# Symposium: Research Methods Involving Children's Drawings in Mathematical Contexts

In this symposium we present and discuss some methodological issues and possible solutions that have been encountered during our research into children's mathematical thinking, behaviours and affective responses, as reflected, at least in part, through their drawings. It has been claimed that, "Drawing can be a window into the mind of a child" (Wolek, 2001, p. 215). Such a statement implies that a child's self-created drawing can provide an indication of his/her internalised mathematical perceptions and conceptions. Note that the word 'drawing' can be used as either a noun or a verb, and hence can refer to either a completed artefact or to the dynamic act of creation. Depending on the aims, theoretical perspective and context of the study, researchers may focus on one form of 'drawing' or explore both forms.

Although drawing has long been an expected component of children's mathematical activity, rigorous research methods utilising mathematical drawings have remained somewhat underdeveloped. In recent years, a number of researchers have grappled with the design and development of specific aspects of methodology in their separate projects. With few established research methods for guidance, researchers have been creating and refining task designs, interview protocols, data capturing strategies, analysis techniques and interpretation processes for their studies of children's mathematical drawing. Each of the symposium papers presents a different research tool or technique that has been developed within its own unique context, with the purpose of stimulating discussion and advancing the development of effective research methods in the field of children's mathematical drawing.

Wolek, K. (2001). Listen to their pictures: An investigation of children's mathematical drawings. In Cuoco, A. (Ed.), *The roles of representations in school mathematics*, NCTM 2001 Yearbook, (pp. 215-227). Reston VA: NCTM.

**Chair/Discussant**: Joanne Mulligan

**Paper 1:** Amy MacDonald & Steven Murphy *Using the drawing-telling approach to reveal young children's mathematical knowledge.*

**Paper 2**: Jennifer Way & Jennifer Thom. *Capturing the mathematical drawing process using a digital pen.*

**Paper 3**: Kate Quane, Mohan Chinnappan & Sven Trenholm. *The nature of young children's attitudes towards Mathematics.*

**Paper 4**: Jill Cheeseman & Andrea McDonough. *Coding young learners' pictorial responses to an open-ended assessment task.*

2019. In G. Hine, S. Blackley, & A. Cooke (Eds.). Mathematics Education Research: Impacting Practice *(Proceedings of the 42nd annual conference of the Mathematics Education Research Group of Australasia)* pp. 99-116. Perth: MERGA.

# Capturing the Mathematical Drawing Process Using a Digital Pen

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This paper contributes to the Symposium: *Research Methods Involving Children's Drawings in Mathematical Contexts* by exploring the use of digital pens as a data gathering tool. The availability of digital recording devices has been a boon to researchers wanting to capture the real-time dynamics of a research situation. When capturing a child's drawing process, an alternative to cumbersome video-recording equipment is a digital pen that records both the creation of the drawing and any nearby utterances. To highlight the affordances and limitations of the digital pen as a data collection tool for children's drawing we utilise examples from two different research projects, one with Australian children and the other with Canadian children.

The methodological issue addressed in this paper is the need to capture the dynamic process of drawing creation. This need resides in the theoretical perspective that the study of children's (re)presentational systems is essential to research that seeks to better understand children's mathematical learning (Goldin & Kapput, 1996). The distinction is often made between internal psychological representations and external physical representations, but it is the interplay between the two that is "… fundamental to effective teaching and learning" (Goldin and Shteingold, 2001, p2). As researchers we seek to infer the 'invisible' internal (re)presentations by interpreting observable external (re)presentations which are typically actions, such as gesture, speech, manipulation of objects and drawings (Bobis & Way, 2018). Drawings are often seen as products or static artefacts. However, the dynamic process of drawing itself enables further examination of cognitive functions and co-emerging understandings (Thom & McGarvey 2015), and so the process of creating a drawing can reveal other aspects about a child's thinking and learning than a completed artefact alone. Consideration of more than one form of (re)presentation enhances the meaning-making potential of the research. One (re)presentational form (in this case drawing) does not operate in isolation from other (re)presentational systems but rather, each is inseparable from the other(s). Thus, the focus of research is on examining events as they happen and to study the collective emergence that occurs amongst verbalisations, contextual influences, gestures and other movements (Depraz, Varela & Vermersch, 2003).

