Knowledge, Beliefs, and Innovative Curriculum

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In this paper, I report on doctoral research in which I studied the changes in mathematical knowledge and beliefs of two Year 5/6 teachers as they implemented a four-week innovative curriculum unit. Such immersion experiences have the potential to develop teachers' understanding of mathematics in the context of the classroom. Year 6 case study teacher Debbi's experience is discussed in relation to curriculum fidelity and opportunity to learn, in particular the foregrounding of higher achieving students. Debbi's firmly entrenched practices, related beliefs, and affective response to the curriculum presented as the dominant filters for reflection and enaction.

Research focused on the classroom application of a teacher's mathematical knowledge and beliefs and the effect of these on student understanding has highlighted the need for further investigation into professional development strategies that promote deep and flexible understanding of curricular content. Calls for change in perspective from a focus on innovations to those driving them, along with views of teaching as cultural activity, suggest that attempts to develop the skills and knowledge of teachers must be done in the context of the classroom (Doyle & Ponder, 1977; Stigler & Hiebert, 1999). Such professional learning needs to push beyond strategies that promote rudimentary change that is quickly relinquished. To challenge the basic premises of teachers' prior beliefs, to "rock the conceptual boat" (Jones & Nelson, 1992), special conditions are necessary.

This study focused on how teachers held mathematical knowledge for teaching, illuminating the complex relationship between a teacher's knowledge and their beliefs, and the extent to which the use of innovative materials yielded changes in these. Interaction with curriculum and support materials can be thought of as an immersion experience (Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2010) that has the potential to build mathematical knowledge for teaching while in the act of teaching. Innovative curriculum tasks put extra demands on the teacher; they tend to be conceptually demanding and unpredictable in nature (no set path of solution). Such features require teachers to make connections between students' informal thinking and the formal knowledge of mathematics, possibly prompting high levels of anxiety in both students and themselves (Stein & Kim, 2010). The major research question underpinning the study was: How do teachers' knowledge and beliefs about mathematics and mathematics teaching change as they teach an innovative mathematics curriculum? Case study methodology (Meriam, 1998) within a constructivist epistemology and an interpretivist theoretical perspective promoted in-depth understanding of the complex interactions and multiple realities of the teachers' world, and the interpretations they made in this context.

The Interconnected Model of Teacher Professional Growth (IMTPG; Clarke & Hollingsworth, 2002; see Figure 1) provided the study's theoretical framework and supported interpretation of mechanisms that trigger change (or growth) in one or more of the four domains of a teacher's world: personal, external, of practice, and of consequence, in this study. It offered a lens through which to describe interaction between domains, the mediating processes of enactment (putting a new idea into action) and reflection, and the resultant (professional) growth. The external domain in this study related to the innovative curriculum unit Some of the Parts (Brittanica, 2006), the Australian Mathematics

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Curriculum, and any other support materials sourced by case study teachers. The domain of practice involved implementation of the innovative unit in the teacher's classroom. Post-lesson reflection formed an important part of the research design, as the aspects that a teacher considers salient are highly subjective, depending on what the teacher values. Teacher-interpreted change by means of post-lesson interviews, therefore, was crucial as such change was "of consequence" for the teacher (Clarke & Hollingsworth, 2002).

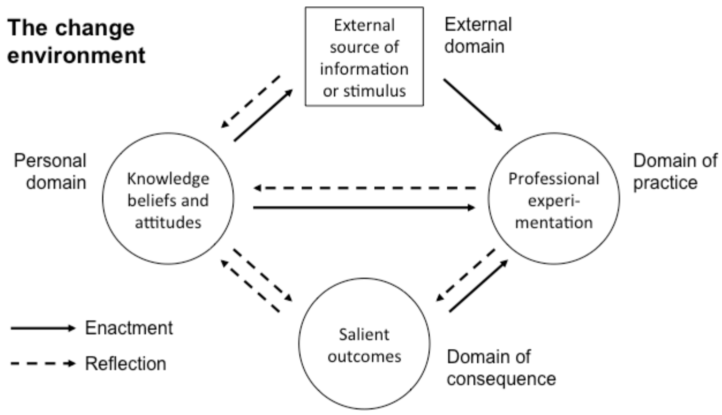

Figure 1. The Interconnected Model of Teacher Professional Growth (Clarke & Hollingsworth, 2002).

