An Ecological Analysis of Mathematics Teachers' Noticing

Dan Jazby
University of Melbourne
dan.jazby@unimelb.edu.au

Most studies which investigate mathematics teacher noticing cast perception into a passive role. This study develops an ecological analysis of mathematics teachers' noticing in order to investigate how teachers actively look for information in classroom environments. This method of analysis is applied to data collected as an experienced primary teacher of mathematics moved between desks and selected students to stop and talk to. An ecological lens draws attention to an active process of looking, employed by the teacher, which locates particular properties in the mathematical representations created by students.

What mathematics teachers notice mid-lesson has been argued to affect the pedagogical actions that teachers take (Jacobs, Lamb, & Philipp, 2010; König et al., 2014; B. Sherin & Star, 2011; M. G. Sherin, Russ, Sherin, & Colestock, 2008; Van Es & Sherin, 2008). Thus, it has been argued that developing teachers' capacity to notice events in mathematics classrooms will improve teaching (Van Es & Sherin, 2008). The 'connecting thread' that links teacher noticing studies is that the study of teacher noticing involves "making sense of how individuals process complex situations" (Jacobs et al., 2010, p. 171). This usually involves developing accounts of teacher thinking which underlie a teacher's capacity to notice (Van Es & Sherin, 2008). Most accounts of teacher noticing are informed by an 'information processing' framework, in which, internal mental processes are required to make sense of events (Kirlik, 1995). This study outlines some limitations to this approach and then suggests an alternative approach based on Gibson's (1979) theory of ecological psychology. Ecological psychology posits that making sense of complex situations is accomplished through information gathering rather than information processing. Hence, it directs researchers to investigate how people actively locate information in their environments which they can use to guide their behaviour.

To illustrate how an ecological lens may illuminate currently obscured aspects of mathematics teacher noticing, this study presents an ecological analysis of an experienced teacher's noticing in a period of between-desk instruction. This data was gathered using a research method called head-mounted video-cued recall interviews (HMV interviews) which was developed by researchers who were mainly investigating the in-the-moment cognition of firefighters (Omodei, McLennan, & Wearing, 2005). Prior to presenting this analysis, three information-processing-focused studies of teacher noticing are discussed. The findings of these information-processing-focused studies are then contrasted with the findings of the ecological analysis developed in this study to address the following research questions:

1. What aspects of teacher noticing are made visible when an ecological lens is applied to mathematics classroom data?
2. How does an ecological analysis of mathematics teacher noticing compare with information processing accounts of teacher noticing?

Information processing approaches to the research of mathematics teacher noticing

Studies of teacher noticing vary in terms of whether they employ definitions of noticing which examine teacher attention, interpretation of events, the decisions that arise from what is noticed, or a combination of two or more of these aspects (B. Sherin & Star, 2011). Jacobs et al. (2010) have argued that, common to all studies of teacher noticing is a research interest in deciphering how teachers make sense of complex classroom situations. The majority of

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these studies employ the theoretical lens of information processing and focus on uncovering the internal cognitive processes and knowledge requirements which enable teachers to make sense of classroom events (B. Sherin & Star, 2011).

This focus on investigating the internal cognitive processes which underpin teacher noticing has been productive; yet it may not be able to capture tacit aspects of how noticing occurs. A study by M. G. Sherin et al. (2008) provides an example of the kind of study which has found there to be a tacit element of teacher noticing. M. G. Sherin et al. (2008) used a head-mounted camera to capture segments of one mathematics teacher's classes over three days. The teacher was able to push a button while teaching which would activate the camera when he felt that something interesting was occurring in a class. Reviewing these recordings of 'interesting' events, M. G. Sherin et al. (2008) found that, at times, the teacher, "had an implicit sense that something was interesting" (p. 43), and that this suggested that there was both tacit and explicit elements involved in teacher noticing. Their analysis of this footage focused on identifying which types of classroom events the teacher felt were interesting, and using the teacher's post-task review of the footage to investigate why the teacher felt an event was worth activating the camera. M. G. Sherin et al. (2008) concluded that noticing occurred in a "rapid and relatively unconscious manner, often like simple recognition" (p. 42); thus, accessing tacit aspects of teacher cognition which underlie noticing was difficult. Studies such as M. G. Sherin et al.'s (2008) describe teacher noticing as being not consciously controlled, being autonomous, and stimulus-driven at times. Moors and De Houwer (2007) have argued that these are the defining features of 'automaticity'. Automatic, tacit cognitive processing, by virtue of being processing that does not occur on a conscious level, cannot be recalled and verbalised by those who employ it (Moors & De Houwer, 2007). Hence, as M. G. Sherin et al. (2008) have argued, the implicit processes that are likely to occur as teachers attend to classroom environments cannot be captured by the video and recall interview methods used by teacher noticing researchers.

