How Do Teachers Learn? Different Mechanisms of Teacher In-Class Learning

Man Ching Esther Chan
The University of Melbourne
<mc.chan@unimelb.edu.au>

Anne Roche
Australian Catholic University
<anne.roche@acu.edu.au>

David J. Clarke
University of Melbourne
<d.clarke@unimelb.edu.au>

Doug M. Clarke
Australian Catholic University
<doug.clarke@acu.edu.au>

This paper elaborates on the teacher change process described in the Interconnected Model of Teacher Professional Growth by providing empirical evidence from a study that investigated the knowledge construction process of three mathematics teachers in Melbourne, Australia. Through a research design that aimed to facilitate teacher reflection regarding their learning processes during the design and teaching of lessons, two mechanisms of teacher learning were identified: consolidation in terms of reinforcement of existing knowledge and beliefs, and realisation of new knowledge and beliefs. This finding prompted a re-conceptualisation of the nature of teacher professional growth.

The promotion of teacher professional growth is a policy focus in many countries including Australia (OECD, 2014a; 2014b). A recent review of the Australian school system commissioned by the Federal government stated that "[r]esearch and experience internationally confirms that ongoing professional development for teachers—some mandated by the school or system, and some through participation in professional learning communities—is an essential part of a teacher's workload in high-performing education systems"(Gonski et al., 2018, p. xv). This finding appears to endorse the widespread use of organised programs of teacher professional development to facilitate teacher learning. We argue that research in teacher learning tends to focus on *formal* professional development programs (c.f., Bell, Wilson, Higgins, & McCoach, 2010; Desimone, 2009; OECD, 2014a), while less attention is paid to teacher learning that occurs through teachers' day-to-day classroom practice. This paper addresses this research gap by reporting on a study that investigated teachers' learning through their classroom practice. Specifically, the paper elaborates on the Interconnected Model of Teacher Professional Growth (Clarke & Hollingsworth, 2002) by explicating the specific mechanisms of teacher in-class learning.

The Interconnected Model of Teacher Professional Growth

The Interconnected Model of Teacher Professional Growth (Clarke & Hollingsworth, 2002; "the Interconnected Model" in short) has been widely employed in education literature (Boylan, Coldwell, Maxwell, & Jordan, 2018), particularly in mathematics and science teacher education (Goldsmith, Doerr, & Lewis, 2014; Justi & van Driel, 2006). The model builds on the earlier Clarke-Peter model of professional growth (Clarke & Peter, 1993; Peter, 1996) and suggests a non-linear and recursive process in which teacher professional growth occurs (see Figure 1).

The Interconnected Model (Clarke & Hollingsworth, 2002) comprises four domains of change in teachers' professional environment: the personal domain (knowledge, beliefs and attitude), the domain of practice (professional experimentation), the domain of consequence (salient outcomes) and the external domain (external source of information or stimulus). The model suggests that changes in the four domains are facilitated by the mediating processes of enactment and reflection, where *enactment* involves putting into action a new idea, a new

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belief, or a newly encountered practice (p. 953) and *reflection* involves "active, persistent and careful consideration" (p. 954).

