

# Learning from Lessons: Studying the Construction of Teacher Knowledge Catalysed by Purposefully-designed Experimental Mathematics Lessons

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A central premise of this project is that teachers learn from the act of teaching a lesson and that this learning is evident in the planning and teaching of a subsequent lesson. In this project, the knowledge construction of mathematics teachers was examined utilising multi-camera research techniques during lesson planning, classroom interactions and reflection. Our goal is a refined understanding of classroom events that create opportunities for teacher learning. This paper reports what one Year 5 teacher appeared to learn from the process.

## Literature and Conceptual Framework

Our overarching research question is: In what form and by what process do teachers learn from the experience of teaching mathematics lessons? This paper focuses on two sub-questions:

- (i) When reflecting on a recently taught lesson, which lesson elements or events do teachers consider most salient and how do these influence subsequent lesson planning?
- (ii) What forms of teacher knowledge and beliefs are foregrounded in the process of reflection on a lesson, and how do these contribute to subsequent lesson planning?

In recent years, a great deal of research has been conducted that provides evidence for what many intuitively believe to be true—that ultimately the teacher is the key to improved student learning (Fennema & Franke, 1992; Hattie, 2003). Artzt and Armour-Thomas (1999) identified “dimensions” of the lesson as “those broad aspects of instructional practice that define critical areas of teachers’ work during the enactment of the lesson” (p. 214). These dimensions are Tasks, Learning Environment, and Discourse. While using the framework of Artzt and Armour-Thomas in creating the experimental lesson plans used in this study, we have also drawn upon the literature of effective teaching of mathematics (Anthony & Walshaw, 2009; Sullivan, 2011), as many of the insights from this research elaborate the categories of Artzt and Armour-Thomas.

Despite the growing recognition of the centrality of the teacher’s role to student learning, teacher knowledge, and teacher learning remain under-theorised. This project takes as its starting point one of the most widely cited models of teacher learning (Clarke & Hollingsworth, 2002, see Figure 1), as this provides an orienting framework for the first research question. Central to this model is the mediating role played by Salient Outcomes (those outcomes of classroom practice to which the teacher attaches significance), which provide both the basis for change in beliefs and knowledge and, once changed, the motivation to engage in classroom experimentation in recognition of changes in those outcomes considered salient by the teachers.

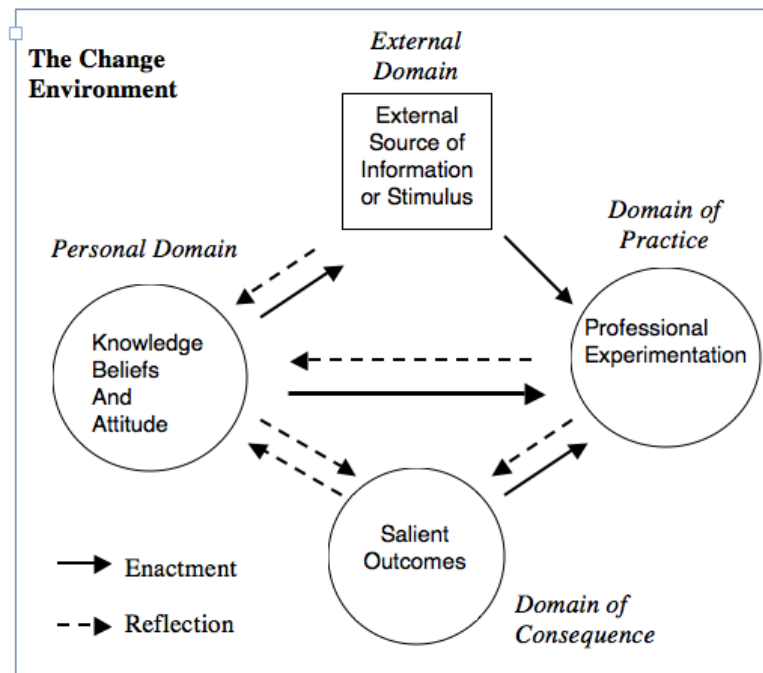


Figure 1. The Interconnected model of teacher growth (Clarke & Hollingsworth, 2002).

