Do Teachers Make Decisions Like Firefighters? Applying Naturalistic Decision-Making Methods to Teachers' In-Class Decision Making In Mathematics

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Research into human decision making (DM) processes from outside of education paint a different picture of DM than current DM models in education. This pilot study assesses the use of critical decision method (CDM) – developed from observations of firefighters' DM – in the context of primary mathematics teachers' in-class DM. Preliminary results show that CDM yields significant amounts of data regarding teachers' cognition during DM and that the process that expert teachers follow when they make decisions may better match naturalistic accounts of DM.

Research into teachers' in-class decision making (DM) falls within a wider area of research regarding how humans make decisions. This study applies the lens of naturalistic decision making (NDM) to teacher DM. NDM research, applied widely in areas such as medicine, firefighting and the military has not been applied to teacher DM. In order to demonstrate how an NDM framework affects teacher DM research, Schoenfeld's (2011) model of mathematics teachers' DM is used to provide a counterpoint to NDM in the following section. Critical decision method (CDM) is a form of semi-structured interview designed to illuminate a decision maker's cognition during real-time DM. While CDM has been applied to DM in situations of high-stakes, life-and-death DM, it may be the case that the DM of teachers – rarely as high stakes as the DM of a squad commander on a battlefield – may not be able to be studied using this method. Hence the current paper reports on the preliminary results of a pilot study that employs CDM to study the real-time, classroom-based DM of expert primary mathematics teachers.

Three research questions guide this pilot study:

1. Can CDM be applied to the context of primary mathematics teaching?
2. What kind of information does CDM generate when applied to this context?
3. Does the information generated have implications for current models of teachers' DM in primary mathematics classrooms?

Literature Review

Models of Human Decision Making

Research regarding how humans make decisions has moved through three key phases (Tolcott, 1992). Rational models of DM focused on developing mathematical models designed to deliver optimal decisions. The calculations used to identify optimal courses of action were complex and these models did not seem to capture how actual human beings make decisions. The second phase began in the 1970s as psychologists started to present people with decision scenarios in laboratory environments in order to study how humans actually make decisions. This led to the development of normative models of DM – normative in that they tested humans' DM under normal or idealised conditions. In the

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mid-1980s, NDM models (the third phase) were developed. Rather than bringing people into labs, NDM research began with the premise that some people are very good at making decisions already, so researchers should investigate how these experts work (Lipshitz, Klein, Orasanu, & Salas, 2001). By investigating a range of skilled professionals making decisions in the field, NDM researchers have developed various models of DM which claim to describe humans' natural DM processes.

In order to illustrate how a NDM frame changes the nature of teacher DM research, Schoenfeld's (2011) recent model of teacher DM is discussed. In Schoenfeld's model, DM is driven by teachers' goals. When DM is viewed through this lens, the key questions to be asked when analysing teacher DM are: what are the teacher's goals; and how did those goals become a priority? Schoenfeld claimed that, by asking these questions, he can model a teacher's DM and predict the decisions that an individual teacher will make in a given situation. Schoenfeld employs the idea of subjective valuations and assigns costs and benefits to the range of options which face a decision maker. This means that "if you know which options someone perceives as being available and how he or she assesses the costs, benefits and probabilities of the possible outcomes, you can compute each outcome's subjective expected outcome" (p. 18). Teacher goals impact on how those costs, benefits and probabilities are assessed. Schoenfeld also argued that in some everyday situations, "it would be crazy to suggest that people actually engage in such computations [of subjective expected outcomes] during decision making" (p. 18) because of the speed of the process of making a decision. Thus the mechanisms by which teacher DM is assessed by Schoenfeld serve more to provide a means to model and predict a teacher's DM, rather than to investigate the actions or processes that the teacher is engaged in during in-the-moment DM. While Schoenfeld claimed that this kind of analysis can explain the behaviour of the teacher decision maker – such as explaining why non-routine decisions were made in videoed lessons – it doesn't explain the actual processes engaged in by the teacher who was not making the kind of cost/benefit calculations carried out in Schoenfeld's analyses. While Schoenfeld acknowledges that calculations of costs/benefits cannot occur in real-time DM situations, his model suggests that teachers are weighing up options when they make decisions. This process is referred to as deliberation by DM researchers (Lipshitz et al., 2001). Thus, according to Schoenfeld, teachers' goals change as a lesson progresses. They consider multiple options to achieve those goals and weigh up their options.