Many researchers have argued that, to notice what is happening in classrooms, teachers require a certain degree of prerequisite knowledge (B. Sherin & Star, 2011). König et al. (2014) found evidence that the knowledge requirements of noticing are not the same as general pedagogical knowledge. They used video-vignettes to test the capacity of 171 teachers of mathematics (with four or less years of experience) to notice and interpret classroom events. They coupled this with a pencil and paper test designed to test general pedagogical knowledge which had been developed in pre-service teacher training. They found that, while participants' performance in the test of pedagogical knowledge was a good predictor of performance on items which measured participants' capacity to interpret classroom events, it did not predict performance on items designed to measure participants' capacity to notice. The capacities to notice and interpret classroom events, when considered as two distinct skills, were also only loosely connected. König et al. (2014) concluded that, while the capacity to interpret classroom events strongly depends on pedagogical knowledge, noticing does not. Like M. G. Sherin et al. (2008), König, et al. invoke automaticity to explain the knowledge requirements of noticing. They "assume that the knowledge needed here [when noticing] has to be sufficiently internalized and therefore consolidated on an implicit level as an automatically activated schema" (König et al., 2014, p. 84). Hence, knowledge is automatically activated when teachers notice classroom events, but is not of the declarative nature that is usually developed in teacher training courses.

Much research has focused on trying to ascertain whether teacher noticing can be developed with training. Jacobs et al. (2010), for example, conducted a study in which 131 participants with varying levels of experience took pencil and paper tests designed to measure their capacity to attend to students' mathematical strategies, interpret children's understandings, and decide how to respond when presented with classroom video and student work sample stimuli. They found that teachers who had engaged in a professional learning program designed to develop their ability to attend to students' mathematical thinking displayed greater capacity in all three areas. Hence, this study provides evidence that noticing and responding to classroom stimuli can be developed through training.

All three of these studies, like many of the studies which B. Sherin and Star (2011) identified in a review of models of teacher noticing, view the sense-making component of noticing as an internal cognitive process. This leads to teacher noticing being modelled as a relatively passive activity (B. Sherin & Star, 2011) in which the teacher passively 'sees' events, then makes sense of them. B. Sherin and Star argued that, "the teacher does not just see; she actively looks" (2011, p. 73). Therefore, they argued, the research area of mathematics teacher noticing would be enriched if theoretical models of noticing could account for (and investigate) how teachers actively look for events to notice. Ecological psychology may be able to provide a lens which brings this currently obfuscated aspect of teacher noticing into focus.

Ecological accounts of noticing and action

Gibson's (1979) theory of direct perception – a key component of ecological psychology – begins with the assumption that a person's psychological experience of perceiving and acting is not governed by conscious internal mental processes. Gibson assumed that people make sense of their surroundings automatically, and that the perception of environmental entities carries with it a sense of what can and cannot be done. Our psychological experience of seeing a chair, Gibson argued, carries with it a sense that we can sit in the chair. There may be neurological activity which invokes memory of previous experience, but this is not psychologically accessible, and thus, is not sufficient to explain the psychological experience of noticing and sitting on the chair (Gibson, 1979). Gibson argued we don't need to create a mental representation of the world around us because the world is its own best model, hence, we need to actively attend to the world if we are to successfully take action within it. Gibson's theory links action to perception, effectively arguing that action occurs in response to what is noticed. If we look through this lens, in order to understand what people do, we need to investigate what they attend to and how they are able to locate environmental entities which will effectively guide their behaviour (Kirlik, 1995).