Shulman (1987) distinguished between Mathematical Content Knowledge (MCK) and Pedagogical Content Knowledge (PCK) and this distinction informed the design of the TEDS-M instrument used in this study (Tatto et al., 2012). Our thinking was also informed by the work of Van Es and Sherin (2002), who have developed a substantial body of research on “teacher noticing”. Related work on decision-making by Schoenfeld (2011) can be usefully integrated with the idea of “adaptive expertise” (Hatano & Inagaki, 1986) to extend the Clarke-Hollingsworth model, by providing a mechanism for both reflection and enaction within a model of teacher learning.

## Research Design

Three middle school teachers with at least five years’ classroom experience were recruited in Melbourne to participate in the study, drawing upon available networks of teachers known to the researchers.

### Data Generation

A key element in this research design is the provision of purposefully-designed experimental mathematics lessons, which provide the initial context for this study of teacher selective attention, reflection, and learning. During a preparatory (pre-active) interview, the teacher was asked to complete the same mathematics tasks as those employed in the lesson about to be taught. The teacher then annotated a provided lesson plan with respect to any aspects of the lesson that the teacher believed would require adaptation or which might represent a particular challenge for either the students or the teacher. A pre-lesson interview just before the lesson focused on the teacher’s thinking regarding the lesson to be taught. An open-ended interview protocol offered teachers the opportunity to discuss (unprompted) such things as: key mathematical or pedagogical

points, likely student difficulties, anticipated important moments in the lesson, intended student learning outcomes, and so on.

The teacher taught the lesson to their usual class. The lesson was filmed using a two-camera configuration: (a) The teacher camera recorded all teacher actions and statements throughout the lesson; and (b) the whole class camera recorded the entire class continuously throughout the lesson.

The original lesson plan categories were used to structure the teacher's reflection on the lesson. Initially, the teacher was asked to: (i) comment on each lesson component; and (ii) to identify salient events in the lesson (activities or actions that the teacher believed were important for some reason). The interviewer encouraged the teacher to explain why the chosen events were important. Each event was then viewed on a synchronised, split-screen video record of the lesson and the teacher was invited to make any comments suggested by viewing the video supplementary to those already made.

Teachers were then asked to develop a written plan for "a follow-up lesson" (Lesson 2) using a structured template provided by the researchers. It was intended that Lesson 2 offer the opportunity to build on the first lesson, in relation to content, student understanding, and student engagement. A second pre-lesson interview followed the protocol for the corresponding Lesson 1 interview in every respect. In addition, the teacher was asked to describe any way in which the teaching of Lesson 1 had influenced their thinking about Lesson 2.

The teacher then delivered the second lesson to their usual class. Once again, the lesson was filmed using a two-camera configuration. Again, the original lesson plan categories were used to structure the teacher's reflection in a post-lesson interview of which the latter half was video-stimulated. After this process had been completed, the teacher was asked to identify anything that she had learned over the course of the two lessons.

One week after the filming was completed, teachers were given a written assessment of content knowledge and pedagogical content knowledge and a beliefs survey adapted from the test instrument developed for the 17-country TEDS-M study (Tatto et al., 2012). Given that the capacity of any individual to learn from a specific experience is dependent on their existing knowledge, it was important to establish general measures of the teachers' knowledge. This information could then provide part of any explanation for the teacher's subsequent capacity to learn from the experience of teaching a lesson.

The study design attempts to maximise authenticity by investigating teacher learning "in situ" – that is, teachers in interaction with students with whom they are familiar and for whose learning they are responsible. The teachers' subsequent learning from any lesson will be dependent on their existing knowledge of their students and of the mathematics curriculum relevant to that grade level. It was hypothesised that this existing knowledge, together with teacher beliefs and values, would determine those classroom events, objects and people to which the teacher chose to attend. This, in turn, would influence the teacher's in-the-moment decision-making, shaping the way in which the teacher translated the lesson plan into classroom activity. Further, the teacher's knowledge, beliefs and values would critically inform their evaluation of the effectiveness of any particular lesson activity and the significance attached to those lesson outcomes they considered salient.

