 2012a). These range from those more aligned with self-regulatory frameworks (e.g., Schraw et al. 2006) and those that reflect the views of early theorists (e.g., Brown 1978; Flavell 1979). The position taken in this paper is consistent with the broad literature on metacognition in science education (e.g., Thomas 2012a; White 1998) that metacognition refers to individuals' knowledge, control and awareness of their cognitive processes and that of others. This definition has been employed in numerous studies investigating and conceptualizing metacognition in science education (e.g., Anderson, Nashon & Thomas 2009; Baird 1986; Georghiades 2004). Irrespective of the theoretical framework employed, research consistently supports the view that (a) an individual's metacognition is a key factor influencing their science learning and that (b) developing and enhancing individuals' metacognition can result in improved science learning. Further, metacognitive knowledge is a common constituent of metacognition across theoretical frameworks.

Flavell (1979, 1981) and Flavell et al. (2002) identified metacognitive knowledge as a key element of metacognition. Metacognitive knowledge encompasses general knowledge about how people learn and process information, as well as an individual's knowledge of their own learning processes. The importance of metacognitive knowledge for facilitating enhanced science learning has been confirmed in science education (e.g., Thomas & McRobbie 2001; Yürük et al. 2009; Zohar 1999). Both students and teachers require metacognitive knowledge that is adaptive for the demands of their respective learning and teaching environments.

Flavell (1987) divided metacognitive knowledge into knowledge about persons, knowledge about tasks and knowledge about strategies. Thomas and McRobbie (2001) further categorized metacognitive knowledge as being *declarative*, *procedural* or *conditional*. Metacognitive declarative knowledge is about knowing that something is the case, for example, an individual's declaration of their definition/s for learning, thinking or understanding (Thomas & McRobbie 2001). It includes knowledge of oneself and others. Therefore, it encompasses person variables (Flavell 1979), which is the knowledge that individuals construct regarding the thoughts and thinking of themselves, their immediate others and people collectively. Metacognitive procedural knowledge, which incorporates Flavell's strategy and task variables, relates to an individual's knowledge of how to perform cognitive and learning activities and how they do so. It also includes information about learning and/or cognitive tasks that an individual possesses that might assist him/her to manage a particular task and also provide an indication regarding the potential level of task success. Metacognitive conditional knowledge relates to knowing when and why to employ procedural and declarative knowledge and why it is important to do so. Implicit in the application of conditional knowledge is an individual's evaluation of the context within which they are to undertake a cognitive or learning task.

In this study, we are concerned with parents' metacognitive knowledge, particularly their metacognitive procedural knowledge and metacognitive conditional knowledge of their own and their children's learning and thinking processes and strategies. We are interested in whether parents view their enactment of such knowledge as appropriate for the museum context and the exhibit/task with which they engage. Such a perspective on how metacognitive knowledge is enacted is consistent with a view that context can influence how individuals think in any given situation. This definition also recognizes that metacognition is influenced by social and cultural factors as well as individual factors (e.g., Anderson, Thomas and Nashon 2009; Thomas 1999). Therefore, while it is important to seek to develop a universal and generalizable framework for metacognition as previously mentioned, it is also important to acknowledge that how individuals' metacognitive knowledge is enacted and its influence on thinking and learning is inextricably entwined with the context within which it guides that individual's cognition. Generalizability across contexts should therefore be approached with some caution.

Using a taxonomy for metacognition, it is possible to begin to evaluate the substance of individuals' metacognitive knowledge and how it is employed and might influence interactions between parents and their children in a science museum context. The taxonomy gives rise to a coding system that is explained later in the paper, and that has applications beyond this study. This paper explores and reports parent participants' metacognitive procedural and conditional knowledge related to themselves and their children and how it shaped their interactions with their children. In this way, we consider not just the parents' metacognitive knowledge regarding themselves, but also their metacognitive knowledge of the cognitive and learning processes of others, i.e., their children, as outlined by Flavell (1979). This provides a perspective for examining factors influencing parent–child interactions within science museums that has not been previously employed.

The Need to Explore Metacognition in Science Centres and Museums

Science learning in informal settings such as museums and science centres is recognized as important and given increasing attention in science education circles. Such settings are characterized as learning environments that provide experiences with the potential for outcomes that are rich in developing interest in science and identity with the scientific enterprise (Bell et al. 2009; Zimmerman et al. 2008). At the same time, these sites have been sometimes criticized for being limited in their capacity to yield higher order cognitive outcomes such as inquiry learning, the synthesis of new understanding and the critical evaluation of existing knowledge (Gutwill & Allen 2010; Randol 2005; Wellington 1990). Further to such criticisms, they afford few opportunities for visitors to become self-aware of their own learning and learning processes. A review of the literature suggests that the investigation of parents' and their children's metacognition, itself a form of higher order thinking, is still in its infancy and largely uninvestigated in science museums. This is despite several authors previously identifying the need for research on parents' and their children's metacognition in the context of museum settings (e.g., Anderson et al. 2003; Bell et al. 2009; Schauble et al. 2002) and some mentions, albeit very few, regarding metacognition in the science museum education literature (e.g., Bell et al. 2009; Fenichel & Schweingruber 2010). Because metacognition is acknowledged as important for effective science learning, it is also somewhat surprising that it has not been more extensively acknowledged and investigated in studies in science museums.

This is not to say that extensive research has not been conducted into students' learning and learning processes in science museums. Many, if not most, studies in science museums have sought to understand what is learned and what influences such learning. This has enabled the articulation of guidelines and tenets for refining exhibits to enhance the possibility that quality science learning will take place (e.g., Falk 2004; Kenichel & Schweingruber 2010; Rennie & Johnston 2004). Of relevance to this study, investigations of family learning and children's learning have received extensive attention in the museum, science education and developmental psychology literature (e.g., Blud 1990; Borun et al. 1996; Crowley et al. 2001; Dierking & Falk 1994; Ellenbogen et al. 2004). These studies have adjusted to and reflected contemporary learning theories as they have developed and corresponding shifts in science education. They have demonstrated that family groups and children do learn science in museum settings and that the nature of learning accruing from engagement in these settings is both diverse and complex.