While in many qualitative research situations the ideal approach might be for the researcher to directly observe the class as a whole and each of the participants while capturing everything using multiple cameras and audio-recording for later analysis, the realities of research contexts such as classrooms, often prevent or limit such ideal data collection methods. Digital pens that capture mark-making and sound, and create 'pencasts' that can be replayed, can provide a useful alternative, or a supplement to, other data collection methods. The purpose of this paper is to share some experiences in using the digital pen as a data collection device and to reveal some of the affordances and constraints that it offers.

## Example 1

### *Research Context*

Example 1 is from a Year 4 child (Ethan, Age 10) participating in the *Thinking Tools: (re)presentations in Primary Science and Mathematics* project that is exploring primary school children's use of drawing(s) as thinking tools. In individual task-based interviews, students drew 'what happened' after rolling a toy car down a ramp that had been set at three different gradients. The interview was also captured by wide-angle video recording. Figure 1 presents Ethan's completed drawing, with comments describing the sequence of construction.

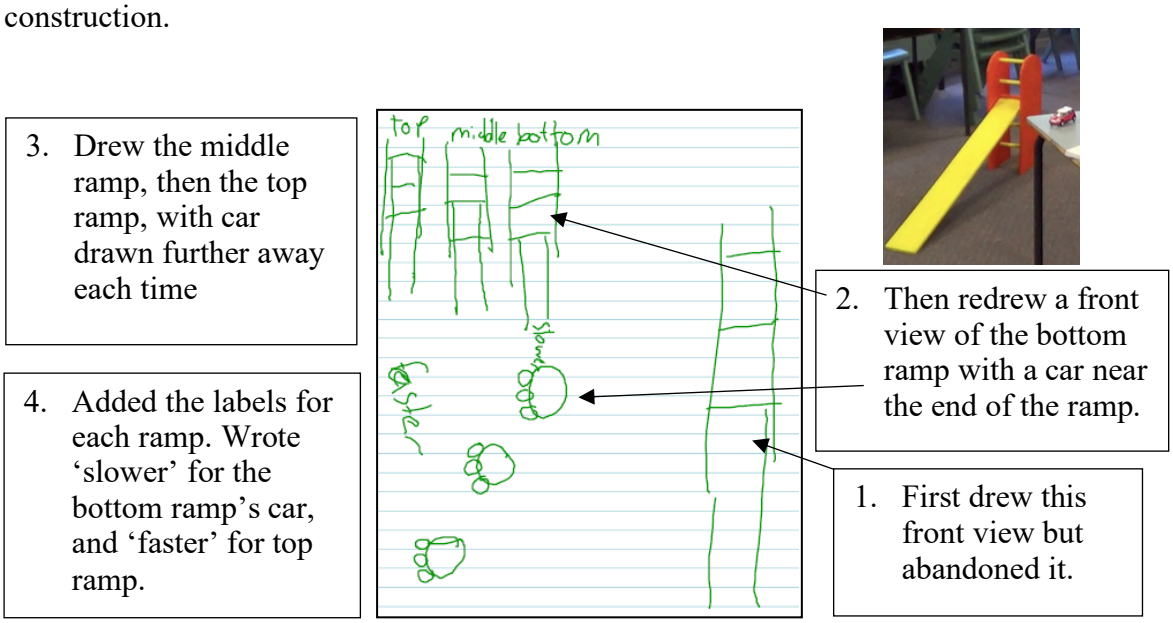


*Figure 1:* Ethan's drawing of the car ramp event

### *Commentary*

Ethan started drawing on the right side of the paper and moved towards the left side (Figure 1). He produced a set of three drawing(s) from a *front view*, one for each ramp level The focus of the drawing(s) was the relationship between ramp height and the distance travelled by the car. When asked why the car went different distances, speed was spoken about, then 'faster' and 'slower' added as word labels. When asked why the car went faster on the top ramp he replied, "It could get more speed because it was going steeper". The connection between slope (steeper) and speed was made verbally (with arm gestures showing angles), but was not (could not be) depicted in front-view drawing(s).