The personal domain of the IMTPG model represents what the teacher knows, believes, or feels in relation to the change occurring in their world. The Mathematical Knowledge for Teaching model (Hill et al., 2008) was used to help focus the analysis of changes in knowledge in the personal domain. Beliefs serve an important function in this model. According to Phillip (2007), a belief *that* is about beliefs, and a belief *in* is about values. Beliefs tend to develop gradually, serving as a filter through which new ideas or approaches are perceived. Newly acquired beliefs then are the most vulnerable (Pajares, 1992). Reflection on such beliefs is necessary, especially when teachers' beliefs are incompatible with goals of the innovation (Borko, Mayfield, Marion, Flexer, & Cumbo, 1997).

Methodology

The case study involved two Year 5/6 teachers as they implemented a four-week fractions unit based on the principles of Realistic Mathematics Education (RME; see, e.g., Streefland, 1991). RME promotes conceptual understanding, progressively using "models of" realistic contexts to develop "models for" abstract representations. Such heuristics are the basis of the Some of the Parts (Brittanica, 2006) unit selected for this research, designed through cross-national collaboration between the University of Wisconsin-Madison and curriculum developers at the Freudenthal Institute. RME assists teachers to establish a classroom culture of "conjecturing, explaining, and justifying" to guide student "reinvention" of mathematics (Gravemeijer, 1999). The instructional design of the teacher support material speaks to the teacher, not through them (Phillip, 2007), outlining in detail the goals of instruction, the mathematics addressed (main concepts explored), comments during instruction, explanation of the models used, possible student responses, and assessment options. Conceptual understanding is promoted through investigation of realistic contexts using models that promote flexible manipulation of fractions, including fraction bars, double number lines, and the ratio table. The unit is organised around key ideas of rational numbers, making it deeply connected to the structures of mathematics, and to the core insights students develop as their mathematical reasoning and understanding develops. For these reasons, the Some of the Parts unit was considered innovative.

Case study teachers volunteered for the research trial. They had at least five years' classroom experience and were both at the same New South Wales government school. The study involved deep observation of knowledge in practice; each teacher was observed for three pre-intervention lessons in their normal routine and then up to 16 lessons during the four-week innovative unit implementation. Individual and group meetings were held with teachers in the term before the Some of the Parts trial to familiarise them with the content and its philosophical underpinnings. Teachers were given the opportunity to read the unit in more depth over the half-year break, and the first week of term was put aside for further clarification if needed.

During both the pre-intervention and innovative unit periods, post-lesson reflective interviews were conducted each day to gauge teachers' perception of the lesson, how it matched their intentions, and moments that they felt were significant. All lessons and interviews were recorded, fully transcribed, and supported by detailed field notes. The Copur-Gencturk (2015) classroom observation record assisted pre-intervention lesson analysis in relation to design and implementation, mathematical discourse and sense-making, task implementation, and classroom culture.

In the pre-intervention phase, teachers completed two questionnaires developed as part of the 17-country Teacher Education and Development Study in Mathematics (TEDS-M; Tatto et al., 2008), to gain an insight into their knowledge and beliefs about mathematics and mathematics teaching prior to the intervention, and as a basis of comparison as the research "story" developed. The first assessed Mathematics Content Knowledge (MCK) and Pedagogical Content Knowledge (PCK), measuring knowledge at least two years beyond the level that the teachers were expected to teach. The second was a beliefs questionnaire presented in a Likert scale of agreement in relation to beliefs about learning mathematics, mathematics achievement, and the nature of mathematics. A background form (adapted from Clarke et al., 2002) was also completed to gain information about the teachers' personal mathematics history and professional development. An in-depth reflective interview was held at the end of the five-week intervention phase.