### *Data Analysis*

The analysis reported in this paper drew primarily on interview data with a particular teacher, supplemented by results from the TEDS-M instruments. All interviews were fully transcribed, and were coded by at least two of the authors, who worked together closely in

the early stages. In coding the teacher responses, our overall guiding question was: What do the teachers notice or pay attention to in preparing for teaching, and in reflecting on the lesson? This is closely tied to both research questions. Text which provided information on this question was coded in four broad categories: Mathematical content (what reference does the teacher make to mathematical content?); Students (what aspects of students' knowledge, behaviour or needs do teachers refer to?); Instruction (what instructional actions or considerations do teachers refer to?); and Teachers (what aspects of themselves do teachers make reference to?). Several excerpts attracted more than one of these codes.

Where two coders assigned different codes to the same interview excerpt, we adopted an inclusive approach—any text which was given a code by at least one coder was included in that category. All four authors were then involved in drawing out particular themes from within the four broad categories. Making sense of the data involved both direct interpretations and categorical aggregation (Stake, 1995). Examples of such themes include student engagement, the adoption of new lesson structures, connections to the everyday, and the role of measurement benchmarks. These themes could then be related to the data on knowledge and beliefs from the TEDS-M instruments.

## Results

From one perspective, the *Learning from Lessons* project can be seen as an investigation into the mechanisms by which teachers develop the “wisdom of practice” conceptualised by Shulman (1987). The theoretical basis for the project derives, as has been discussed, from the Clarke-Hollingsworth (2002) model of teacher growth, in which a key determinant of teacher learning is the particular classroom outcomes (e.g., student performances or lesson efficiencies) that the teacher considers to be “salient”. Both the study design and the associated analytical framework take the following connective chain as fundamental: Teacher Change (and therefore Teacher Growth or Learning) is critically dependent on those classroom events to which the teacher chooses to attend while teaching a lesson. This selective teacher attention is a direct reflection of the classroom outcomes the teacher considers to be salient. Decisions of salience reflect the teacher's system of values and beliefs. Teacher selective attention is also significantly determined by teacher knowledge. Put simply, a teacher's attention is directed towards those things that the teacher knows and believes to be important. Any understanding of teacher learning in the classroom must start from the documentation of those things to which teachers attend. In terms of the Clarke-Hollingsworth model, teacher attention reflects teacher judgements of salience and constitutes a key mechanism providing the matter for teacher reflection.

It became evident in our analysis of teacher interviews and the classroom videos that while teacher *attention* might be identified with some confidence, consequent *learning* was much more difficult to document empirically. In the following discussion, the findings with regard to the operationalisation of teacher *in situ* learning will be illustrated with examples drawn from a single teacher (“Tracey”) of a particular Year 5 class. In discussing this teacher's learning, we found it useful to draw a distinction between the development of teacher knowledge and the on-going refinement of teacher adaptive practice. In empirical terms, this distinction corresponds to the difference between a declarative “claim to know” (the individual's epistemic stance) and an observable (or recounted) change in the individual's practice. We found evidence of both types of learning in our data.

Our principal source of evidence for learning was the body of interview data. As has been outlined, five interviews were conducted with each teacher. The illustrative results that follow are reported as (i) those things to which the teacher chose to attend in her

interviews before and after each lesson; and (ii) those epistemic claims or reported changes in practice that can be taken to constitute teacher learning.

### *The Teacher: Tracey*

Tracey has been teaching for 13 years, following the completion of a BEd in 1998. This study took place in her second year of teaching Year 5. Based on questionnaire and test data, Tracey answered approximately 80% of the TEDS-M mathematics content knowledge (MCK) items correctly, with 60% of the items addressing pedagogical content knowledge (PCK) answered correctly. She described herself as fairly confident in teaching mathematics (6/10) and, specifically, more confident that she could address the needs of low-attaining students (7/10) than high-attaining students (6/10). She described her instructional approach as focusing on putting ideas into a practical context very often. In her responses to TEDS-M beliefs items, she did not endorse “Learning mathematics through following teacher directions”, but strongly affirmed “Mathematics as a process of inquiry” and “Learning mathematics through active involvement”. From her questionnaire responses, Tracey can be described as having a conceptual orientation, rather than a calculational orientation (Philipp, 2007). These personal attributes of knowledge and belief help us to understand both the patterns in Tracey’s attention and the form taken by her consequent learning.

