Parents' Metacognitive Knowledge on Their Interactions with their Children in a Science Museum

David Anderson[1], Gregory Thomas[2]
[1]University of British Columbia, Vancouver
[2]University of Alberta, Edmonton
david.anderson@ubc.ca

Abstract: *Despite science learning in science museums being recognized as important and given increased 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 metacognition being an important influence on learning within and across contexts. This paper presents findings from a study that investigated parents' metacognitive procedural and conditional knowledge. These key elements of 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 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 for the particular exhibit at the science museum, and for the child involved. These findings have implications for exhibit and activity development within science museum settings toward the enhancement of both parents' and children's learning experiences.*

Keywords: Metacognition, Science Museums, Parents, Children, Interaction

This paper brings together the research fields of metacognition and learning in informal settings such as science museums. To acknowledge the importance of metacognition as a factor influencing parent-child interaction and learning within science museums, 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.

1.Theoretical Background

The position taken in this paper with respect to our epistemology of metacognition is consistent with the broad literature on metacognition in science education (e.g., Thomas, 2012; White; 1998) that metacognition refers to individuals' knowledge, control and awareness of their cognitive processes and that of others (Anderson, Nashon & Thomas, 2009; Baird, 1986). Research consistently supports the view that, (a) an individual's metacognition is a key factor influencing their science learning, and (b) that developing and enhancing individuals' metacognition can result in improved science learning. Thomas and McRobbie (2001) 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 or thinking (Thomas & McRobbie, 2001). 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, refers to a person's knowledge of how to perform cognitive and learning activities and how they do so. It includes information about learning and/or cognitive tasks that an individual possesses that might assist him/her manage a particular task, and also provides 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 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.

2.The exhibit context

The exhibit selected within the museum for the study was "Math Tracks" which was part of a larger Handling Calculus exhibition at the *Science Museum of Minnesota*. The exhibit itself was comprised of two parallel tracks upon which carts traveled. The overall aim of the exhibit was to help participants develop an understanding of the relationship between motion and the slope of various graphical representations that represented that motion. The exhibit could be manipulated in several ways. For example, the cart could be manually moved by hand up 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. An extensive description is available at http://www.smm.org/static/explorations/calculus.pdf

3.Methodology, Participants and Data Collection Procedures

An interpretive case study methodology (Stake, 1995) 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' metacognitive procedural and conditional knowledge, and any influence of that knowledge on their interaction with their children within a specific science museum exhibit.

Data collection took place over the course of five continuous days at the museum. Participants in the study were 12 parent-child groups who were casual visitors to the museum and who consented to participate. Parents with their children aged 8 to 15 years of age 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 to 15 minutes immediately following the activity. Each consenting parent and their child were then taken to the Math Tracks and given a brief two to three minute introduction regarding the nature of the exhibit. They then engaged freely with each other and the exhibit for between six and ten minutes before being interviewed together about their experiences and the thinking they engaged in. The dyads' interactions and discourse were recorded with video cameras at the front and rear of the exhibit. The interviews with each dyad took place immediately following their interactions with the exhibit. 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 (Rowe, 1991; Thomas, 2012). Because individuals are the prime witnesses to their own thinking, interviews provide valuable insights into the nature and use of metacognitive knowledge (Paris, Saarnio & Cross, 1986) as they constitute prima facie data of what one knows.

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 understanding of one another as learners. We developed and employed a coding scheme where we identified *Metacognitive Knowledge (procedural) of Others* (MKpO): Knowledge about the cognitive strategies and learning processes that others employ to achieve their learning goals; *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; *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; and *Metacognitive Knowledge (conditional) of Self* (MKcS): Knowledge about when and why (i.e., in what context) they choose to employ their own metacognitive procedural knowledge.

4.Results, Interpretation and Reporting

Our analysis and interpretation of data from all twelve 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 from our analysis of data across all twelve dyads. In reporting our findings we present 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 that 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. 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 was examined by first characterizing the interaction that occurred between the parents and their respective children. This approach provides 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. Below follows a sample case of Kym (parent) and Stan (child) (pseudonyms) to illustrate parents' metacognitive knowledge and its influence on the interactions at the exhibit. Other exemplars are found in Thomas and Anderson (2012).

Kym and Stan (9 years old): The interaction between Kym and 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. This pattern of interaction was repeated continuously throughout their engagement. 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]. 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] 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.] 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] 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?

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 her learning (MKpS)

I think that every person learns a 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 to be appropriate for this exhibit context because, (a) she "probably understood sooner" than Stan the concept/s involved in the simulation, (b) was "much more conservative with computer types of things," while Stan, as alluded to previously, and (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 solution."

5.Conclusion

From our study we have become aware that parents arrived at the science museums with definite and reportable views, 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 their interaction with their children at 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 museums. It may be 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. This raises the potential issue of whether science museum exhibits should be designed to 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.

References

Anderson, D., Nashon, S., & Thomas, G. P. (2009). Evolution of research methods for probing and understanding metacognition. *Research in Science Education, 39*(2), 181-195.

Baird, J. R. (1986). Improving learning through enhanced metacognition: A classroom study. *European Journal of Science Education, 8*(3), 263-282.

Erickson, F. (1998). Qualitative research methods for science education. In B.J. Fraser &K.G. Tobin (Eds.), International handbook of science education (pp. 1155 - 1173). Dordrecht,The Netherlands: Kluwer.

Flavell, J. H. (1979). Metacognition and cognitive monitoring. *American Psychologist, 34*, 906-911.

Paris, S. G., Saarnio, D. A., & Cross, D. R. (1986). A metacognitive curriculum to promote Children's reading and learning. *Australian Journal of Psychology, 38*, 107-123.

Rowe, H. A. H. (1991). Observing thinking and learning processes. In G. Evans (Ed.), *Teaching and learning cognitive skills* (pp. 9-26). Melbourne: Australian Council for Educational Research.

Stake, R. E. (1995). The art of case study research. Thousand Oaks, CA: Sage.

Thomas, G. P. (2012). Metacognition in science education: Past, present and future considerations. In B. J. Fraser, K. G. Tobin, & C. J. McRobbie (Eds.), Second international handbook of science education (pp. 131-144). Dordrecht, The Netherlands: Springer.

Thomas, G. P., & Anderson, D., (2012). Parents' metacognitive knowledge: Influences on parent–child interactions in a science museum setting. *Research in Science Education. Early View*, DOI 10.1007/s11165-012-9308-z

Thomas, G. P., & McRobbie, C. J. (2001). Using a metaphor for learning to improve students' metacognition in the chemistry classroom. *Journal of Research in Science Teaching, 38*(2), 222-259.

White, R. T. (1998). Decisions and problems in research on metacognition. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 1207-1212). Dordrecht, The Netherlands: Kluwer Academic Publishers.