However, as previously noted, there is a clear distinction between cognition and learning processes and the metacognition that executively controls such processes (Nelson & Narens 1994; Thomas 2012b). Therefore, it cannot be implied that studies into the learning and cognitive processes, including the scientific reasoning of individuals within science museum contexts, can be extrapolated to inform with any certainty our understanding of their metacognition. This being noted, some studies have pointed, albeit obliquely, to the need to examine more closely what parents know about how their children learn, and how parent metacognitive procedural and conditional knowledge influences and might be used to enhance their children's learning. Crowley et al. (2001) highlighted the support parents provided for their children's reasoning via spontaneous collaboration. Seminal work by Gleason and Schauble (1999) into how parents scaffold their children's scientific reasoning in unfamiliar museum settings found that parents assumed most of the difficult conceptual tasks and did not cede the conceptual roles to the children. In their study, the parent–child dyads were observed in their engagement around *The Creek* exhibit at the Children's Museum of Indianapolis at which they manipulated the physical attributes of model boats and a model stream in order to increase the speed of the boats in trail races. From their study, they concluded that parents characteristically provided forms of assistance that appeared to be sensitive to their child's capabilities with the execution of boat race task. However, they suspected that parents did not generally understand what their children did not know about variances in the physical manipulables and hence failed to provide the kind of assistance to help their learning. They concluded that parents who wished to assist their children's learning might need to increasingly "understand how their children think—not just in general, but about central kinds of problems and content domains" (p. 343). Hence, our interest in this study is related to the "how" and "when" of metacognition, the procedural and conditional, and not the "what" of metacognition, the declarative. Such forays into understanding visitor's metacognitive knowledge are useful to the planned design of exhibit experiences, since with such knowledge, additional experiences might be envisioned that would assist visitors to know how to more effectively engage and to assist others in their learning experiences.

Methodology

Overview

The methodology adopted for this study is described and justified below. Firstly, we explain the interpretive orientation of the study. This is followed by an outline of the physical context of the museum exhibit and why it was selected for this study. The participants and data collection procedures are then detailed and justified as appropriate. Finally, the data analysis procedures used to deduce parents' metacognitive knowledge of their children's cognition and how we consider such metacognitive knowledge influenced their interactions with their children are described.

Methodological Orientation

An interpretive methodology was adopted for this study. Erickson (1998) argues that interpretive research takes into account social action that is "locally distinct and situationally contingent" (p. 1155). In this study we explored parents' metacognition, in particular their metacognitive procedural and conditional knowledge, and any influence of that knowledge on their interaction with their children within a specific science museum exhibit. We consider such interaction to be social and to be locally distinct. We also consider the research and findings to be situationally contingent because, as explained below, we asked participants to consent to be part of our study. Therefore, we cannot say for sure whether or not they would have chosen to engage with the exhibit we selected for them without our direction, or how they would have engaged with it if they had chosen, unsolicited, to do so. While aware of these issues, we argue that exploratory studies such as this are necessary to advance our understanding of the factors influencing parent–child interaction especially as such interaction is, as previously explained, an important factor influencing the discourse and learning taking place in science museums.

Such a research orientation is also particularly useful for research in museums settings because it entreats the researcher to undertake intensive, first-hand observations in the field and, where appropriate, to blend those observations with data collected via the use of other methods. We consider that the use of the blend of methods outlined below is consistent with our research goals and permits direct investigation of the phenomena of interest (Falk 2004). As is explained below, this interpretive study is highly qualitative in orientation, and while we summarize our findings as assertions we do so acknowledging that others might interpret the data we present differently to ourselves. Still, we seek to provide sufficient detail to support our assertions so that they resonate with readers who can then gauge their generalizability with reference to their own knowledge, contexts and experiences.

Science Museum and the Selection of Exhibit

This study was conducted at the Science Museum of Minnesota, located in St Paul, a large city in mid-west USA. The exhibit selected within the museum for the study was "Math Tracks" which was part of a larger Handling Calculus exhibition (Science Museum of Minnesota, n.d.). An extensive description including photographs is available at http://www.smm.org/static/explorations/calculus.pdf. We selected Math Tracks as the physical context for exploring visitors' metacognition because it met several criteria considered important (Borun & Dritsas 1997; Gutwill & Allen 2010). Firstly, it had (a) features that could be manipulated in multiple ways, (b) multiple starting points of engagement and (c) multiple potential outcomes depending on participants' manipulation and starting points. Secondly, the exhibit was predominately non-didactic in orientation and did not consist of a prescribed and largely inflexible set of possible events or activities. Rather, it enabled an inherent diversity of possible experiences that had potential to result in cognitive challenge and higher-order reasoning and learning outcomes. Thirdly, at the same time, the exhibit was both intelligible and engaging. This meant that visitors with minimal or no instruction or prior experience could understand and comprehend the aim of the activity and maintain an intrinsic willingness and desire to persist without easily giving up. We considered that these criteria were necessary for the exhibit to be novel and mentally challenging enough to stimulate visitors to engage in higher-order thinking and draw on their metacognitive knowledge.