Ecological accounts of in-the-moment activity have been developed in a range of fields. To illustrate how this approach produces a more active account of noticing, several studies from sports psychology are presented. Sporting performance often requires that athletes notice and respond to events within milliseconds (Araujo, Davids, & Hristovski, 2006). Guided by Gibson's theory of direct perception, Passos, Araújo, Davids, and Shuttleworth (2008) looked at the relationship between athletes and their environments in order to explain automatic action which occurred in response to variability in the situation encountered. They hypothesised that an athlete's perception of actual conditions guides his/her behaviour more than recall of memories of previous experience (Araujo et al., 2006). A rugby player's decision to pass a ball to a teammate, for example, could be modelled as being guided by his/her perception of entities in his/her environment (such as the position of opposition players and teammates). While rugby players need technical development to learn how to pass a ball to their teammates, an ecological model can be useful when investigating players' tactical development. Tactical development helps players read play so that they can make better decisions about *when* to pass the ball as they encounter variability and uncertain information in their environment (Passos et al., 2008). To do this they need to rely on 'occurrant', directly perceived information which is accessible via active processes of perception (Araujo et al., 2006).

In a study relating to the punches used by boxers in training, Hristovski, Davids, and Araújo (2006) investigated whether boxers' perception of environmental entities could be used to model rapid noticing and decision making. They found that a relatively simple pattern of perceptual interaction was employed by boxers, but this pattern kept boxers aware of variations in the properties of their environment (such as the distance between their fist and a training bag relative to the boxer's body scale). Perception of variation in the properties of the environment could be modelled to predict the likelihood that particular punches would be thrown at any given time. Araujo et al. (2006) used the term 'online steering dynamics' to account for these processes, where an athlete attended to particular properties of entities in their environments to guide their behaviour.

Kirlik (1995) noted that, while Gibson (1979) argued directly against information processing accounts of perception, many researchers have found that ecological and information processing analyses are complementary. Kirlik (1995) took the position that employing both lenses simultaneously enables different types of behaviour to be understood more fully. Automatic responses can be analysed via an ecological lens, while an information processing lens can account for behaviour which is guided by conscious processes of deliberation and sense making. Hence the justification for the use of an ecological lens not only relates to the way in which it captures active elements of noticing but also to its capacity to shine light on the automatic or tacit elements of teacher noticing encountered by König et al. (2014) and M. G. Sherin et al. (2008).

An ecological account of teacher noticing assumes that noticing is an active process. Noticing does not always require conscious information processing to make sense of complex situations. In mid-lesson conditions, teachers are posited to partly rely on 'online steering dynamics' where they actively look for information which can guide their action in response to variable and uncertain classroom conditions. An ecological analysis of classroom data seeks to ascertain where a teacher actively looks for information which, in their opinion, will be useful in guiding their behaviour. It also seeks to investigate which of the properties of the environmental entities that a teacher is attending to are employed to guide the teacher's actions.

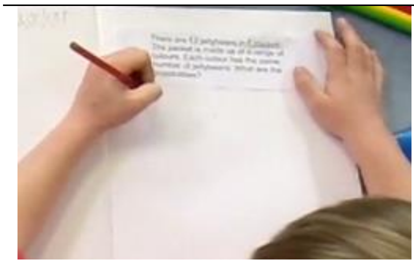
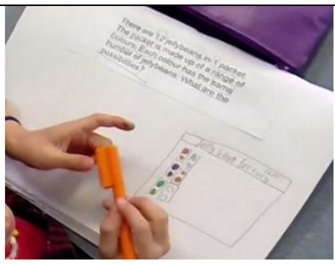
Method

The data presented in this study were gathered using head-mounted video cued recall interviews (HMV). HMV interviews involved placing a GoPro camera on teachers' heads as they taught a 50-minute mathematics lesson. The teachers then reviewed the video approximately 10 minutes after the event and provided commentary on what they were thinking, feeling and attending to during the recorded event, using the free-recall protocol suggested by Omodei et al. (2005). Omodei et al. (2005) have consistently found that the use of head-mounted cameras has not interfered with or distracted participants in HMV cued recall studies. Just in case students find a head-mounted camera distracting, teachers wore the camera for two lessons prior to data collection. This gave the teacher time to grow accustomed to the weight of the camera, and students were able to adjust.

To test an ecological analytical framework, data from an experienced teacher's (over ten years' experience) lesson were analysed. During a 15-minute period of between-desk instruction that took place during a regular mathematics lesson, the teacher – Miranda – moved around the room. As she moved, she either stopped to talk to students or continued to walk past students in her vicinity. This variation in Miranda's behaviour at this time (e.g. stopping to talk to or walking past students) provided two conditions which were able to be contrasted and analysed. Miranda taught grade 1 and 2 students (6–8-year olds) at an inner-city school in Melbourne. Miranda was asked to prepare a mathematics lesson and was free to design the lesson in whichever way she saw fit. In the lesson, students were asked to try to find every possible way in which 12 could be shared into equal groups and were provided with counters and workbooks to record their solution attempts.