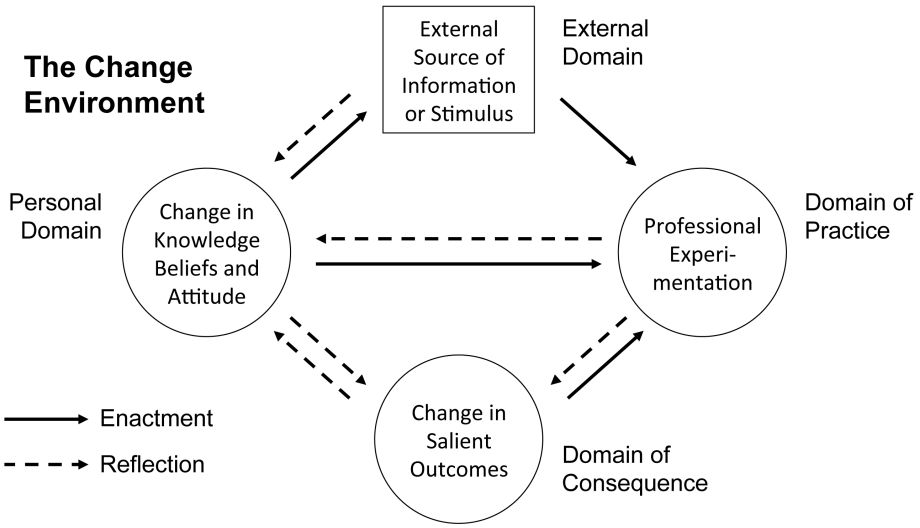

Figure 1. The Interconnected Model of Teacher Professional Growth (Image adapted from Clarke & Hollingsworth, 2002).

In a review of some of the most cited teacher professional learning models, Boylan et al. (2018) suggested that compared to other models of teacher learning (e.g., Desimone, 2009; Guskey, 1986), the Interconnected Model particularly emphasises the agency and perception of teachers in their own learning. Unlike the models proposed by Guskey and Desimone where student learning outcomes are prescribed as the ultimate focus of teacher change, Clarke and Hollingsworth (2002) believed different teachers may consider different classroom outcomes as salient, such as increase in student motivation or maintenance of classroom control. Depending on their prior beliefs and knowledge and what are considered as salient outcomes, different teachers may interpret the efficacy of new practices differently.

In the review, Boylan et al. (2018) commented that the processes of enactment and reflection are under-theorised in the Interconnected Model, where the distinction between the two processes is not sufficiently clear. One way of interpreting Boylan et al's (2018) criticism is that, while the internal process of teacher reflection is appropriately distinguished from enactment, where the latter involves putting something into practice, the actual process of reflection is not specified in detail or empirically exemplified. There also appears to be lack of clarity regarding what constitutes teacher professional growth according to the model. In this paper, we attempt to give a more explicit empirical grounding to the learning mechanisms represented in the Interconnected Model (Clarke & Hollingsworth, 2002), through a research design that aimed to facilitate teacher reflection regarding their learning processes during the design and teaching of lessons.

Research Design

The data reported in this paper came from an international research project, which aimed to investigate the knowledge construction process of mathematics teachers in Australia, China, and Germany (Chan et al., 2017). The project combined focused case studies with an online survey of mathematics teachers' selective attention and consequent learning in the three countries. The case study data from Australia formed the focus of this paper.

Participants

Case studies were undertaken of three teachers, teaching Years 5, 6, and 7 respectively. The three teachers were from different schools in Melbourne. The Years 5 and 6 teachers had five and four years of teaching experience respectively, and the Year 7 teacher had 27 years of teaching experience at the time of the study. It should be noted that in Melbourne, Years 5 and 6 are primary school grade levels and typically taught by generalist teachers, whereas Year 7 is a high school grade where mathematics is typically taught by a mathematics specialist teacher.

Data Generation

The three teachers were separately given a different set of three researcher-designed lesson plans appropriate for their year level. Each of the teachers was asked to adapt the lesson plan provided and then deliver the lesson to their usual class (17 to 26 students in a class). After teaching the first adapted lesson, the teachers were asked to design a follow-up lesson themselves and deliver this lesson to the same class a few days after the first lesson. This process was repeated for each of the lesson plans provided, resulting in the delivery of three adapted lessons and three follow-up lessons per teacher. Pre- and post-lesson interviews were conducted with each of the teachers on the same day of the adapted and follow-up lesson delivery.

The study was designed to generate data on each teacher's adaptation of a pre-designed lesson, the teacher's actions during the lesson, the teacher's reflective thoughts about the lesson and, most importantly, the consequences for the planning and teaching of a second lesson. All of the pre- and post-lesson interviews and the adapted and follow-up lessons were video recorded, with the video recording of the lesson just taught used in the post-lesson interview to stimulate the teachers' recall and reflection on the lesson.