The exhibit itself (Fig. 1) was comprised of two parallel tracks upon which carts traveled. Each cart could carry a miniature metal model of a familiar character that the participants could select (i.e., Little Red Riding Hood, the postman 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. Playing the scripts generated graphs on a screen that was located at the front of the exhibit, raised and clearly visible to the participants. The overall aim of the exhibit was to help participants develop an understanding of the relationship between motion and the slope of a curve on a graph representing that motion. The exhibit could be manipulated in several ways. For example, the cart could be manually moved by hand up

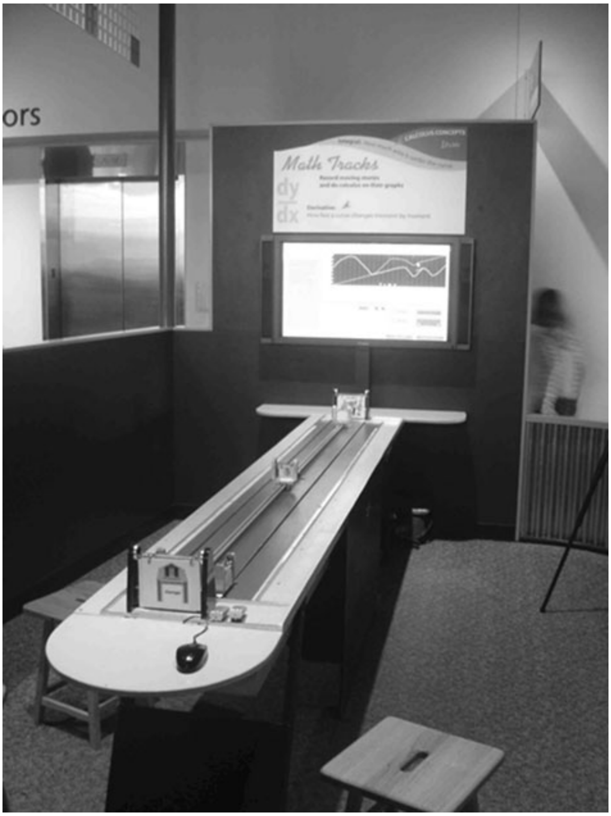

Fig. 1 The Math Tracks exhibit at the science museum of Minnesota

and down 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 of the carts with metal models on them would then be electronically recorded and then displayed as displacement, velocity and acceleration versus time graphs on the screen. Alternatively, displacement, velocity and acceleration versus time graphs could be created and manipulated by means of a mouse and then activated, resulting in the corresponding movement of the carts and metal models along the track.

Participants and Data Collection Procedures

Data collection took place over the course of 5 continuous days at the science museum. Participants in the study were 12 parent–child groups who were casual visitors to the museum and who consented voluntarily to participate in the study. Parents with their children aged 8–15 years were approached in the entry gallery, provided with a brief explanation about the study and invited to experience the Math Tracks exhibit and to be interviewed by three members of the research team about their experiences for 10–15 min immediately following the activity. Each consenting parent and their child were then taken to the Math Tracks and given a brief 2–3-min introduction regarding the nature of the exhibit. They then engaged freely with each other and the exhibit for between 6 and 10 min before being interviewed together about their experiences and the thinking they engaged in. During the dyads' interactions with each other and the exhibit, the research team unobtrusively observed the participants' interactions and engagement from behind at a distance of about 3 m and noted aspects of the engagement that might later be explored in the interviews. Also, the dyads' actions and dialogue during their engagement with the exhibit were audio and video (front and rear) recorded.

The interviews with each dyad took place immediately following their interactions with the exhibit. This timing of the interview improved the recency of participants' recall of the events immediately preceding, reducing the opportunity for any sharpening and leveling (Koriat et al. 2000) of their original perceptions. Evaluation of individuals' metacognition, particularly their metacognitive knowledge that is a focus of this study, relies heavily on self-reports. Interviews are a primary methodological means of eliciting information regarding individuals' knowledge and use of cognitive strategies (Nelson and Narens 1990; Rowe 1991; Thomas 2012a). Because individuals are the prime witnesses to their own thinking, interviews provide valuable insights into the nature and use of metacognitive knowledge (Paris et al. 1986) as they "constitute *prima facie* data of what one knows" (Gavelek & Raphael 1985, p. 106). Further, as Rennie and Johnston (2004, S8) note in relation to conducting research in science museums,

> Visitors must be involved in the research process, not simply observed from a distance, because there is a sizable inferential gap between what visitors both say and do. Seeing through the eyes of the visitor means that, at some stage, data must be collected *from* the visitor and this requires self-report data, or recording what visitors both say and do.

Therefore, we considered the interviews to be an essential element of our data collection, providing a window into participants' views of their own thinking as they engaged with the exhibit and each other and of their metacognitive knowledge related to that thinking.

The dyads were interviewed in a relaxed, friendly, semi-structured manner regarding their thinking and actions during their engagement with each other and the exhibit using a stimulated recall protocol developed by Anderson, Nashon and Thomas (2009). Questions asked in the interviews related to how and why they engaged with each other as they did, how they considered they were thinking and what they were thinking as they engaged with the exhibit, and how their thinking was similar and different to the thinking they considered they employed in different, non-museum situations. Additional questions followed to probe their awareness of individual and collective metacognitive knowledge about the strategies they employed during their engagement in the activity, the fruitfulness or otherwise of those strategies, and their mutual understanding of one another as learners. The interviews were also audio and video recorded.

Data Analysis Overview

This study investigated (a) what parents knew about how they and their children learned and thought and (b) whether their metacognitive procedural and conditional knowledge influenced their interactions with their children during their engagement with a moderately complex simulation in a science museum. We stress that our interest is not in the learning that took place or the success or otherwise of the participants with achieving the goals of the exhibit. Rather, it is on the metacognitive knowledge of parents and whether it influenced their interactions with their children and consequently with the exhibit. In this way, it varies from much previous research in science education within science museums.

The participants' discourse and actions were analyzed from the videotapes to characterize each dyad, noting similarities and differences. We considered this analysis necessary because to understand if parents' metacognitive procedural and conditional knowledge influenced their interactions with their children, we needed to understand and characterize the interactions themselves. At the same time, we were also cognizant that trying to infer the nature of the parents' metacognitive knowledge solely from any of our interpretations taken from the video analysis would be stretching the limits of credibility. Therefore, seeking self-report data from the interviews to confirm or disconfirm tentative assertions arising from the video analysis was seen as essential and in keeping with the aforementioned recommendation of Rennie and Johnston (2004). In analyzing the video and audio data of the dyads, we were concerned with the extent and nature of instructions, questions and comments in general given to the child, and between the parent and child, who it seemed determined the course of the activity with the exhibit, and who controlled and physically manipulated the material aspects, e.g. computer mouse and metal models of the exhibit.

