Learning to Notice: One Aspect of Teachers' Content Knowledge in the Numeracy Classroom

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Current mathematics education reform efforts require teachers to learn in the act of teaching. At the forefront of this challenge are questions concerning the content knowledge that teachers bring to their work and how this might develop. In order to characterise how content knowledge is managed to meet the demands of reform, we investigated the processes through which teachers constructed, enacted, and negotiated knowledge within their classrooms. In this paper we report on one aspect of the teachers' experiences, namely 'learning to notice' critical mathematical instances during classroom interactions.

Current mathematics education reform efforts require teachers to *learn in the act of teaching.* Central to those reforms is an awareness of the critical role of the teacher in changing the traditional ways in which mathematics has been taught and learned in schools (Even, Tirosh & Markovitis, 1997). In the 'new' mathematics environment students encounter, develop, and use mathematical ideas and skills in the context of genuine problems and situations. The teacher's role is to choose appropriate ways to represent subject matter, ask questions, suggest activities and develop discussions.

Deficit thinking about teachers' knowledge that has underscored research on teaching has changed to building on what teachers already know. Research is now beginning to probe how teachers question, revise and refine, test their content knowledge and extend their knowledge to "more powerful forms of classroom teaching" (Doerr & Lesh, 2002, p. 130). The provision of new-activity based contexts for student learning is now understood to be insufficient for reform to occur. This is because activity-based instruction can be devoid of meaning unless the teacher is capable of providing students with appropriate challenges and helping them bring meaning out of the activity. For this to happen what is needed are opportunities for "teachers engaging with the knowledge and considering the implications for their instruction" (Rhine, 1998, p.27).

The Numeracy Development Project provided those opportunities within the current reform in New Zealand mathematics classrooms. In 1997, the Mathematics and Science Task Force group had called for an initiative to improve teachers' professional skills, knowledge, and confidence (Ministry of Education, 1997). The resulting professional development project, the Numeracy Development Project (Ministry of Education, 2001), acknowledged that:

> teacher's understanding of subject matter and of pedagogy are critical factors in mathematics teaching. The effective teacher has a thorough understanding of the subject matter to be taught, comprehends how students are likely to learn, and knows difficulties and misunderstandings they are likely to encounter. (p. 2)

Sherin (2002) provides a conceptual framework for understanding what effective teachers actually do in the process of change. In Sherin's formulation *learning in the act of teaching* occurs as teachers negotiate among "three areas of their content knowledge: their understanding of the subject matter, view of curriculum materials, and knowledge of student learning" (p. 119). Effective teachers draw on a wealth of established routines for

thinking about and teaching particular subject matter. But rather than just using these familiar practices, effective teachers apply their knowledge flexibly (Hattie, 2002). Specifically, they adapt and modify these familiar practices and in turn, these practices initiate the development of new pedagogical routines and new understandings of the domain. Sherin (2002) refers to these *content knowledge complexes* as "pieces of subject matter knowledge and pedagogical content knowledge that are accessed together repeatedly during instruction [and] become connected" (p.124).

Three classes of interactions of teachers' content knowledge were identified by Sherin (2002) when implementing reform. In a more limited approach the teacher *transforms* the reform into his or her own more traditional approach. Routines familiar to the teacher are retained and the delivery of the lesson takes on quite a different form than that anticipated by the curriculum reform developer. Teachers who transform the reform practices make use of new resources in a limited way, and only insofar as those resources match their own beliefs and familiar practices.

In the second case teachers *adapt*; they develop new content knowledge and implement the lesson as planned. These teachers change their beliefs and learn new ways of doing things but in a limited capacity. It is often a "novel student idea that prompts teachers to reflect on and rethink their instruction" (Schifter, 1996, p.130). Whilst those novel student ideas may initiate teacher questioning and probing, at the same time they do not contribute to a changed focus or an altered lesson pathway. The challenge to teacher content knowledge does not substantially change practice.

In the third case teachers *negotiate*. Not only do they develop new content knowledge but at the same time they make changes in a lesson as it unfolds in the classroom. This change can be described as a cyclic process, in which teachers' understanding of the subject matter, their perception of the reform, and their views on student learning, all play a critical part. New content knowledge develops as teachers skilfully negotiate amongst these factors.