The questions asked during the pre-adapted lesson interviews were generally about the adaptations that the teacher had made to the lesson plan provided and the reasons for the adaptations, and what the teacher anticipated from the lesson. The post-adapted lesson interviews were generally about what the teacher thought were the significant or unexpected moments in the lesson just taught, challenges experienced by the students and what the teacher thought he or she had learned from the teaching of the lesson. After answering these initial questions, the teacher was offered the opportunity to review the video recording of the lesson just taught and to elaborate on previous responses referring to the video footage. The pre- and post-lesson interviews for the follow-up lessons adopted a similar format focusing on the teacher's reasoning behind the design of the follow-up lesson and the reflection on the follow-up lesson respectively.

The pre-lesson interviews ranged from 10 to 30 minutes and the post-lesson interviews ranged from 30 to 60 minutes, depending on the teacher. All of the interviews were fully transcribed.

Data Analysis

The analysis reported in this paper drew on the interview data with the three case study teachers, and specifically, the teachers' responses to interview questions related to their learning. The analysis focused on characterising the learning processes reported by the teachers. Referring to the thematic analysis steps described by Braun and Clarke (2006), the analytical process in this study involved:

1. Data familiarisation through transcript reading and re-reading.
2. Identify interview questions that explicitly sought teachers' reflection of their own learning.

3. Collate the interview responses to those questions identified in Step 2.
4. Compare and contrast the teachers' responses to identify emerging codes.
5. Apply the codes to the interview responses, revise codes, and refine code definitions.
6. Identify patterns within and between teachers' responses and emerging themes based on the coded statements.

Initially, five questions across the four interviews (two interviews each, pre- and post-lessons, for the adapted and follow-up lessons) were included in the analysis. The five questions explicitly asked what the teachers thought they learned from the activities carried out as part of the project (lesson plan adaptation, adapted lesson teaching, creation of follow-up lesson plan, and follow-up lesson teaching). After examining the teacher responses to all interview questions, responses to two additional questions about which events the teachers thought were unexpected were also included in the analysis because there seemed to be similarities between the teachers' responses to these questions and to the learning questions. Table 1 lists the interview questions that were part of the analysis.

Table 1
List of Learning-Related Interview Questions

Interview session	Interview questions
Pre-adapted lesson	• Please describe anything you have learned as a result of participating in the task activity, and in reading and planning the lesson. Explain your response.
Post-adapted lesson	• Was there anything that happened during the lesson that was really unexpected by you?*
	• Which moments in the lesson do you think provided learning opportunities for YOU? What did you learn?
Pre-follow-up lesson	• Please describe anything you have learned as a result of planning/preparing this lesson. Explain your response.
Post-follow-up lesson	• Was there anything that happened during the lesson that was really unexpected by you?*
	• Which moments in the lesson do you think provided learning opportunities for YOU? What did you learn?
	• Is there anything else you have learned over the course of the two lessons and your participation in this project?

Note. Questions that were added to the analysis at a later stage are marked by *

Rather than summarising the coded data, we report in this paper on how the coding categories emerged from our analysis of the data, and how the coding categories might help to explicate the mechanisms of teacher learning that underpin the Interconnected Model (Clarke & Hollingsworth, 2002).

Findings

After reviewing the reflective statements of all three teachers, we found that all of the teachers identified things that they thought they had learned in the course of participating in the project. For example, in the post-lesson interview of the first adapted lesson, the Year 5 teacher learned that his students did not apply a particular problem-solving strategy that was covered in the past:

> I was surprised that looking through the sheets that not many of them like physically sort of circled or highlighted key information, which felt like a problem-solving strategy we've done in the past. (Year 5 case study teacher).

For the Year 6 teacher, she said she learned about Pick's Rule, one of the researcher-designed lesson topics in the project.