Klein's (1997) recognition-primed decision (RPD) model is a leading NDM model. It was developed, primarily, by assessing the DM of experienced firefighters but has been applied to a wide range of fields. After analysing the cognitive processes of expert decision makers, the RPD model argues that concurrent deliberation of options rarely happens for the expert. Instead, when faced with a difficult decision, experts focus on reading the situation. Once they have a reading of the situation, they start to generate alternative courses of action one at a time. Each alternative course of action is assessed via mental simulation of its impact until a workable course of action is found. Expert decision makers tend to make better decisions because they are better at reading the situation; they tend to generate courses of action which will work as the first option they consider and they often do not deliberate concurrently between options. Novices, on the other hand, do deliberate concurrently (Randel, Pugh, & Reed, 1996); this has been associated with poor performance in decision tasks.

According to Klein (1997), getting an accurate read of the situation is vital for expert decision makers as the situation suggests the courses of action which are available. For a seasoned firefighter, smoke billowing from one part of a burning building suggests a different course of action to smoke billowing from another part of the building (Klein, 1993). Hence, recognition of key environmental cues, facilitates the development of meaningful assessments of the situation, which ensures that the first options considered by the expert are ‘reasonably good’ ones.

Contrasting Schoenfeld’s and Klein’s DM models illustrates two substantially different approaches to researching teachers’ in-class DM. According to Lipshitz et al. (2001), who are, admittedly, firmly in the NDM camp, Schoenfeld’s model could be characterised as being ‘input-output oriented’. It tries to establish the output (decision made) given certain inputs (teacher goals and resources). Klein’s model is ‘process oriented’ in that it seeks to uncover the processes which underpin effective DM. The process of DM is characterised by concurrent deliberation of options in Schoenfeld’s model, while Klein argues that experts consider options serially most of the time. While Schoenfeld developed a model of DM first and then sought to test whether it could be used to predict teachers’ DM, an NDM approach entails finding teachers who are good at making real-time decisions and trying to find out what they do and how they do it in ill-structured, dynamic classroom environments.

Critical Decision Method (CDM)

CDM is a form of cognitive task analysis which has been used successfully by NDM researchers in a range of fields. It consists of a semi-structured interview which is described in more detail in the method section. CDM involves asking experts to recall critical incidents – incidents where their DM abilities were tested. The goal of CDM is to use the critical incident as a means of getting an expert decision maker to reflect on their cognition during a difficult decision (Crandall, Klein, & Hoffman, 2006). This generates data regarding the interviewee’s cognition which can be used to build a picture of the process of expert DM and uncover the knowledge and skills which support that process (Cannon-Bowers & Bell, 1997).

Many of the situations in which CDM has been used successfully have been memorable, life-and-death situations. Perhaps teachers’ decisions, designed to enhance students’ mathematical thinking, will not be as memorable as the kind of decisions studied using CDM in the past and interviewees will be unable to recall critical incidents. Hence this pilot seeks to test the viability of this method in the context of primary mathematics teaching. Crandall et al. (2006) stated that CDM may not be appropriate when trying to capture DM in combat-like situations. While primary maths classrooms should not be combat situations, perhaps there could be some similarities between combat situations and some classrooms – they could both be situations “where people work under severely stressful conditions and handle very high workloads, [which] can create a blur of events that are difficult to recall as discrete cases” (p.84). This could lead to a lack of detail in teachers’ recall of a critical incident, or recall of an individual critical incident may be blurred with events from other incidents. It is hypothesised that those who are expert decision makers in primary maths classrooms will recall critical incidents in some detail. This pilot tests the hypothesis and also tries to ascertain the level of detail recalled.