It is our contention that support and encouragement for teachers in this difficult process of redefining their teaching practice can be provided through the development of a community of learners (Dufour, 2004; Sherin & Yan, 2004). Within the community, teachers learn to think in new ways, by engaging in and reflecting on, new kinds of mathematical teaching experiences. Teachers develop an attitude of enquiry towards their teaching and an increased awareness of the learning potential while involved in a community (Shulman & Shulman, 2004). A "critical colleagueship" develops within an atmosphere where "members trust each other but at the same time participate in a professional discourse that includes and does not avoid critique" (Wilson & Berne, 1999, p. 195).

Description of Study

We report on the first year of a two year study on Teacher Knowledge. It is one of four research 'nests' situated within a larger project, *Numeracy Practices and Change*. The objective in this initial year was the development of a small scale supportive community of learners that includes teachers, facilitators, and researchers. It is envisaged that in the second year more in-depth investigation with the teachers will take place.

In this first year we focused on questions concerning the content knowledge that teachers bring to their teaching. We explored how this content knowledge might develop if teachers are to manage the more complex demands of reform. Sherin (2002) has argued

that a key characteristic in promoting changes in content knowledge complexes is the development of classroom noticing. We want to investigate how, as a result of their own listening and questioning, teachers began to notice changes in their teaching behaviours. We looked at how they transformed, adapted and negotiated within the context of their own mathematics teaching. We asked:

- Did teachers learn to notice? If so,
- How did they learn to notice?
- What did teachers learn to notice?
- Did 'learning to notice' have any affect on the teachers' development of content knowledge complexes?

Design research was used in hope of disentangling teachers learning to notice from the complexity of mathematics teaching (Doerr & Lesh, 2003; Wood & Berry, 2003). We were mindful of two characteristics of the design experiment; firstly, the deliberate intention of an improved process or product. We sought indicators, based on Sherin's (2002) framework of interactions, of teachers learning to notice and noted how this evolved over time and across settings. The second important characteristic of the design experiment was the multiple cycles of analysis. We were able to engineer our particular focus on teachers' learning to notice and systematically study this form of learning. This approach allowed us to provide support for teachers within the learning context through the cyclic nature of the meetings (Cobb, Confrey, diSessa, Lehrer & Schauble, 2003).

A supportive and encouraging community of learners was critical to teachers' management of the reform (Wilson & Berne, 1999). Key to the success of developing a community was the initial building of trust. This was slowly built up as the eight teachers from three primary schools attended eight meetings, either half or full day, over a period of eight months. At each meeting teachers discussed and trialled rich tasks and problems which challenged their content knowledge complexes. Rich tasks were subsequently trialled (and videoed) in the teachers' classrooms. Care was taken by the researchers in designing the tasks as teachers taught across a range of class levels and, consequently, catering for a range of student ability levels within the task provided was a challenge (Doerr & Lesh, 2003). The tasks needed to promote a change in teaching approach; they needed to encourage the teacher to negotiate during the teaching episode and to reveal the students and teachers current way of thinking.

Each meeting focussed on a number topic, for example; place value, fractions, ratios and proportional reasoning. Questioning techniques were modelled, trialled and discussed within the problems and rich tasks. The cycle continued as teachers then trialled some of these rich tasks/problems back in their own classrooms, reflected on the outcomes and then discussed this at the subsequent meeting.

Extensive use was made of teaching video footage both supplied by the researchers and from the teachers' own classroom episodes. Whilst viewing video footage, teachers were encouraged to notice significant mathematical instances. Focus was on the ideas children raised and how the teacher responded; what this indicated about the students and the teacher's maths understanding, the subject content involved, student and teacher responses and possible teaching pathways (Sherin, 2000; 2001). Reflective prompts in supporting teachers as they learned to notice were used. These prompts included: What is important? Can I understand what is happening here? What is this a case of? (Sherin & van Es, 2003).

Our data collection began early and continued through each successive meeting with the teachers. Data sources included:

- Audio taping of discussions at the meetings,
- Teachers' journal entries of significant mathematical moments between meetings,
- Videos of classroom episodes as provided by the teachers and the researchers,
- Researchers' field notes,
- Group discussion following a written questionnaire, and
- Taped individual interviews at the completion of the research.

The researchers' field notes initially provided instances of teachers learning to notice. Relevant excerpts from audiotapes of the meeting were transcribed and collated; these were cross-referenced into teacher profiles and within the framework of interactions. Often these audiotapes included discussion from the video watching as teachers became more acutely aware in their noticing. At the end of the research period teachers' journals, individual interviews and final group discussion were analysed for anecdotes of noticing experiences and comments regarding changes in teaching approaches.