In analyzing the interview data and identifying procedural and conditional metacognitive knowledge of parents, we developed and employed a coding scheme as shown in Table 1. The intimations of the parents were analyzed using this coding scheme.

In bringing the analysis of the videotape together with the analysis of the interview data, we explored the extent of any coherence between (a) parents' procedural and conditional metacognitive knowledge and their interactions with their children and (b) our interpretation of each dyad's character as a whole. If, for example, we noted that parents made statements about their children's learning processes (MKpO) and their interactions with their children were not consistent with or did not reflect that metacognitive knowledge, then we would question whether there was any credible relationship between parents' MKpO of their children's thinking and learning processes and the activity that transpired with the museum exhibit.

Table 1 Metacognitive knowledge coding system and examples

Metacognitive knowledge category	Code	Definition	Example from parent
Metacognitive Knowledge (procedural) of Others	MKpO	Knowledge about the cognitive strategies and learning processes that others employ to achieve their learning goals	He's a visual thinker, he's a picture thinker … he's the type of thinker that, without touching it (sic) he'll think about it, and he can actually develop concepts in his brain as to how it's going to work. He'd rather figure it out on his own than be told. (May, talking about her son Kris's learning processes)
Metacognitive Knowledge (procedural) of Self	MKpS	Knowledge about the cognitive strategies and learning processes that an individual him/herself employs to achieve their own learning goals	I need to redo something two or three times before it goes in, "Oh, Oh, Oh, Right!" … doing them again and again until it starts to make sense. That's definitely a common way I learn stuff. (Nicki, parent talking about her own learning processes)
Metacognitive Knowledge (conditional) of Others	MKcO	Knowledge about when and/or why (i.e., in what context) other persons choose to employ their metacognitive procedural knowledge	He's really visual/spatial. If he sees something visually, if he can manipulate things while he's learning, it really helps him grasp the concept of something like this [exhibit] as it would be represented on paper. It helps him so much more to have something physical and visual to relate to. (Elaine's awareness of the appropriateness of her son Mark's learning process engagement with the exhibit)
Metacognitive Knowledge (conditional) of Self	MKcS	Knowledge about when and why (i.e., in what context) they themselves choose to employ their own metacognitive procedural knowledge	I just know that if you're going to accomplish what this thing (exhibit) is asking you to do, it's important to read the instructions and follow step by step. (Duke talking about how the nature of the exhibit shaped how he thought the task had to be strategized)

Results, Interpretation and Reporting

Our analysis and interpretation of data from all 12 dyads relevant to the aims of this study can be summarized in the following two assertions:

Assertion 1: Parents reported metacognitive procedural and conditional knowledge regarding their 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, seeing this as appropriate pedagogical action for them within the science museum context and for the child involved.

These assertions are supported by our analysis of data across all 12 dyads. In reporting our findings, we present three cases that reflect variations in both the interaction between parents and their children, and in the metacognitive knowledge reported by each parent. This use of cases is in keeping with our aims of this study which were to establish what metacognitive procedural and conditional knowledge parents in the dyads possessed about how they and their children thought, and whether this knowledge influenced their interactions with their children during the Math Tracks simulation. Our aim was not to exhaustively identify, characterize and/or categorize all possible variations in metacognitive knowledge and/or variations in interactions between parents and children.

Each case is presented by first characterizing the interaction that occurred between the parents and their respective children. This is to provide the reader with insights into what transpired when each member of dyad was interacting with the exhibit and with each other. This is followed by the results and interpretation of the analysis of the interview data related to the parent's metacognitive procedural and conditional knowledge regarding their own and their child's learning processes, and whether this knowledge influenced their interactions with their child and the exhibit. Parents' views on the conditionality of their actions within the museum context are outlined where possible. In each case, the names of the participants are pseudonyms. The parent is named first in each pairing.

Kym and Stan (9 Years Old)

The interaction between Kym and her son Stan was characterized by Kym asking Stan what "stories" he would like to enact with the exhibit and her then providing direction as to how he manipulated the models. The interaction outlined in the transcript below is from their initial interaction with the exhibit following them being given general instructions regarding how it functioned. This pattern of interaction was repeated continuously throughout their time of 8 min and 7 s with the exhibit. Kym would ask Stan what story he wanted to do and would read the instructions for them. Stan would choose the story to be enacted and manipulate the models and the mouse, sometimes without instruction. Occasionally, Kym would help set up the flips (visual checkpoints along the route of the cart models that coincided with particular story elements, like a bridge or grandma's house, and that were chosen for each particular story by selecting and "flipping" over an image at the specified location on the tracks). With one story she helped Stan with moving the carts when more than one needed to be moved at the same time. However, apart from that she was seated and reading instructions aloud, providing direction for his hands-on engagement while at the same time allowing him to explore options with the exhibit without her direction, and monitoring his and their performance.

Kym: What do you want to do?
Stan: Ahhh (uncertain)
Kym: You want to pick a story? Just grab one with the mouse and pick it if you want.
[Stan clicks on a story line with the mouse].
Stan: There you go.
Kym: Ok. Read and listen to the story.
[They listen to the audio storyline.]
Stan: Next.
Kym: Set up the flips like this. So, we've gotta set them up on the track there. [Pointing to the tracks on which the carts travel.] You see how the red goes along the top there? So, you want your red cart out [showing Stan the red car]. You need the stop light in the middle there, and then that one's not used [pointing to a flip position]. There the post office at the end [Pointing to the post office flip location], and this is the green car on this side [Showing Stan the green car]. Unless you want to do another story?