This study defines an incident as critical in the context of a primary maths classroom if:

1. the interviewed teacher identifies the incident as non-routine;
2. the incident relates to students’ understanding of mathematics (rather than a behaviour management issue, for example);
3. the interviewed teacher felt that the incident was challenging;
4. the teacher did not have a ready response to the incident.

Routine incidents may be met by experts with a certain level of cognitive automaticity (Crandall et al., 2006). Cognition which is automatic may lead an expert to not be completely conscious of all aspects of the cognitive processes employed during DM. Thus, CDM focuses on incidents which were non-routine and challenging in the eyes of the interviewee. In this kind of situation, interviewees will have relied less on automatic responses and will be better able to recall what they were actually thinking during the incident. Investigation of routine incidents can lead interviewees to recall standard rationalised accounts of their thinking (Crandall et al., 2006). By focusing on an incident where the teacher did not have a ready response, it is hoped that teachers' cognition in situations where they had to 'think on their feet' can be captured.

Methodology

CDM involves conducting a semi-structured interview consisting of four 'sweeps' (Crandall et al., 2006). In sweep one, interviewees are asked to recall a critical incident (defined in the previous section) and describe the sequence of events in which the incident occurred. For this study, interviewees were asked to recount what happens in a 'routine' mathematics class before they are asked to recall a critical incident with interviews taking about one hour. There are two reasons for this: teaching routines can vary from teacher to teacher, so having the interviewee describe their routines will provide the interviewer with a clearer picture of which aspects of the critical incident are outside of the teacher's routine behaviours; and that this step will help the interviewee identify non-routine incidents.

In sweep two, the information concerning the critical incident gathered in sweep one is reviewed and put into a timeline. For the purposes of this study, it is predicted that precise timeline information will not be required. Hence, sweep two will entail ensuring that events described in sweep one are in the correct sequence, with rough estimates of time between key events. In sweep two, decision points are identified. These are points at which a change in course occurred. Thus, while proceeding with a teaching plan may constitute a decision, the aim of sweep two is to identify points at which there was cause to reassess the course of action.

In sweep three, decision points are investigated in more detail. Interviewees are asked to recount what they noticed about the situation (cues) around the decision point and what they were thinking at the time. In this study, teachers will be probed regarding their mental picture of the class and individual students, their understanding of the mathematics occurring at each point and their goals as the incident unfolds.

The final sweep involves posing hypothetical questions about each decision point. In this study, hypothetical questions addressed hypothetical situations where the mathematical content was different (what if the student had been drawing a triangle instead of a square?), the teacher had been different (what if the teacher was in their first year of teaching in this situation?), the students had been different (what if the students hadn't studied that last week?) and the content area had been different (what if this was a history lesson?).

For the purposes of this current study, the data were coded as either pertaining to teachers' cognition during the decision making incident or not. A more detailed analysis of this data set is underway and is envisaged as being reported in future publications when the pilot study has been completed. Particular note was taken of whether an alternative course of action generation was deliberative (concurrent weighing of costs and benefits – as in Schoenfeld's DM model) or serial (think of options one at a time and mentally simulate their consequences until a workable solution is found – as in Klein's RPD model).

For this pilot of CDM in education, participants were selected from primary teachers known to the researcher. CDM relies on capturing experts' cognition. The expertise of participants was decided by the researcher – based on his experience working as a Numeracy Specialist in Victorian Government Schools who has engaged in coaching activities with many teachers. This is by no means intended to be a highly reliable measure of teacher expertise. It is envisaged that, if the pilot study suggests that CDM can be used to investigate expert teacher DM, subsequent studies, employing more rigorous assessments of teacher expertise, will be conducted. For the purposes of testing the viability of CDM, a sample of convenience, drawn from the researchers' professional contacts, has been used. While this paper reports preliminary results from three CDM interviews, the pilot aims to collect data from five teachers.