> So, I have never heard of this before, Pick's Rule. So that was brand new to me. (Year 6 case study teacher).

Although the Year 7 teacher was very familiar with the topic of probability, she was surprised that she got caught up during a lesson in the irrational thought of trying to predict patterns in the outcomes of dice rolls. This helped her to see things from her students' perspective when they learn about probability.

> ... even for me, as a teacher, knowing probability really well, to think that it (the dice roll) is not really random. I got sucked into that for a few rolls, so, I thought, "If I'm thinking that, I can see why [the students] find it hard to lose that idea," and I think most people, even though you know logically that's the case, I think it's really hard in a practical situation to go, "Yeah, we've had three twos, so, it has to be a four or something next." I think it's just - so, I found myself slipping into that, and that surprised me a bit. (Year 7 case study teacher).

The above statements all suggested something that was unexpected, surprising, or new for the teachers, giving a sense of novelty in what the teachers observed or realised.

In contrast, we found statements given by the teachers that seemed to confirm the teachers' already held beliefs and expectations, even though they thought that was also part of their learning. For example, the Year 5 teacher thought the lesson topic on the context of a mathematical problem "reignited" his emphasis on the topic in his teaching.

> I would've liked to have thought that it was a big priority in my teaching, but reading this, it's probably reignited that light of realising that, "Hey, the context of the problem is super, super, super important." ... I certainly have got more appreciation of that. So, that would be learning out of it, for sure. (Year 5 case study teacher).

The Year 6 teacher thought the importance of content knowledge in her teaching was something that she had "learned" from her participation in the project, even though it was something that she already knew.

> It's something that I already knew but just really reiterated, the importance of your content knowledge because when something does happen that's unexpected if you don't have that background it's really hard to have those teaching moments. (Year 6 case study teacher).

Similarly, the Year 7 teacher thought the importance of asking students questions to ascertain what they know was an important part of her teaching, but something that she thought her participation in the project had re-confirmed for her.

> It's reconfirmed the fact that if you don't keep asking kids questions, you can make the assumption they know more than they do. (Year 7 case study teacher).

Through these statements, the teachers expressed their existing knowledge or beliefs, and how the new situation, activity, or event had "reignited", "reiterated", or "reconfirmed" those knowledges or beliefs. These statements appear to be different from the earlier statements that suggested something new or novel.

Based on the teachers' responses to the learning questions, we propose two different learning mechanisms: One mechanism is consolidation because the observed classroom phenomena confirmed the beliefs and expectations that a teacher already held. The other mechanism is destabilising what a teacher believed because what happened was unexpected, adding new knowledge or creating a new realisation for the teacher.

These two learning mechanisms (consolidation and new realisation) were also evident in the responses of the three teachers during the very final interview regarding what the teachers thought they had learned having gone through the process of preparing, teaching, and reflecting on three adapted and three follow-up lessons for the project.

The Year 5 teacher commented on some of the difficulties he experienced when delivering one of the lessons and what he learned from them.

> Look, tackling that division lesson now (was difficult) because we're in the middle of our multiplication, division unit. It would be interesting to see how different the lesson would be with a little bit of a refresher unit before it. (Year 5 case study teacher).

For the Year 6 teacher, she mainly reflected on the process of creating the follow-up lessons, particularly in terms of the amount of new content necessary in the follow-up lesson compared to the previous lesson. She also highlighted the value of not underestimating the ability of the students to grasp content that may appear too difficult for them.

> … I think the main thing I've learnt was just the small changes you can make to then make it a second lesson – it doesn't need to be a whole different thing. … Also, I think not underestimating kids, like, definitely Pick's Rule, I looked at it and I went "that's going to be far too hard for them", but they got so much out of it. And it doesn't actually matter if it's too hard, they'll get something out of it. (Year 6 case study teacher).

The responses of these two teachers are illustrative of the learning mechanism of new realisation. On the other hand, the response of the Year 7 teacher contrasts the two learning mechanisms.