Data Analysis

Making sense of the data in order to address the research question relied both on direct interpretation and categorical aggregation (Stake, 1995). Constant comparison began with initial observations, background survey information, responses at interview, notes made through direct observation of lessons, and results of the TEDS-M instruments. These data were compared with others, both within and across datasets (Merriam, 1998), allowing consistent refinement. Questions arising from the data, then, were asked during the field experience as well as after its completion. Interviews were fully transcribed and coded using *NVivo 11*. Coding was guided by the overarching research question and connected "sensitising concepts" (Patton, 2002), informed by the relevant academic literature. Preliminary categories located via axial coding helped form a conceptual structural order that facilitated further analysis. The central themes arising from the data formed the basis for the research "story". These themes included curriculum fidelity and planning, opportunity to learn, measures of success, reflection on practice, and growth and change. The first two themes are discussed in relation to Year 6 teacher, Debbi.

Results and Discussion

Debbi was a busy and industrious teacher with around 40 years' experience at the time of this study. She worked hard to plan lessons in her normal routine. Debbi said she "loved mathematics" (5.8.15) and was keen to teach it in a more specialised role to higher achieving students. Debbi indicated on her background survey that she was highly confident in her ability to teach mathematics in general, and to address the needs of high-attaining students. She was less confident to address the needs of low-attaining students but still rated this within the high range (7 on a scale from 1 to 10). Debbi thought the Australian curriculum had been "dumbed down" over the years, and hailed the merits of the "more progressive" U.K. and Singapore, which extended students more effectively (14.7.15). Debbi's lessons were planned for an hour each day in sub-strands (e.g., Monday – Number and Algebra, Tuesday – Fractions and Decimals, etc.).

During the pre-intervention period, Debbi used a variety of engagement activities, as well as conducting her favoured "Mental Maths" sessions for around 20 minutes of a 50-minute lesson. These 10 short-answer questions related to the sub-strand topic of the day; students answered individually and then marked them as a class. As Debbi wrote up the questions, she hinted about how to complete them. These questions were an established part of Debbi's class routine and their hierarchy was well understood by the students.

Amid lessons there were public messages for students about what constituted success in their classroom. Some students were publically praised and rewarded for making mathematical connections and being "smart thinkers" while others were individually named to the class in relation to problem-solving strategies that might match their weaker abilities. Students who got 10 out of 10 in the Mental Maths session had their names recorded on posters up in the room, alongside students who could recite multiplication tables from x2 to x12 in less than 20 seconds. This information was then summarised in a poster that classified students as "champs", "almost a champ", and "more work needed". Students were grouped by achievement based on an assessment at the beginning of the year (with minor ongoing modifications made); classroom tasks and expectations were planned accordingly.

Students seated in tiered groups made it easier to manage questions during class tasks and to provide support, Debbi explained. It also satisfied her desire to accelerate content to abstraction for those students in her top group. Lesson elements were consistently described as being "fun" or "challenging", often interchangeably, suggesting the high value that Debbi placed on engagement and her high-achieving students. This belief was a utopian alternative to that with which she grew up, recalling her own education as delivered "all at one level" (5.8.15).

Debbi's sub-strand per week programming format allowed much time between continuous lessons to modify content and approach, based on what happened the previous week. Debbi considered her current teaching philosophy of "breaking the strands up" as successful, a structure that allowed constant monitoring of students (5.8.15). This belief was embedded early in Debbi's career, making it tightly held. Such trade experience was positively affirmed when Debbi was in control of the lesson design and content, making her feel effective.

Viewing Debbi's pre-intervention lessons through the Copur-Gencturk (2015) observation record revealed differences in the way that the students responded to the tasks, how many tasks were planned for each lesson, and the time dedicated to each part of the lesson (each subtask). The degree to which Debbi perceived that her "top group" was being challenged and her expectations of what the students should be able to complete influenced the types of discourse and classroom culture considerably. The packed and pressured structure of the first two pre-intervention lessons decreased the time available to investigate, to discuss mathematical content in depth, or for students to contribute significantly to class discussion. Debbi's pacing and desire to keep "moving forward" thwarted teachable moments.

As this study aimed to observe possible changes in Debbi's mathematical knowledge for teaching while implementing innovative curriculum, a measure of her personal competence in this area was considered important. In the TEDS-M assessment, Debbi scored 20 out of a possible 29 in questions relating to MCK, and 12 out of 20 for PCK. A third of the difficulties Debbi encountered related to extended reasoning, suggesting that explanations of mathematical ideas may be challenging for her. In the pre-intervention phase, this could also be inferred from the Copur-Gencturk (2015) observation protocol.