Results

CDM interviews were able to generate data regarding the in-class DM of the three interviewees. Interviewees were able to recall critical incidents which related to students' mathematical thinking and to provide details about each incident. Discrete cases were recalled with a reasonable amount of detail. Interviewee responses often took careful consideration. For example, none of the interviewees could initially explain how they came up with the alternative course of action used. After sweep three of the interview, interviewees were able to examine the information which was available to them before the decision and highlight which information had been at the forefront of their mind. CDM was able to facilitate interviewees' ability to reflect on their cognition during DM. Of all of the data coded, 60% pertained to the interviewees' cognition during the critical incidents investigated.

The cognitive processes of all interviewees were remarkably similar and in the three cases reported here. The first alternative course of action generated was 'reasonably good' and was immediately enacted. Figure 1 has been created in order to visually represent the cognitive processes of the three interviewees. There are two agents in the figure: the classroom (which produces student cues in the form of body language and utterances) and the teacher (who enacts lesson plans, assesses the situation, decides that the course of action needs to change, then generates, assesses and enacts new courses of action). There was no evidence of concurrent deliberation between competing options.

All three interviewees developed situation assessments – a mental picture of what is happening now – at various times leading up to and after the critical incident. Preliminary analyses of the environmental cues which were attended to, point to students' body language and utterances (such as "huh?" and under-the-breath muttering, rather than actual sentences) as being attended to keenly by the interviewees. However, in order to read what students were thinking during the lesson, teachers used a process of self-monitoring. All interviewees described "listening to myself" as they taught. This involved critical assessment of their own teaching performance from the perspective of a student. This kind of self-monitoring helped build situation assessments like, "I knew things were going badly. I was thinking that, if I was sitting on the floor listening to a grown up say these things, it wouldn't make much sense". This process of self-monitoring helped develop projections of the cause of student difficulty ("I thought that students were finding it [the teacher's explanation] too rule-based so they couldn't see the connection") and helped generate 'reasonably good' alternative courses of action ("I needed a context that the kids would be familiar with, if they were going to see how it worked – then, bang! Temperature!

The kids will get this [subtraction with negative numbers], if I make it a story about temperature”).

After the new course of action was adopted, student cues and the process of self-monitoring continued to determine whether the new course of action had the desired effect on student thinking. In all cases, interviewees took changes in students’ body language, utterances (“oh, I get it”), conversation between students and student mathematical activity to gauge the success of the new course. In all three cases, the new course of action seemed to work and, so, no new course of action was generated.

Interviewees expressed that their goals during the lesson stayed the same. While the desire to develop a new course of action was expressed in terms of goals (“I wanted the kids to get it conceptually, and I could see that the way I was teaching wasn’t going to get that across”), the goals which drove the first and alternate courses of action were the same in the view of the interviewees.