Stan: Green car's good.
Kym: OK. Alright. Just press next.
[Stan presses the "next" button using the mouse]
Kym: There we go.
Stan: Sure
Kym: You should be set to go I think. Let's see what happens.
[Stan clicks on "start" and the green cart begins moving, and there is a corresponding change in the slope of the curve in the display. Both observe the graphical display.]
Kym: So it graphs out the motion of the cart thing.
Stan: Yeah. So are you trying to match it, or…
Kym: No [interrupting], I think you get to do your own thing. What they're really looking at is … (does not finish the sentence).
Stan: Alright.
[Stan repeats the same action of the carts by clicking the start pattern again]
Kym: [Immediately after he has clicked the "start" button] That one's OK. You want to go to more experiments? You want to try something else?
[Stan stands up of his own volition and without prompting from his mother and moves the red cart, and there is a corresponding change on the graph on the display]
Kym: Oh, you're going to move it?
[Stan moves the cart to the top of the track and then back to its origin, stopping and starting the cart at various times. At the same time he is moving the cart, he is looking at the graphical display where the motion of the cart is being represented in real time. He then moves back to the start end of the tracks near where the mouse is and stands.]
Kym: Do you want to see how fast you were going?
[Stan clicks on the start button, and the motion of the red cart that he just did is repeated without him moving it. He and his mother watch this.]
Stan: Cool!
Kym: You want to try another experiment? You want to try the speedboat one or something? Click into more experiments down there in the right hand corner and let's see what else we've got. You want to do the dog one, or boats or cars, or what?

Kym considered that her interaction with Stan was consistent with her view that Stan was "a hands-on learner…not shy about clicking on things and trying different things" (MKpO) and that his actions with the exhibit were characteristic of those in other contexts: "He's big on Lego building and computer games …. He'll just go for it and is comfortable trying different things" (MKcO). This differed from her metacognitive knowledge regarding her own learning processes that she reported as, "I'm typically a reader, a studier. Those are the ways I learn things (MKpS). I'm much more conservative with computer types of things" (MKcS). She also suggested that the variations between her and Stan might reflect a more general difference between her and "kids" in general (MKpS v MKpO): "… the kids, they're much more into an atmosphere (sic) where it's tactile … they're less likely to read about it … so (they're) touching it, playing with it (MKpO)." She further submitted that she would not classify Stan as a book learner like herself suggesting, "I don't think that would be his primary preference in learning styles" (MKpO). She went on to further clarify what she meant by "learning style" and how it related to her understanding of how her son learnt and how it differed from how she learnt (MKpS):

I think that every person learns a little bit differently. I'm not a scientist on the subject [of learning styles], but I wouldn't say Stan is a straight-up book learner

> (MKpO). His interests vary a lot, and he certainly doesn't naturally tend to go to the book or the Internet to look up things he's interested in (MKpO). That's where I see the hands-on style of learning.

Kym suggested her role in the activity with Stan was characterized as being a "coach." She considered this role and her asking Stan to take control of the mouse and the models as being appropriate for this exhibit context because (a) she "probably understood sooner" than Stan the concept/s involved in the simulation and (b) she was "much more conservative with computer types of things," while Stan, as alluded to previously, (c) was more someone who was "comfortable trying different things (sic) out" (MKpO). During the task Kym allowed Stan to control the mouse and engage with the exhibit in ways not suggested by her, but at the same time through her questioning and reading aloud of instructions, she sought to influence his and their progress with the exhibit. This also reflected her view that people may not easily understand a graph's curve in relation to the movement of the physical entities it represented, and how she tailored her directive role as a coach, allowing her son to "play" with the exhibit while at the same time being guided by her so that their time with the exhibit might be successful:

> I don't think everybody necessarily understands a graphic representation right of the bat (sic). It's easier to physically play with it (the exhibit) than to understand graphically what it means. I think you have to play with it to make it do what you want it to do on the problem solving side. (MKpS)

Consistent with her view that "every person learns a little bit differently" (MKpO), Kym considered that she differentiated her interaction with each of her three children, of which Stan was the middle, according to their individual characteristics. "I think that they each have a unique personality and unique learning styles and interests, and I cater to what those are" (MKpO). With the oldest, she suggested she would have "sat back and let her do most of the problem solving," and with the youngest she suggested she "probably would have been more directional to get to the solution."

Don and Ally (12 Years Old)

The interaction between Don and his daughter Ally was characterized by the father taking a very non-interventionist, predominantly silent approach and letting Ally explore the simulation at her own pace and allowing her to have the final choice over the course of the activity at all times. Their interaction with the exhibit was 7 min and 3 s in length. There were long gaps of up to 31 s between Don speaking with Ally, and most often he only spoke when spoken to by her. Hence, there are no detailed transcriptions of dialogue supported by description of the dyad's actions and gestures as for the other two cases reported in this paper. In fact, Don's hands remained on his lap for the duration of their interaction, and he did not make any physical gestures to guide his daughter's actions. Never at any stage did Don touch any part of the exhibit. He sat very still, only turning his head to follow what Ally was doing as she engaged with the exhibit. He seemed very intent on observing her.

Don was also intent on allowing Ally considerable freedom. Whenever Ally sought his approval or advice on what aspect of the exhibit to explore or action to take, Don typically replied, "Yeah, if you want to do that," or "Whichever one you want." Ally did all the manipulation of the models and of the mouse controlling the graphical display. This further evidenced his predominantly hands-off, non-interventionist approach. As noted, there was very little verbal interaction between the two, with Don only initiating conversation with Ally without her first asking a question when she had reached a point where it seemed she could make no further progress for a lack of understanding of the technical aspects of the exhibit. His intervention with respect to her lack of understanding of technical aspects was especially evident with respect to her manipulation of the physical variables of the exhibit. In such instances he would read instructions shown on the exhibit aloud to her, only once, and not discuss them, prompting her to think about the instructions and what she was doing. For example, at the start of their interaction with the exhibit, to get her started he read, “Press record to act out the story by moving the mouse along the red track” which was an instruction on the computer display. He then added, “I think you do that yourself, pushing it.” Later in the activity Ally suggested to Don that the metal models should return to the start to begin a new “story.” Don’s reply was “Well, just do that. Free exploration. Restart the scene? See, down there on the right? You can go move the cars back if you want, or you can start where they are.” This was as much as he ever spoke to her at any one time of their time with the exhibit.