### *Teacher Selective Attention*

The targets of teacher attention were classified as concerning: Instruction, Mathematics, the Student, or the Teacher. On the basis of our analysis, we were able to detect distinct characteristics of the teacher’s attention associated with each of these four categories.

*Instruction.* The lesson provided by the researchers dealt with student estimation of mass and the subsequent lesson developed by Tracey dealt with student estimation of angles. In interview, Tracey made specific and repeated reference to three features of the lesson structure: the “hook” or story shell used to engage students and situate their activity at the beginning of the lesson; the three-part structure (estimation and measurement, discussion, and further estimation) (see Lovitt & Clarke, 1988); and the summing up phase of the lesson. She chose to utilise the same features in her second lesson.

Other considerations about instruction for the planning of this lesson included the timing or pacing of the lesson (e.g., “when they’re all sitting and each thing is being measured, it might be a bit time-consuming there and the kids might get a bit bored”) and how she might group the students for the activity (e.g., “I did think about that because I was going to place them, perhaps, with someone with high ability skills but I just thought also the conversations that they’re going to have are probably just as important and I’d like them to be with, perhaps, people they’re comfortable with. So I’m just going to let them choose their pairs.”). One aspect that she felt did not go as well as she had hoped was the summing up phase (e.g., “I’m very aware of it in all lessons, not just this one that the reflection at the end is really the key. And, perhaps, I didn’t leave enough time for that in this lesson and it quite often happens that the time for reflection is not there.”). This concern to provide sufficient time for an adequate reflection at the end of the lesson led her to reduce the number of opportunities to estimate in each round (from five to three).

*Mathematics.* In discussing her planning for both lessons, Tracey made frequent and quite detailed mention of mathematics content, however mathematics was much less frequently mentioned in her post-lesson reflections. A persistent emphasis was the role of referents (her term “benchmarks”) by which the students could make judgements in relation to estimating quantities. The other persistent emphasis was “Measurement Units” – which is understandable, given the focus of both lessons.

The theme “connection to the everyday” appeared to be implicitly connected to a concept of embodied learning (although not articulated by Tracey in those terms). This was clear in Tracey’s discussion of whether or not to include a discussion of the relationship between a gram, a cubic centimetre, and one millilitre of water. This seemed to constitute a significant focus of reflection for her and also a form of learning. For example: “And then I thought that the idea of water and how heavy water is and relating it to the millimetre and the cubic centimetre might be something that interests them which is something we could run with” (Pre-Lesson Interview 1) and “So I had to make a decision there to, perhaps, we’ll bring up the water thing and water being equivalent, mls and grams, bring that up later in another lesson” (Post-Lesson Interview 1). The prioritisation of “connection to the everyday” is also consistent with Tracey’s responses to the TEDS-M beliefs questionnaire.

Compared to Lesson 1, the Lesson 2 Pre-Lesson Interview was more concerned with the curriculum, probably because the responsibility for choosing the topic had been handed to Tracey. The interview included many references to the curriculum (AusVELS was cited) and Tracey tried to work out how the lesson would connect with the curriculum. Tied up with this was her uncertainty over the students’ prior knowledge.

*The students.* Except for the preparatory interview, Tracey gave consistent attention to student engagement/disengagement. In the first pre-lesson interview, she discussed the importance of the pacing of the lesson so that the students did not get bored. After teaching the first lesson, she noticed the disengagement of the students towards the end of the lesson and reported that her instructional decisions for the lesson were determined by the students’ performance and engagement during the lesson: “So I guess it’s the kids’ response and how they’re performing during the lesson and their engagement I think helps me decide mostly when I need to move on and that.” Similar comments regarding student engagement and interests were made in the second pre-lesson interview.

Tracey’s concern for student engagement was consistent with the attention she gave to student knowledge in planning her first lesson: “I just thought I might make sure that. . . they understand what mass is. . . they may not have done mass for a while and they confuse it with volume or something” and the second lesson: “I’m not sure of previous knowledge about angles so we’re going in blind a bit so I just did a little recap.”