Results and Discussion

A snap shot of cases described here is provided to highlight the changes in the ability of our eight teachers in noticing. At the beginning of the year the teachers tended to focus on children's behaviour and procedural maths when viewing videos both supplied by us and their own teaching episodes. As the year progressed teachers became more aware of the significant mathematical moments as evidenced in their teaching videos and when reviewing the videos of others. This is illustrated by a comment from Mike:

> Having a look at the video and seeing how much talking I'm actually doing. I'm definitely learning from watching myself in action. I used to think this was a great lesson the kids are getting the things out of it, but then when you just mention that now…hell, you know, I did jump in a bit too much. I needed to shut up and let the kids do the talking, they would have learnt a lot more instead of saying YES YES YES and me thinking I've done a good lesson. And what had they learned? I hadn't even asked them! And didn't even talk about them.

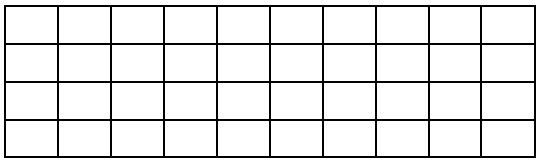
Learning to notice was suggested as a key teaching characteristic in promoting changes in content knowledge complexes (Sherin, 2002). As a result of their own listening and questioning, teachers began to notice changes in their teaching behaviours as they transformed, adapted and negotiated within the context of their own mathematics teaching.

Responses from the initial interview provided an insight into the degree of change brought about by the earlier numeracy reform for one teacher. Joe appeared to be very much transforming new materials into his existing practices. When asked to describe his maths teaching at the beginning of the year Joe responded:

> The last two years that I have been teaching I was fortunate enough to go through the Numeracy Project so that gave me a grounding on the Numeracy Project. I was using Numeracy in the classroom and the numeracy way of teaching but at the start of the year I guess I was using a balance of pulling out stuff from the numeracy project and using it in conjunction with what had been done previously.

Throughout the research teachers varied greatly in their ability to notice. This was often dependent on the demands made on their content knowledge. At one of the meetings teachers solved the following problem (Fig. 1);

Shade 6 of the small squares in the rectangle shown below.



Using the diagram, explain how to determine each of the following:

Figure 1. the percent of area that is shaded

Figure 1. the decimal part of area that is shaded

Figure 1. the fractional part of area that is shaded.

Figure 1. Problem for teachers. (Stein, Schwan-Smith, Henningsen & Silver, 2000, p.13.)

Teachers discussed how they solved the problem; some were surprised that they were able to solve it proportionally while Mary and Mike, who were considered by the group to be the better mathematicians, struggled and found they had to solve C, then use the algorithm to solve B, and then use this to answer A.

Mary videoed herself working with a group of students to solve the problem and shared it at the next meeting. One student solved it easily thinking proportionally while two struggled to apply a formulae. Mary, in the video, used proportional reasoning as a teaching point; she negotiated with the students, building on their current knowledge to develop further understanding. However she admitted to being unsure of where she should have taken the children to next. Mary accessed her current content knowledge complexes and was able to modify them but her lack of deep subject knowledge meant that she was unable to fully negotiate a change in her content knowledge complexes.

Continuing with this episode when Mike was viewing the video he recognised a novel idea offered by a student but suggested the next stage of the teaching episode would be to teach the children how to apply the formulae. Mike, when accessing his current content knowledge complexes, did not see the need to change his traditional method of teaching proportional thinking. His content knowledge complexes were challenged but not altered.

Another noticeable change was the teachers' awareness of the types of questions they asked. Teachers were noticing changes in their teaching as they implemented their lessons. They were beginning to ask fewer directive questions. When Joe was asked to clarify a comment he made about "better questions" his response was:

> Because in a lot of ways, my questioning was directly leading the student to the right answer. I was in some ways influencing their answer and it wasn't giving them a chance to think about the … Asking better questions and more open-ended questions. So why did you think that? What made you think that? Why are you doing that? How are you doing that? How do you know that's right? Does anyone else see that, can you explain it again so everyone else can see what you're doing?