Don considered that he had always been more successful as an “experiential learner” (MKpS) adding, “If I read it in a book I might not pick it up as well as I would to see it actually in some sort of real life event” (MKpS). He further clarified his position stating, “I can look at how to do something in a manual or book, but if I then go and do it myself it stays with me better” (MKpS). He considered that Ally learned best the same way as he did (MKpO), i.e., she learnt better from first-hand experiences “as opposed to having somebody show” her what to do (MKpO). He summarized his approach to his interaction with Ally as “I was just letting her see what she’d pick up from the experience.” Don further explained his approach with Ally by suggesting that it was appropriate to “give little hints” to help her “find out how to do it” herself, just “like with a math problem” she needed to “understand the logic” (behind the activity) (MKpO), and his role was to guide her thinking and facilitate her to “work out the actual details and steps” for herself as much as possible. He was conscious of monitoring the times during his interaction with Ally at the exhibit where he had given sufficient information.

Don also reported that the approach he reported using with Ally would not be appropriate for his other two children, one of whom would only consult a manual “if he couldn’t do it without the manual” (MKpO) and another who would “follow right through the book and then go follow the steps” (MKpO). In this way he suggested understanding differences in his children’s learning activity preferences (MKcO), further highlighting the Ally-specific interaction he had with her at the Math Tracks exhibit.

Duke and Nikki (8 Years Old)

The interaction between Duke and his daughter Nikki was characterized in the first 4 min and 20 s of their total 8-min and 5-s engagement with the exhibit by Duke providing very little if any opportunity for Nikki to initiate and determine her own course of interaction with the exhibit. The only choices she was given during that first period of their interaction with the exhibit were to choose which story they would work on, to agree to click the mouse to initiate the movement of the carts and to agree to help her father move carts or set up flip tiles for particular stories. On several occasions during this first section of their interaction, Duke went against what Nikki suggested as a choice of activity, usually not explaining why he did so. Nikki openly and clearly disagreed with Duke three times about what he decided they should do, but on each occasion she was over-ruled and complied with the course of action decided by her father. Exemplary dialogue from the first 4 min, 20 s of their interaction with the exhibit is:

Nikki: I want to do "racing boats."
Duke: Racing boats. [Nikki without advice from her father clicks the mouse activating the "racing boats" audio storyline]
[They begin to listen to the audio storyline]
Duke: Shall we put the docks … (doesn't finish sentence).
[Audio storyline finishes]
Duke: OK. So, are you going to push one of those, one of those boats?
Nikkie: [No answer]
Duke: So let's set up the flips. [Dad stands and begins setting up the flips and carts]
Nikki: [Still sitting] I wanna do this one. [Disagreeing with Duke, and holding the mouse to suggest she wants to be in control of it.]
Duke: Let's set up the carts [boats] first.
[Nikki remains seated while her father begins to set up the boat models at the start end of the track.]
Duke: [Returning to where Nikki is still seated and leaning over.] Are you a boat person?
Nikki: I'm a boatman.
Duke: Ok, so what's this over here? [Moving to the centre of the track]
[Nikki gets up and moves to where he is to observe what he is doing as he turns the flip cards in the centre to find the one that fits with the racing boat storyline. They then move from the centre to the end of the track where Nikki, without being asked, turns the flip cards to choose those that fit with the same storyline. They then return to their seats at the start end of the track.]
Duke: All right, should we restart this scene?
Nikki: Yeah
Duke: Restart [Father takes the mouse and clicks to restart the scene storyline]
Nikki: Oh yes. I want to do it. [Father retains control of the mouse clicking through the menu until the storyline begins to replay]
Duke: More experiments. You wanted to do the boats, right?
Nikki: We already listened to this. [Disagreeing with Duke about having to listen to it again.]
Duke: Right but we gotta … [doesn't finish sentence]. It says, "Read and listen to the story. Set up the flips." See that? Step number 2. And then, we go "next." Right? OK? So now, do we want to record our own?
Nikki: Yeah.
Duke: Should we do a recording?
Nikki: Uh, huh. Yeah.
Duke: And you're on one side?
Nikki: Yes, I'm on this one [Pointing to the green cart side]
[Duke clicks the mouse to activate the record button on the display.]
Duke: Ok, let's see what happens here. So here we go.
[Both stand and take a cart each, moving it along its respective track to act out the racing boats storyline. They both complete moving the carts and then return to their seats at the start end of the track.]
Duke: Ok, what are we doing? Let's see.
Nikki: Play.

Duke: Should we play what just happened? [Father passes the mouse to Nikki.]
Nikki: Yeah.
Duke: Ok. So click on play. [Nikki clicks the mouse to activate the play button on the screen, and the carts begin to move as they did when the dyad moved them in accordance with the storyline.]
Duke: Oh. Look at this.
Nikki: [Nikki begins to laugh lightly.]
Duke: You were hesitant, and I went all the way down.
[The storyline is completed by the models and the graph.]
Duke: Pretty cool, huh? You just made your own little video.