Tracey seemed to create more opportunities for students’ reflection at the end of the second lesson compared to the first one. “I think hearing them reflect on the lesson last time, I think that was important” and “I think it was the way they verbalised it and also the others were paying more attention this time around as well. Whereas the last time they weren’t and that. . .”

*The teacher.* There were very few statements where Tracey referred to her own capabilities, confidence or feelings. She did comment in relation to the topic of angles, that “perhaps, it’s my own lack of knowledge about angles as well. I couldn’t quite maybe explain it as clearly as I . . .” She noted that for the second lesson (which she had prepared) that she “got more ownership of this so I knew exactly where I wanted to go.” Apart from these, self-referential statements by Tracey were rare.

## Discussion

On the basis of our data, teacher learning could be identified in the form of developed knowledge or adaptive practice. Examples of each were available.

Evidence of knowledge development included Tracey's comments on mathematical content and curriculum, new instructional strategies, the prior knowledge of her students, and the significance of particular elements of lesson structure. We would argue that the distinction between declarative knowledge and adaptive practice is an important one. Tracey not only articulated new forms of declarative knowledge, this knowledge was frequently described or actually enacted in the form of adaptive practice.

Within the category of adaptive practice, Tracey attached particular value to the three-part structure, whereby students are given two opportunities to estimate, and to the "hook" which was not new to her but something she had not used often. The third aspect was the reflection at the end of the lesson, which she had added to the original lesson template. This lesson feature was clearly important to her as she worked hard to improve this stage in the second lesson. Each of these can be interpreted as indicative of adaptive practice.

Her final interview emphasised the importance of drawing student attention not just to the measurement units as such but to the role of the "benchmarks" in helping them to make better estimates. It seems reasonable to suggest that this constitutes a form of learning for Tracey, whose interview statements suggested that she was likely to be giving the same emphasis to this strategy in her future teaching of any topic in measurement.

Tracey's interviews illustrate how her professional learning was tied to particular practical aspects of the lesson, but ones with instructional implications, such as measurement benchmarks, and connections to the real world. Further, when responsible for the choice of topic, Tracey paid significant attention to location in the curriculum and to student prior learning. In particular, after the lesson, she was more inclined to reflect on the mathematics her students did or did not know prior to the lesson (i.e., their preparedness) to a greater extent than the mathematics they actually learned during the lesson.

## Conclusions and Implications

To a significant extent, our analysis has addressed the question: What are the dominant emphases in Tracey's interviews, how do these change, and is there evidence of learning? This question represents the pragmatic challenge addressed by the research design employed in this study.

The analysis of data pertaining to Tracey has demonstrated both the efficacy of the approach and also validated the intended connectedness of the data sources. For example, the teachers' personal attributes of knowledge and belief, as documented through the TEDS-M instruments and the teacher interviews, did provide insight into the patterns in the teacher's attention and the form taken by any consequent learning. These consistencies align well with the hypothesised connection between teacher knowledge, beliefs and values, teacher selective attention, and teacher learning. It is through the documentation of these connections that we hope to identify the mechanisms underlying Shulman's *wisdom of practice* (Shulman, 1987) and the processes of reflection and enaction that mediate change in the Clarke-Hollingsworth model (Clarke & Hollingsworth, 2002). Once a process is understood, it may become possible to increase its effectiveness.

In respect of practical implications of this research: teachers are busy people, and the opportunities for reflection, if not structured by others, are sometimes lost. We can envisage a teacher professional learning program where a group of teachers choose a

lesson from a bank of recommended lessons, adapt the lesson as necessary for their students and then teach it. A questionnaire, using similar prompts to those used in our post-lesson interviews, could catalyse teacher reflection. Teachers would then construct an appropriate follow-up lesson to the provided lesson, and teach it, completing another reflective questionnaire. The teachers would meet as a group to share their experiences.

It is our opinion that the research design of this project proved capable of generating the data needed to document at least two broad forms of teacher learning from the experience of teaching lessons: developed knowledge and adaptive practice. It does appear that teachers learn from the activity of teaching lessons. Our challenge is therefore to better understand that process in order to optimise its occurrence. The effectiveness of the research design in catalysing teacher reflection has significant potential for future adaptation to professional learning contexts.

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