Opportunity to Learn and Fidelity to the Innovative Curriculum

Hiebert and Grouws (2007) defined teaching as a bi-directional relationship that includes interactions among teachers and students around content. A student's opportunity to learn is influenced by the teachers' choices of curriculum topic, their goals for learning, the time allowed for classroom tasks, the tasks posed, and considerations about students' entry knowledge. In providing opportunity to learn, teachers make pivotal decisions in relation to interpreting the written curriculum, setting up the features of the task in the classroom and then implementing it to meet the valued learning goals. Opportunity to learn and curriculum fidelity, or alignment of the intended and the implemented curriculum (as represented in the Some of the Parts unit), emerged as related themes in Debbi's classroom.

Opportunity to learn the skills and strategies promoted by the heuristics of RME were influenced by Debbi's interpretation of the unit and the decisions that she made in relation to its implementation. Debbi seemed very concerned about when the Some of the Parts unit was originally published as she had taught in the U.S. in 1993 and used "a lot of textbooks like this, which was considered lazy teaching" (11.6.15). Her colleague, Mark, committed to the recommended pacing and planning of the unit, displaying a trusting relationship between himself, the unit philosophy, and lesson sequencing (Lomas & Clarke, 2016). Debbi's stated intention to "follow" the curriculum, however, was not necessarily complemented by her "trust" in it.

The unit developers stressed an informal approach as the unit lessons began, encouraging teachers to draw upon the everyday experiences of all students without formal reference to fractions. Despite this, Debbi encouraged students to use measurement (rulers) as the problem-solving strategy to decide on fair shares rather than the informal division encouraged by the unit writers. She also introduced procedural cues to assist students with "easy ways" to solve problems, such as, "if the denominator is even, always divide it in half first" (27.7.15), a prompt that became increasingly problematic for her.

At times, Debbi would use the realistic context scenarios given in Some of the Parts, like sharing fruit strips or being shipwrecked on an island and needing to drink from coconut cans, but the connection to the associated model was not fully explored. Possible comparisons of how the mathematical models were the same or different were lost, and opportunities to explore informal problem-solving strategies removed. Debbi was concerned about the "mundaneness" of the models and tasks presented (20.7.15). She taught lessons far more quickly and in less depth than that suggested by curriculum designers. Students were often hurried through their thinking to facilitate this goal. Use of the ratio table and the tasks in Section E (How Far?) where students order benchmark fractions and calculate distances using maps were the aspects of the unit that Debbi enjoyed teaching most, as she thought they were the most appropriate for Year 6.

The early provision of what Debbi called "focus" questions, related to concepts addressed much further on in the curriculum unit, was evidence of Debbi's concern about catering for the stronger students in her class while teaching the innovative unit. It could be argued that such modifications demonstrated Debbi's sound Knowledge of Content and Students (KCS; Hill et al., 2008); she knew her class well and what they would find easy or difficult. This decision was made, however, before students were given the opportunity to interact with the curriculum, the contexts it provided, and the models it promoted.

Prioritising the needs of her higher-achieving students by way of lesson design, pace, and ensuing class conversation skewed the opportunity to learn in favour of her "top group". Debbi said that she was concerned at the level of challenge in the curriculum unit, yet regularly read and interpreted tasks for students to achieve her goal of moving quickly through content. In post-lesson reflection, the significant moments for Debbi generally related to how well her grouping structures were functioning, how many tasks she had got through in a lesson, and the "mastery" that her top group had achieved in relation to the tasks that she had designed herself. Modifications of curriculum are expected as teachers adapt curriculum to the needs of all their students; this is part of a teacher's role in creating opportunity to learn. This was the stated motivation behind Debbi's decisions to choose disparate pieces of the unit. Her focus, however, was on a small group of students.

Grouping of students by achievement was an important part of Debbi's differentiation goal, providing an idealistic alternative to her own as a learner. She was determined to apply this familiar grouping structure philosophy and practice during the innovative curriculum phase, setting up a situation whereby "extra" and "different" work was consistently needed. Debbi's self-concept was significantly tied to her ability to extend her brighter students. It is what she enjoyed, and what she valued. Use of the Some of the Parts curriculum, she feared, would affect their engagement and academic trajectory.