Following the initial 4-min 20-s period of the episode with the exhibit, the nature of the interaction between Duke and Nikki changed markedly, with Nikki being allowed much more control over their course of action. While Duke still read instructions out aloud and provided cues for Nikki as to which buttons she should activate with the mouse and in what order, Nikki was able to select storylines, and, apart from one time, when she asked her father to help with manipulating the curve of the graph so as to control the movement of one of the carts, she was in control of the mouse and the progress of the activity. Duke also began providing suggestions for her to consider to stimulate her to think about the connections between the car and the graph, e.g. "How about you make the red car come back here at the end, come back to us at the end?" but he did not enforce those suggestions, allowing her considerable self-determination. Further, he took on a role of trying to explain explicitly to Nikki the relationship between the shape of the graph and elements of the carts movements, e.g., "Do you notice that the more flat [the curve], the car doesn't really move much? It just sits there. But if you have big angles, the car will actually move more?" and "Can you see by the graph which way it's [the cart] going?" In doing so he attempted to stimulate her to think about the science concepts and relationship between the movement of the carts and the representation of the graph that was a focus aim on the exhibit. Therefore, the interaction between Duke and Nikki varied markedly between two clearly identifiable parts of their engagement with the exhibit.

Duke explained that he considered himself a very methodical learner, "I am very much by the book, by directions; step one through ten, you know? Assembling a piece of furniture, some people throw the directions away. I'm step one, step two. Very organized" (MKpS & MKcS). He considered that this was a consequence of his own life history; "As a child, you're probably just more likely to experiment and just do things on your own (MKpO). [Then] you get a lot of direction whether it's in school or at a day care or at home." He also considered that he and Nikki were very much alike and that he understood her thinking processes.

I know that she and I are a lot alike. I see myself in her a lot of different things she does, so I just feel like because she's my child and because I know she takes after me in a lot of different ways, I almost know (sic) how she thinks (MKpO) and how she acts, and I can relate to her.

This knowledge, he suggested, influenced the interaction between him and Nikki with the exhibit.

I wanted her to have fun with it and create whatever she wanted to, to try to give her as much flexibility as possible. But also keep it somewhat structured. I wanted her to have a learning experience as well, so I tried to keep it a little organized and follow the directions because in school (MKcO) she'll answer questions, but sometimes she'll forget to read the directions (MKpO). I'm aware of that and I was trying to help her;

> point 1, point 2, point 3, because otherwise she just goes all over the place and likes to click things (MKpO).

He further suggested that the progression that he had been through as a learner from being unstructured and "experimental," as he described Nikki, to more methodical "definitely" influenced how he interacted with her in the exhibit. "How I try and teach her is based on a lot of my own experience going through life … and so, I exert my influence on her in that way." He added,

> I just know that if you are going to accomplish what this thing (sic) is asking you to do, it is important to read the instructions and follow step by step (MKpS and MKcS). And if I was to let her just run with it, she wouldn't be able to see the full value of this [exhibit], what it does from start to finish. I really wanted her to see the actual outcome."

Duke also reported that he was aware that he could have interacted differently with Nikki. This view was based on his knowledge of how she interacted with a computer program in their home environment.

> Another approach I could have used was to let her "run with it." And I do that at home. She has some computer games that I haven't put any influence on, for example, Webkins [http://www.webkinz.com/]. She just does her own thing with it (MKcO). I don't know whether that's because she's following the instructions step by step or just figuring it out as she goes.

In relation to the two-part nature of the interaction with Nikki, Duke explained that he considered that before he could allow Nikki to be in control of her interaction with the exhibit he needed to understand, himself, what was entailed in the exhibit:

> I picked it up fairly quickly, but I was still learning myself [about the exhibit]. So that was a little bit challenging to quickly figure it out for myself so that I could influence her a little bit. When I was learning I wasn't paying as much attention (MKcS) to what she was doing because I was trying to make sure we set the thing up correctly. But once I got it, I let her do whatever she wanted to do. Once I knew she was on the right track, I kind of let her go.

Finally, Duke considered that Nikki was a "little different" from her younger sibling whom he suggested "catches on to things (sic) and does things on her own … is experimenting and doing and getting into trouble" (MKpO). He added that on the basis of what he knew about his younger daughter, he would act the same way with her as with Nikki, "When I have one-on-one time with the younger one, again, I try to provide some structure, some framework."

Discussion

Enhancing science learning in science museums is an increasing priority for educators from across many spheres. Government and civic groups commit substantial funding towards the development and maintenance of science museums, and it is increasingly expected that as well as providing some level of entertainment value, they will contribute to the cultural and educational capital of the communities within which they are located. Research in the past has examined students' cognitive processes in science museum settings, and this research has provided feedback for exhibit developers and science educators on the need to engage visitors in "hands on–minds on" activities and exhibits in addition to stationary exhibits that were once traditionally associated with museums. The Math Tracks exhibit is an example of such evolution occurring in museums.

This research adds to an emerging but still infant literature regarding metacognition in science museums and other informal learning settings by suggesting that person metacognitive variables are important in shaping how museum visitors interact with an exhibit such as Math Tracks that has a "hands on–minds on" orientation. In this study we were attending to the personal context (Falk & Dierking 1992; Rennie & Johnston 2004) of the parents and exploring how they influence the social context of their child, including the interactions that "produce the nature and outcomes of the (child) visitor's museum experience" (Rennie & Johnston 2004, p. S6). In particular, we explored how parents' metacognitive procedural and conditional knowledge regarding their own and their children's learning processes might influence how they interact with their children.

Parents possessed metacognitive procedural and conditional knowledge regarding their own and their respective children's learning and thinking processes. They differed regarding what they considered as important for their personal learning. Kym reported that reading was central to her learning processes. Don reported that engagement with a learning experience in an unfettered way was important for him. Duke articulated his view that following steps involved in undertaking a task was central to successful completion and learning from a task. Each parent had a different view of their learning disposition that they articulated. Each parent also had an understanding, i.e., metacognitive procedural knowledge, about how their child learned. Kym viewed Stan as a hands-on learner, and was aware that he differed from her in this regard. Both Don and Duke considered that their daughters were similar to them in terms of how they learnt. Interestingly, Duke reported that there was a need to attend to what he saw as a problem with how Nikki learned, in that he considered that she did not follow steps closely enough, a flaw he identified he had been taught. Such metacognitive procedural knowledge those parents possessed regarding their own and their children's learning processes formed part of the personal context of the museum experience for each parent and his/her child.