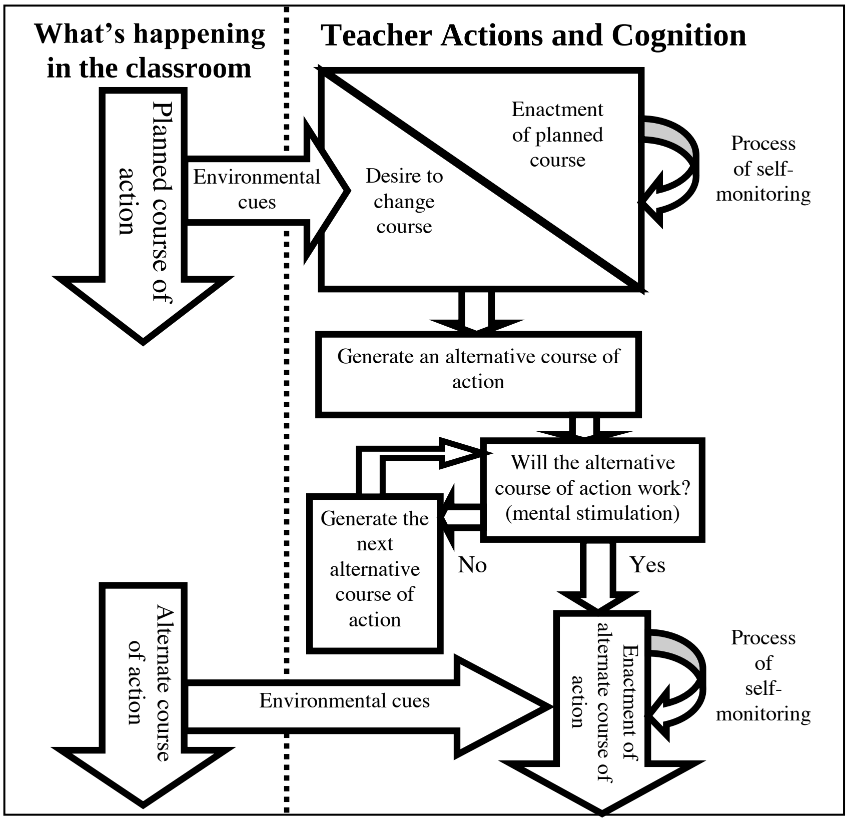

Figure 1: Proposed model of the process of teachers’ in-class DM

Discussion

The three primary mathematics teachers interviewed using CDM were able to recall incidents where they needed to make a challenging decision in real-time in order to influence students’ mathematical thinking. The fact that these kinds of critical incidents could be recalled in detail enabled the use of CDM as a means to capture their cognition during these incidents. This addresses the first research question of the pilot study and suggests that CDM may be able to be applied to the context of primary mathematics teaching.

For the second research question of this study, the data provided by the 3 interviewees indicated there was one key decision point in each lesson where adaptive expertise was required. The bulk of the data generated by CDM pertained to teachers' cognition during an episode of adaptive expertise (60% of the total data). Hence, if one's goal is to understand the cognitive processes at play in teachers' in-the-moment DM, CDM may be able to generate useful data. Similarities between the three interviewees' cognitive processes may have implications for current models of teachers' DM in primary mathematics classrooms (research question 3). Figure 1 represents the common sequence of teacher thinking and observation described by interviewees. The process described is more similar to NDM accounts of DM, yet pre-existing NDM models (such as Klein's RPD model) are not a perfect match.

NDM studies from outside of teaching would suggest that cues in the situation generate plausible courses of action. Lipshitz et al. (2001) characterised this process as 'situation-action matching decision rules' and argued that experts do x because of situation y. If one only considers the information interviewees attended to which was in the classroom environment, the information was remarkably similar despite differences between situations. Students' body language and vocal utterances were attended to the most, yet, at best, these cues were used to ascertain whether students understood what was happening, but could not be used to ascertain the nature of the misunderstanding. Slumped posture, 'confused eyes' and utterances such as, "huh?" were attended to whether student confusion related to subtraction of negative integers in a Grade 5 class or subtracting one-digit numbers in a Prep class, but these cues alone did not suggest how to address the particular student misunderstanding relating to the specific mathematical content being taught. In order to build a situation assessment, there is some evidence that interviewees used a process of self-monitoring that involved critically attending to their own teaching from the perspective of a student. As one interviewee put it, "I was listening to myself and thinking, would this make sense? If I was one of the kids, would I get what's going on here?" When the environmental cues signalled a lack of comprehension on the part of the students (shown on the left hand side of Figure 1), this process of self-monitoring (shown on the right-hand side of Figure 1) was used to develop a situation assessment which included possible causes of student confusion. Interviewees stated that, in order to make the assessment that an alternative course of action was required, indicators from *either* student cues *or* the process of self-monitoring were required. The assessment that no alternative was needed required both student cues *and* the process of self-monitoring to be going well.

This pilot provides some evidence that expert teachers' DM follows patterns similar to experts in other areas – experts generate few options of alternative action because the first options generated are 'reasonably good'. NDM models postulate that options generated are assessed serially by mental simulation until a workable solution is found. While there is evidence that mental simulation was used to assess options, all three interviewees enacted the first option considered. Hence the serial generation of alternative options present in Figure 1 has not yet been observed in this pilot study. None of the interviewees suggested that the options they came up with were optimal, but all interviewees claimed that the alternative courses of actions they embarked on worked to some degree. This suggests that expert teachers do not engage in concurrent deliberation between options – weigh up the benefits and disadvantages of multiple courses of action until an optimal solution is found – in real-time decision making moments. In fact, there was no evidence of deliberation in any of the interviews. Thus, based on this small sample, if one's goal is to describe the cognitive processes that expert teachers actually employ when making decisions in-class, a model that incorporates aspects of NDM seems promising.