> ... when I sort of feel I haven't learnt anything new (from my participation in the project activities), it's reinforcing what we do, I think, but I don't know I've learnt lots of new stuff 'cause all my learning kind of – in terms of this stuff, I think – a lot of my pedagogy (learning) happened five or six years ago – yeah. And that would be the big change. (Year 7 case study teacher).

The Year 7 teacher suggested that much of her "learning" happened in the first 17 to 22 years of her teaching career. After that, a lot of what she did in her day-to-day teaching was reinforcing what she already knew or did. This suggests that for the Year 7 teacher, the learning process appeared to be different for her at the beginning of her teaching career compared to later in her career.

Discussion

The purpose of this paper is to explicate the processes of teacher learning that are central to the Interconnected Model (Clarke & Hollingsworth, 2002). Through the use of purposefully-designed experimental mathematics lesson plans, teachers were asked in this project to adapt a researcher-designed lesson plan, teach the adapted lesson, and create and teach a follow-up lesson. The pre- and post-lesson interviews conducted in the study provided opportunities for the teachers to reflect on what changes in their knowledge and practice were evident, and how those changes occurred. From the teachers' responses to the learning questions, we could distinguish two learning mechanisms: one is consolidation in terms of reinforcement of existing knowledge and beliefs, and the other is realisation of new knowledge and beliefs. We suggest that these two mechanisms both contribute to teacher learning, particularly in their day-to-day teaching practice as teachers expand their existing knowledge base (consolidation) and form new knowledge and beliefs (new realisation).

While some may argue that reinforcement of existing beliefs and knowledge should not be considered to constitute learning, we would argue that reinforcement is a valuable mechanism that maintains and strengthens a teacher's current knowledge and practice. Without such a mechanism, a teacher may not form a knowledge base or routine that helps them carry out their day-to-day teaching activities. We envisage the process of consolidation

as confirming a principle of instruction and possibly equipping the teacher with another context or situation to which the confirmed principle applies. In the language of schema theory, the additional confirming experience has extended the teachers' network of instances to which the principle applies and increased the likelihood of its future application in the teacher's practice.

In terms of the Interconnected Model (Clarke & Hollingsworth, 2002), we suggest that the two learning mechanisms add to our understanding of the reflective process in the model (see Figure 1). From the case study teachers' reflective statements, we found that the teachers' professional experimentation experience can either consolidate or create new realisation in their knowledge beliefs, and attitude. The resulting "change" can be an expansion or strengthening of their existing knowledge, beliefs and attitude (consolidation), or a reconfiguration or adjustment of their existing knowledge, beliefs and attitude to the new information or situations (new realisation). If we legitimise consolidation as a mechanism of teacher learning, then depending on how a teacher perceives the external sources of stimulus and the results of professional experimentation, the consequent learning could result in either a change in practice or the maintenance of current practice in their enactment of their learning. Consistent with the Interconnected Model, teacher agency is emphasised here, where the maintenance of current practice should be a conscious decision made by the teacher rather than an unthinking response to be considered a result of learning.

This re-conceptualisation of teacher learning processes in terms of consolidation and new realisation poses questions for further research in teacher learning. By distinguishing these two learning processes, we can ask the questions: What characterises teachers who have a greater tendency to experience learning as new realisation? What characterises those who have a greater tendency to experience learning as consolidation? What types of events or conditions trigger new realisation or generation of new teacher knowledge? What are such new knowledges or new realisations about? These questions will be addressed in future papers in the project together with the research teams in China and Germany, drawing from the survey and cross-cultural components of the project.

Conclusion

The Interconnected Model of Teacher Professional Growth (Clarke & Hollingsworth, 2002) is one of the most well-cited models of teacher learning (Boylan et al., 2018). It is hoped that explicating the different processes represented in the model would help to contribute to a better understanding of teacher in-class learning, and ultimately, the optimisation of such learning.

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