It is clear that the parents had definite views about how to interact with their children and also how the activity should proceed. Kym allowed Stan to do all of the activity while providing considerable verbal and physical guidance to him. Don allowed Ally almost complete independence when she engaged with the exhibit, only interceding when she considered she was stuck on a procedural matter, and even then not offering much advice to her. He made no contribution to manipulating the physical environment of the exhibit. Duke was clear about the need to ensure that Nikki was aware of the importance of following the steps necessary to operate the exhibit so that learning could be maximized. He was intent on understanding the steps involved in operating the exhibit himself, and before allowing Nikki more opportunity to interact with the exhibit in a way she wanted to.

As noted by Gutwill and Allen (2010), "parents are natural guides for their children" (p. 738). We continue an established line of research that asks, "On what basis do they guide them?" Previous studies have not considered parents' metacognitive knowledge or any type of metacognition in general and its influence on interactions and learning in science museums. In light of our reporting and analysis of the cases above, we suggest that parents' metacognitive procedural and conditional knowledge of their own and their children's learning processes influenced their interactions and the nature of the guidance they provided for their children as they engaged with the Math Tracks exhibit. The parents tried to accommodate how they considered the activity should proceed by seeking a balance between their metacognitive procedural knowledge of their own learning processes and that of their children. Further, the parents were aware of their thinking regarding their actions and expressed the view that their actions were appropriate for the child concerned and for the exhibit they were engaged with. The nature of their interactions was influenced by what they reported knowing about how they and their children learned and how such metacognitive knowledge influenced how they proceeded. It is also interesting to note that each parent reported variations between the children in each of their families with respect to their learning processes and orientations. They also considered that if they were to engage with their other children at the exhibit, the nature of their interaction with them would be according to the characteristics of each child, and that how they considered each child learnt would be a factor that influenced this interaction.

We are confident in such claims on the basis of the methodology and analysis we employed. In particular we contend that there is congruence between the actions and discourse of the participants, the metacognitive procedural and conditional knowledge of the parents and how they themselves considered that such knowledge influenced their interaction with their children. As stated previously, if we could not establish a clear interplay between these elements, we would not be able to make such assertions. The use of mixed methods that were complementary to each other and each focused on different aspects relevant to the issue under investigation (Rennie & Johnston 2004) enabled us to develop a clear picture as to the nature of the interactions between parents and children and establish whether such interactions were influenced by the parents' metacognitive procedural and conditional knowledge, both in our own minds and in those of the parents as evidenced by their claims during interviews.

We reiterate that each of the three cases reported and the two aforementioned assertions emanating from our analysis reflected the situation within all dyads in this study, without exception. In making our claims, we, at the same time, acknowledge that we imposed our choice of exhibit on the participants for reasons previously outlined. Even though they consented to be part of the study, it was not totally their decision or free choice to take part in this specific element of the museum's curriculum. The exhibit is the physical context. It is part of what is happening; therefore, we cannot say with certainty that the nature of the parents' interaction with their children and the exhibit would be the same for all other exhibits in this or any other science museum. That being noted, we are confident of our findings and the assertions arising from them. In this study with these participants, the two assertions are strongly supported. We did not ask parents to justify or defend what they did. Rather, they gave their views freely during interviews in a spirit of sharing. Our task was not to evaluate the efficacy or appropriateness of the metacognitive knowledge and/or the interactions between the parents and their children. Nor was it our aim or task to establish, by some measure, whether parents' views were "correct" or otherwise. Rather, we sought to observe, record, analyze, understand and report on the nature of parents' metacognitive procedural and conditional knowledge and its influence on their interactions with their children during their engagement with a moderately complex simulation in a science museum according to well-established theoretical and methodological frameworks. The key point is that parents do possess such metacognitive knowledge and it does influence their interactions with their children, and, we suggest, this should be accounted for as an interpersonal contextual factor in studies on interactions between children and their parents in science museums. We can locate no study that previously reports on this specific matter in relation to metacognition and parent–child interaction in science museum settings. This makes this study noteworthy for future scholarship and research in this area. We are confident that further studies will confirm the generalizability of those assertions to other science museum contexts and exhibits. While the learning that takes place in science museums might be contextualized (Rennie & Johnston 2004), it might be considered that parents employ their metacognitive knowledge regarding their children's learning processes across contexts. And this needs to be accounted for in the consideration of how museum exhibits are conceived.

Conclusion

From our study we have become aware that these parents arrived at the science museums with definite and reportable views and metacognitive knowledge about how they and their children think and learn, and about the affordances and constraints of such thinking and learning processes and dispositions. They transferred these impressions from learning contexts outside the science museum into it. These views influenced the nature of their interaction with their children with this exhibit. If the same is true for parents in general, then this adds another dimension to what might be needed to maximize children's learning in science museum contexts. It may be that it is necessary to educate parents regarding the value of interacting in certain ways with their children so that (a) the metacognitive procedural and conditional knowledge of both parties and its enactment is made "visible" for both through discussion about thinking and learning processes and strategies, and (b) the activity with the exhibit itself becomes, therefore, a metacognitive experience that enables parents and children to review and evaluate their thinking and learning processes within and beyond the museum setting. This raises the potential issue of whether or not science museum exhibits should be designed so that they incorporate experiences that stimulate visitors to metacognitively reflect about their own learning processes and the learning processes of those with them. If such matters were to be considered, there is no doubt that they would create additional demands on those who design science museum learning environments by increasing the factors to be considered in such design. However, given the acknowledged importance of metacognition for science learning, and for learning in general, beginning to consider how to acknowledge the importance of metacognition within the field of science museum education has the potential to enhance both the participants' metacognition and their learning of science within and beyond science museum settings, and also the quality of their science museum experiences.

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