As Davis (1997) and Stein (2001) highlight, asking just these types of questions does not ensure teachers are truly scaffolding the learning of their students. Although the open-ended questions were an important shift for Joe, for him to be truly involved in a cycle of negotiation, he needed to be aware of how best to follow-up the students' response and hence how to make significant changes in the direction of the lesson. This involved, for Joe, both in-depth subject knowledge and pedagogical content knowledge.

Linked closely to this change in questioning was the change in *wait time*. The teachers noticed when reflecting on their maths teaching an increase in the time they waited for a student to respond. As they became more confident questioners, teachers became more comfortable with allowing the students more time to think about and formulate their responses. Joe responded:

> Pause time, giving kids time to answer the questions. Cause I'm noticing a lot more what they are doing with hands, and don't just give them the answer to push them along. It is often important for the groups learning to actually stop and listen and give them time to figure it out and talk about what they are doing.

Joe acknowledges the importance of student thinking and the importance of allowing wait time for them to develop and articulate their thinking. However he did not demonstrate an awareness that his own lesson might need to change course in situ.

All teachers volunteered that their planning had to change. Teachers became more adaptable in their teaching and no longer needed to adhere strictly to formal planning and lesson delivery of the past. This recognition illustrates a progression towards a more adaptable approach to teaching, with teachers allowing themselves scope to negotiate, rather than transform new material into an existing teaching approach. Mike comments:

> I won't plan the whole week now. I'll just plan today, and I will have an outline of what we will focus on for the week, but I'll just plan a day and then after we've done that I'll look at what we'll do the next day …I still actually use the Numeracy Books, more as guidance now, where as before I was using them more like a programme. We have a lot more problems and use that as a guide, what things can I do with different groups.

However all teachers expressed an uncertainty from not knowing 'where to next?' To negotiate successfully teachers need to demonstrate a significant change in the direction of the lesson (Sherin, 2002). This uncertainty of 'where to next?' indicates that perhaps very few of the teachers in the study were fully negotiating their way through this mathematical reform.

> It is probably my skill of knowing "where to next?" They will come up with something and I will think that isn't in my lesson plan, but where shall we take that next? Kind of thing. Because it is not prescriptive as such, being aware and conscious of what questions I am going to ask, and if they come up with something else what am I going to do after that? Especially if they go out on a tangent, it is quite good learning to go on that tangent. Also, where are we going to go to next if we have learned that key concept we might learn it in a different way or use different numbers and I am thinking what are we going to do after that? [Rachel]

Rachel's concern indicated a possible lack of depth in her content knowledge, both subject knowledge and pedagogical content knowledge. She was conscious that the teaching pathway for her was not apparent. Yet she had made great strides in that pathway by learning to notice in the classroom.

Joe summed the change in learning to notice of the teachers when he said:

> Something that I've learned this year is that you can let the children guide a lot of the learning, it's OK to stop and smell the roses a little bit. If something comes up, that's a great little teaching moment – go for it – grab it – even if it goes off on a tangent somewhere, rather than having to just stick to the book- close the book – someone's brought up that idea so let's talk about that.

Summary

If teachers are going to provide students with appropriate mathematical challenges and assist the students to gain meaning, they need to be able to access their own content

knowledge whilst engaged in the act of teaching. It is crucial teachers are able to notice the significant mathematical moments and respond appropriately. As the teachers involved in this research learnt to notice it became clear that this impacted on other aspects of their mathematics teaching. All commented on how their questioning had become more open-ended and how this in turn affected their planning. Teachers changed their planning to highlight the major concepts to be developed. It also gave them the confidence to be more flexible and cater for student ideas. During teaching, the teachers allowed students more time to think and whilst involved in this wait time, they were actively watching the students to gain clues into their thinking and understanding.

Sherin suggests that "emphasis on understanding the ideas that students offer is one of the hallmarks of mathematics education reform" (2001, p. 84). Teachers need to adapt to ideas the students raise in class and therefore must listen to those ideas, access their content knowledge complexes to decide how best to proceed. In this process they will consider their own mathematical understanding and their knowledge of the students' learning. If their understanding is insufficient they will be unable to complete the cycle of negotiation that will allow changes to their content knowledge. In this research teachers indicated how the lack of depth in their content knowledge complexes impacted both on their ability to notice and knowing 'where to next'. The investigation set the scene for a deeper probe of teachers' content knowledge surrounding reform practices.

Acknowledgement. The authors wish to acknowledge that this project was funded through the New Zealand Ministry of Education's *Teaching and Learning Research Initiative (TLRI).*

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