### *Affordances and Constraints*

An important feature of our analysis was the 'layered' approach. With our particular interest in what each child chose to draw when (re)presenting their thinking, we first replayed the pencast without sound to isolate the interpretation of the drawing itself. We found the clarity of drawing detail and sequence provided by the pencast to be very useful. Subsequent analysis included the synchronised sound-track, which enabled elaboration of the initial interpretations through listening to the child's verbal explanations. It also allowed identification of the effects of questioning by the researcher on the child's development of reasoning and the initial (re)presentations. The final layer of analysis drew on the video

recording which revealed data beyond the pencast— what actually happened during the car experiment, as well as the child's movements, gestures and expressions.

## Example 2

### *Research Context*

The second example features the drawing(s) of one student—Sophia, who participated in a three-month study with her kindergarten and grade one class for 19 geometry and spatial reasoning lessons. In this excerpt, Sophia (7 years old), Emma (6 years old) and April (6 years old), were shown a photograph (Figure 2) and asked to express what they saw in a manner that was accessible to the others. The children then explored how what they saw in the photograph could be part of a 3D object and, what part(s) of the object might be seen when looking from different perspectives. Figures 2 also includes the sequence of key moments in which images and verbalizations by Sophia emerged and were dynamically captured by the digital pen:

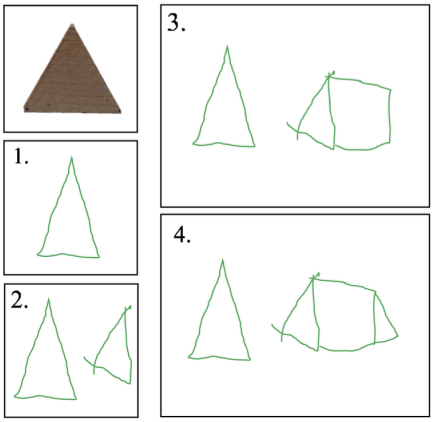


*Figure 2*. Digital photograph presented to the group and Sophia's sequence of drawing(s).

### *Commentary*

Sophia's first drawing expressed what she saw in the photograph and verbally identified as "a triangle" (Figure 2.1). Later to the right of the paper, she drew what might be seen if the triangle was the 'front' of a 3D object and she was looking at it from the 'back' or opposite view (Figure 2.2), justifying "Because triangle, triangle, something else." Sophia then added to the drawing what the triangle in the photograph might be if it was a 3D block (Figure 2.3-4). Following this, she exclaimed, "Ha-ha! I just noticed something. That's so funny! It's the shape that we're drawing. The paper. See? Triangle, triangle, rectangles."

### *Affordances and Constraints*

The digital pen captured Sophia's drawing(s) and dialogue in real time, providing a moment-to-moment account of how her thinking and reasoning emerged over the course of the lesson as drawing(s) and verbalisations; more specifically, the ways she moved conceptually back and forth as she considered the triangle from different perspectives and dimensions; the ongoing conversation of the small group; and how her drawing(s) as both act and artifact enabled further explorations of the triangle. Because the pen synchronously records drawing(s) and verbalizations, it was possible to replay any instance of the children's drawing activity (and conversation) by 'clicking' on a specific part of the drawing using the

pen or on the computer after uploading the video and audio data from the pen. As the playback quality of sound and drawing(s) was very clear, certain parts of conversations and drawing(s) were replayed in later lessons to facilitate reflection and further inquiry with the teachers and children. It is also possible to amalgamate data from other pens to conduct comparative analyses across student work and to examine the collective thinking of a group or entire class; for example, according to temporal events or identified themes.

We mentioned in the first example that video data was necessary to capture other gestures, movements, and use of materials. The data was also required to examine how the different modes related to one another and with the study context at large. In a similar way, it was only by analysing the pencast of the second excerpt with the video data from the lesson that it became evident how Sophia continuously used— in addition to drawing(s) and verbalisations— found materials, the 3D space in front of her and distinct whole body and hand gestures to situate, draw, sculpt and connect triangles and rectangles on various planes.

## Conclusion

As a data collection device, the digital pen affords an effective and practical means for capturing and reviewing the dynamic (re)presentation processes of drawing(s) and verbalisation. In data analysis, the pencasts facilitate a sharp focus on specific features of drawing(s) and intricate relationships between mark-making and verbalisations, which supports the researcher in making well-founded inferences about children's thinking and reasoning. The addition of video-recording to capture other interrelated (re)presentations, such as body movement and hand gestures, further enriches interpretations of the interplay between the child(ren)'s internal and external (re)presentations.

## Acknowledgement

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