Conclusion

This pilot study aims to assess the viability of CDM in education and provide a source of data which could suggest descriptive models of the processes that experts follow in making a challenging decision in a real-time, classroom environment. The ultimate goal of the research project, of which this pilot study is part, is to develop methods for supporting the development of in-the-moment DM skills for primary maths teachers. As Cannon-Bowers and Bell (1997, p. 100) stated, "the most fruitful way to characterise NDM-consistent training might be to view it as a mechanism to *support* natural decision-making processes, and as a means to *accelerate* proficiency or the development of expertise". This paper provides initial analysis of the data generated. Further analysis aims to test the tentative model of the natural decision-making processes of expert teachers proposed in Figure 1. More detailed coding of the pilot study's data may be able to capture some of the knowledge, skills, environmental cues and mental schemata which support that DM process. Pre-existing NDM models, such as Klein's RPD model, would direct attention to environmental cues as cues suggest courses of action. However, at least in the challenging cases of DM presented by interviewees, teacher DM was not entirely based on matching environmental cues to courses of action. Teachers' situation assessments also relied on a process of self-monitoring, as student thinking is a less observable phenomenon than the kinds of phenomena engaged with in firefighting or warfare – areas where NDM models were developed. Lipshitz and Ben Shaul (1997) suggested adding a construct of mental schemata to Klein's RPD model. The process of self-monitoring described by interviewees suggests that a construct such as mental schemata might play an important role in teacher DM which seeks to develop situation assessments of students' mathematical thinking.

References

Cannon-Bowers, J. A., & Bell, H. H. (1997). Training decision makers for complex environments: Implications of the naturalistic decision making perspective. In C. Zsambok & G. Klein (Eds.), *Naturalistic decision making* (pp. 99-110). Mahwah, NJ: Lawrence Erlbaum Associates.

Crandall, B., Klein, G. A., & Hoffman, R. R. (2006). *Working minds: A practitioner's guide to cognitive task analysis*. Cambridge, Mass: MIT Press.

Klein, G. (1993). A recognition-primed decision (RPD) model of rapid decision making. In G. Klein, J. Orasanu, R. Calderwood & C. Zsambok (Eds.), *Decision making in action: Models and methods* (pp. 138-147). Westport, CT: Ablex Publishing.

Klein, G. (1997). The recognition-primed decision (RPD) model: Looking back, looking forward. In C. Zsambok & G. Klein (Eds.), *Naturalistic decision making* (pp. 285-292). Mahwah, NJ: Lawrence Erlbaum Associates.

Lipshitz, R., & Ben Shaul, O. (1997). Schemata and mental models in recognition-primed decision making. In C. Zsambok & G. Klein (Eds.), *Naturalistic decision making* (pp. 293-304). Mahwah, NJ: Lawrence Erlbaum Associates.

Lipshitz, R., Klein, G., Orasanu, J., & Salas, E. (2001). Taking stock of naturalistic decision making. *Journal of Behavioral Decision Making, 14*(5), 331-352.

Randel, J. M., Pugh, H. L., & Reed, S. K. (1996). Differences in expert and novice situation awareness in naturalistic decision making. *International Journal of Human-Computer Studies, 45*(5), 579-597. doi: http://dx.doi.org/10.1006/ijhc.1996.0068

Schoenfeld, A. H. (2011). *How we think: A theory of goal-oriented decision making and its educational applications.* New York, NY: Routledge.

Tolcott, M. A. (1992). *Understanding and aiding military decisions*. Paper presented at The 27th International Applied Military Psychology Symposium: A focus on decision making research, Stockholm.