Using the video data available, each instance where Miranda either stopped to talk to or walked past a student working at his/her desk was identified. At these points, recall interview data was coordinated with video data. Table 1 demonstrates how these two sources of data were coordinated to make a cohesive unit of analysis. The data presented in Table 1 shows a still image from video footage that was captured as Miranda walks past one student then decides to stop and talk to a second student. By contrasting the visual information available in each students' mathematical representation when Miranda decided to stop and talk to or walk past a student, it was possible to the identify properties of students' mathematical representations that Miranda was monitoring. Table 1 also shows how Miranda's recall of interview data could be used to confirm whether she was attending to environmental entities that were present in the video footage. Her recall of events provides evidence that, from her perspective, she was looking for an instance where a student had recorded a solution attempt; she was attending to the mathematical representations that students had created on the desks in front of them, and that this influenced her decision to stop and talk to this particular student. This instance of stopping and talking to a student was then coded as being influenced by Miranda's attention to a student's mathematical representation. In some cases, Miranda recalled that she talked to a student because, "he was a slow starter". These instances were coded as being influenced by information outside of her current environment.

Table 1. coordination of data sources when Miranda switches focus between student groups

Visually accessible information when Miranda walks past a student	Visually accessible information when Miranda stops next to a student	Recall data from this point of the lesson
		"I was trying to find some people who had started recording … I just noticed, as I was going past … that she'd completed one … I just wanted to check her thinking. He [the first student] didn't have a finished one"

Results

During the 15-minute period of between desk instruction in the lesson, Miranda stopped and talked to individual students 16 times. Of the 21 students in the class, 12 received individual attention from Miranda (4 students received individual attention twice).

In 10 instances, Miranda recalled attending to students' mathematical representations before she decided to focus on an individual student. Each mathematical representation that Miranda attended to prior to deciding to focus on an individual student was examined, and these representations could be grouped into three different categories. Some of these representations were unusual in that only one child in the class had produced this kind of representation. The first image in Figure 1 shows an example of an unusual representation. This student was the only student to have used counters of differing shapes in their mathematical representations. Miranda recalled that, "he's the only one who's done this [use counters of different shapes]; he's an interesting one". Attention to unusual representations occurred 4 times prior to a decision to focus on an individual student. Twice, Miranda switches focus when she sees a correct mathematical representation. The middle image in Figure 1 provides an example of a correct representation of 12 shared into equal groups which occurred during the lesson. Attention to correct representations occurred early during between-desk instruction. After correct representations were attended to two times, Miranda started to attend to incorrect representations. The third image in Figure 1 provides an example. Miranda recalled that, “I could see him building even piles … but that’s not 12”. She then moved next to the student and began to question him about his representation. Attention to an incorrect representation occurred prior to focusing on an individual student 4 times.

Figure 1. An example of an unusual, correct and incorrect representation attended to

In 3 instances, Miranda attended to student body language instead of students’ mathematical representations. In 2 of these cases, a child’s facial expression was taken to mean that the child was upset about something and needed reassurance from Miranda. In one other case, Miranda recalled that she focused on a student because she could see ‘that she was working’ before other students had finished collecting the equipment they needed for the lesson.

In the final 3 instances, Miranda did not recall attending to any particular environmental entity. Instead she referred to students’ performance in other lessons. In these three cases, she chose to focus on individual students because they were ‘usually slow to get started’, despite the fact that, in two of these cases, video footage from the head-mounted camera shows that they were as far through the assigned task as other students around them who did not receive individual attention.

What was attended to when the teacher did not stop to focus on an individual student?

Miranda walked past students without stopping 21 times. Recall data provides evidence that, when Miranda walked past a student and decided not to focus on that student, she was still attending to students’ mathematical representations. Table 1 shows what was visible to Miranda when she walked past a student (the image on the left), and when she focused on another student (the image in the middle column). The first image shows a student workbook which does not have any mathematical representation. On 13 occasions, when student workbooks lacked a mathematical representation, Miranda walked past a student and did not stop. Whilst she stopped when she saw two correct mathematical representations early during the period of between-desk instruction, she ceased focusing on students with correct representations after this, unless the representations were unusual. She walked past correct, usual representations 8 times in the later stages of between-desk instruction.