Debbi said that affirmation of her core belief in relation to grouping students was the major benefit of teaching the innovative curriculum. It also made her think hard about how much differentiation was needed in a class. By differentiation, she meant different tasks for each achievement group. Some of the Parts unit tasks were not levelled. Differentiation opportunities depended on the teachers' understanding of their conceptual basis as outlined in the curriculum, and the models that supported them. Suggestions made in the Reaching All Learners section of the unit assist teachers to support and/or extend students, contributing to its potential to provide opportunities for all students to learn. Complementary tasks for each section were also offered. Despite this, Debbi felt that the curriculum experience reaffirmed her belief that weaker students needed rote learning, questioning whether they needed an understanding of fractions at all. Such students would have to rely on procedural knowledge in the future as they "had been doing hands-on concrete aids for seven years and they still haven't got it". She said she was not worried about these students because "they were never going to get it" (3.8.15).

Momentary Change

Beliefs serve as a filter through which new ideas or approaches are perceived, and the challenge to reflect on these needs to be present, particularly when a teacher's beliefs are incompatible with the goals of the innovation (Borko et al., 1997). In her normal routine and during the innovative curriculum phase, reflection on practice was uncomfortable for Debbi. She was more at ease when reflecting on her regular lessons than those during the innovative curriculum. Contradictory, defensive, and/or confusing statements often followed pensive and contemplative moments after each of the 11 lessons taught. Having said this, at the end of the research, Debbi said that the opportunity to regularly discuss her experience with the researcher was beneficial, lamenting that there was little collaboration between herself and the other case study teacher.

Amidst the resistance, Debbi did reflect on the challenges that the innovative curriculum created in relation to her own subject matter knowledge (SMK) and ways to best address student misunderstanding (KCS). The automaticity of Debbi's teaching (as she described it) was challenged, and her anxiety about this was apparent. Frustration about how to explain ideas, confusion about why students did not understand concepts, and even her consistent response about not being able to remember many aspects of the lessons she had just taught pointed to such unease.

Debbi was particularly concerned when she felt that her understanding of the content in Section D (How Much?) was insufficient to continue the lesson. In this section, recipes are used to apply understanding of operations with fractions, and benchmark fractions are used to estimate portions of food measured in grams. Debbi reflected on her inability to make the connection between the title of the unit How Much and the tasks presented. She acknowledged that her confusion might have been caused by the "jumping around" that she did inside the unit. Debbi said that the different models in these tasks had created challenges for all her students, but that she had found their use "very powerful" (27.7.15). The feedback from her "top group" at this time was positive, which was salient for Debbi. In post-lesson discussion, Debbi reflected on her own learning opportunities, citing the need for time to think more deeply about ways to differentiate for her whole class when teaching ratio. Debbi voiced the change she was noticing in her practice: "I am coming to terms with an approach, a different approach… it's changing my habits to some degree… it challenges me, yeah" (27.7.15).

Conclusion

Analysing Debbi's response to the innovative curriculum through the IMTPG model (Clarke & Hollingsworth, 2002), it is apparent that Debbi's belief in her ability to plan and deliver lessons that provided opportunity for high-achieving students to learn was strongly held and resistant to change. It was also where her confidence lay, and her self-concept connected. Debbi did not consider the innovative curriculum a "knowledgeable other" from which to learn, so there was little reflection on her own teaching practice. This embedded belief promoted hand-picking of tasks during the research and thwarted a wider view of the unit goals and associated models. This also prevented opportunities for whole-class investigations and discussion around important key ideas of rational number. There was evidence that the management of such heuristics may have been challenging for Debbi's subject matter and pedagogical content knowledge, causing further anxiety. Fleeting changes of approach occurred when Debbi reflected on the meaning lost for both her and her students through her haphazard approach. In this immersion experience, curriculum fidelity had an observable influence on the opportunity to learn for both Debbi and her students. Beyond curriculum fidelity, it was Debbi's deeply affective relationship with the curriculum that influenced the quality of this experience, as her values became the dominant filter to interpret all others.