Discussion

Recall data suggests that most of Miranda’s decisions to either stop and focus on a student or not stop were predicated by attention to environmental entities. Primarily, Miranda attended to students’ mathematical representations. In contrast to passive information processing accounts of teacher noticing, an ecological analysis of Miranda's noticing investigates where she looks to locate information which can guide action and what it is that she is actively looking for in those locations. Throughout this part of the lesson, Miranda moves around the room so that she can see students' mathematical representations and, to a lesser extent, student body language. Hence, data which captures her attention to these two sources of environmental information enables the identification of where she actively looks for information to guide action.

By contrasting the mathematical representations Miranda attends to which precede a decision to stop with those that precede a decision to not stop, Miranda's 'online steering dynamics' can be investigated. Throughout the between desk instruction phase of the lesson, Miranda is looking for unusual, student-created mathematical representations. She describes these as 'interesting' and takes action to ask students about what they have done when she sees representations with this property. As the between desk instruction phase of the lesson begins, she is also looking for correct, completed solution attempts; although, after focusing on two students who have produced these, she stops looking for them during this phase of the lesson. After finding these two correct attempts, she starts to actively look for incorrect representations. Early in this period, she also looks for students whose body language she takes to mean that they are upset. From an ecological point of view, Miranda is making sense of what is happening in the classroom by actively looking at particular sources of information (e.g. mathematical representations) and checking for particular properties (e.g. being unusual) which will provide her with 'occurant', online information to steer her actions.

Conclusion

Through the employment of Gibson's (1979) theory of direct perception, teacher noticing is cast as an active process where making sense of a situation involves searching for information in a dynamic, variable environment. Because teachers must act in environments which contain such variability (Jacobs et al., 2010), they must take action which cannot be completely pre-planned in order to be responsive to variation (Passos et al., 2008). To borrow terms from sports psychology: teachers need both technical development (e.g. knowing how to respond to what they see), and tactical development (e.g. knowing how to 'read the play' and decide when a particular technical skill is required). The ecological analysis of an experienced teacher's in-the-moment behaviour presented in this study enables the analysis of the teacher's active behaviour which guided the teacher's tactical decisions to either stop and talk to students or move past students as they worked at their desks. It provides evidence that Miranda was actively looking for student representations which had particular properties – such as unusualness or incorrectness – which enabled her to make sense of what was happening in the classroom and manage variability in student activity. This produces a coherent explanation of variations in Miranda's behaviour with regard to stopping and talking to students.

Investigation of the active perceptual behaviours which are part of teacher noticing directly addresses the concern that B. Sherin and Star (2011) raised in relation to most studies of teacher noticing that employ information processing models of noticing. Information processing approaches assume that the senses passively receive environmental information (Gibson, 1979), yet B. Sherin and Star (2011), who have been researching teacher noticing for some time, argued that teachers actively look for environmental entities to notice. Hence, an ecological analysis of classroom data sheds light on aspects of teacher noticing which are not currently well explained in information processing accounts. This does not mean that information processing and ecological approaches to the study of teacher noticing are incompatible. In fact, it is the researcher's opinion that they are complementary, as information processing accounts of noticing uncover aspects of noticing (mental processes which make sense of a situation) that an ecological approach is blind to, while an ecological approach uncovers aspects (active behaviours which guide the location of environmental information) which are under-researched when information processing models are used (B. Sherin & Star, 2011). Future research aims to provide an analysis of HMV cued recall data that combines both theoretical perspectives in a complementary manner so that “both contribute to a more complete understanding of human-environment interaction” (Kirlik, 1995, p. 87).

When used in the area of sports psychology, ecological analyses have been argued to have implications for training athletes’ tactical development (Passos et al., 2008). In the analysis presented in this paper, Miranda’s tactical decisions to either walk past or stop and talk to a student are argued to be primarily guided by attention to two sources of environmental information (mathematical representations and student body language) and the monitoring of three properties visible in students’ mathematical representations (unusualness, correctness and incorrectness). Presuming that future research finds that these ‘steering dynamics’ are employed by other competent teachers of mathematics, attention to these dynamics could be incorporated into training programs, such as those described by Jacobs et al. (2010), which aim to develop mathematics teachers’ capacity to notice. Further analysis of HMV cued recall data, captured with teachers of varying levels of classroom experience, may be able to shed light on aspects of teachers’ ‘tactical development’; early analysis of this data suggests that inexperienced teachers do not employ steering dynamics which are similar to Miranda. Hence, further research which employs an ecological lens may be able to account for changes in teacher noticing which occur as teachers gain experience.

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