References

Borko, H., Mayfield, V., Marion, S., Flexer, R., & Cumbo, K. (1997). Teachers' developing ideas and practices about mathematics performance assessment: Successes, stumbling blocks, and implication for professional development. *Teaching and Teacher Education, 13*, 259-278.

Britannica. (2006). *Some of the parts.* Chicago, IL: Author.

Clarke, D. M., Cheeseman, J., Gervasoni, A., Gronn, D., Horne, M., McDonough, A.,… Rowley, R. (2002). *Early Numeracy Research Project final report.* Melbourne: Mathematics Teaching and Learning Centre, Australian Catholic University.

Clarke, D., & Hollingsworth, H. (2002). Elaborating a model of teacher professional growth. *Teaching and Teacher Education*, *18*(8), 947-967.

Copur-Gencturk, Y. C. (2015). The effects of changes in mathematical knowledge on teaching: A longitudinal study of teachers' knowledge and instruction. *Journal for Research in Mathematics Education, 46*(3), 280-330.

Doyle, W., & Ponder, G. A. (1977). The practicality ethic in decision-making. *Interchange, 8*(3), 1-12.

Hall, G. E., & Hord, S. M. (1987). *Change in schools: Facilitating the process.* Albany, NY: University Press.

Hiebert, J., & Grouws, D.A. (2007). In F. K. Lester (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 371-404). Charlotte, NC: Information Age.

Hill, H. C., Ball, D. L., & Schilling, S. G. (2008). Unpacking pedagogical content knowledge: Conceptualizing and measuring teachers' topic-specific knowledge of students. *Journal for Research in Mathematics Education*, *39*(4), 372-400.

Gravemeijer, K (1999). How emergent models may foster the constitution of formal mathematics. *Mathematical Thinking and Learning, 1*(2), 155-177.

Jones, D., & Nelson, B. S. (1992**,** March). *A conceptual framework for studying the relevance of context to mathematics teachers' change*. Paper presented at the Research Methodologies for Studying Teacher Change Conference, Nashville, TN.

Lomas, L., & Clarke, D. M. (2016). Changes in teachers' knowledge and beliefs about mathematics and mathematics teaching: A case study. In B. White & J. Clark (Eds.), *Opening up mathematics education research*: *Proceedings of the 39th Annual Conference of the Mathematics Education Research Group of Australasia* (pp. 389-396). Adelaide: MERGA.

Loucks-Horsley, S., Love, N., Stiles. K. E., Mundry, S., & Hewson, P. W. (2010). *Designing professional development for teachers of science and mathematics.* Thousand Oaks, CA: Corwin Press.

Merriam, S. B. (1998). *Qualitative research and case study applications in education*. San Francisco, CA: Jossey-Bass.

Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62*, 307-332.

Patton, M. Q. (2002). *Qualitative research and evaluation methods.* Beverly Hills, CA: SAGE.

Philipp, R. A. (2007). Mathematics teachers' beliefs. In F. K. Lester (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 257-315). Charlotte, NC: Information Age.

Stake, R. (1995). *The art of case study research.* Beverly Hills, CA: SAGE.

Stein, M. K., & Kim, G. (2010). The role of mathematics curriculum materials in large-scale urban reform. In J. T. Remillard, B. A. Herbel-Eisenmann, & G. M. Gwendolyn (Eds.), *Mathematics teachers at work* (pp. 37-55). Hoboken, NJ: Taylor and Francis.

Stigler, J. W., & Hiebert, J. (1999). *The teaching gap: Best ideas from the world's best teachers for improving education in the classroom.* New York, NY: The Free Press.

Streefland, L. (Ed.). (1991). *Realistic Mathematics Education in primary school: On the occasion of the opening of the Freudenthal Institute.* Utrecht, The Netherlands: Technipress.

Tatto, M. T., Schwille, J., Senk, S., Ingvarson, L., Peck, R. & Rowley, G. (2008). *Teacher Education and Development Study in Mathematics (TEDS-M): Policy, practice and readiness to teach primary and secondary mathematics. Conceptual framework.* East Lansing, MI: Teacher Education and Development International Study Centre, College of Education, Michigan State University.