

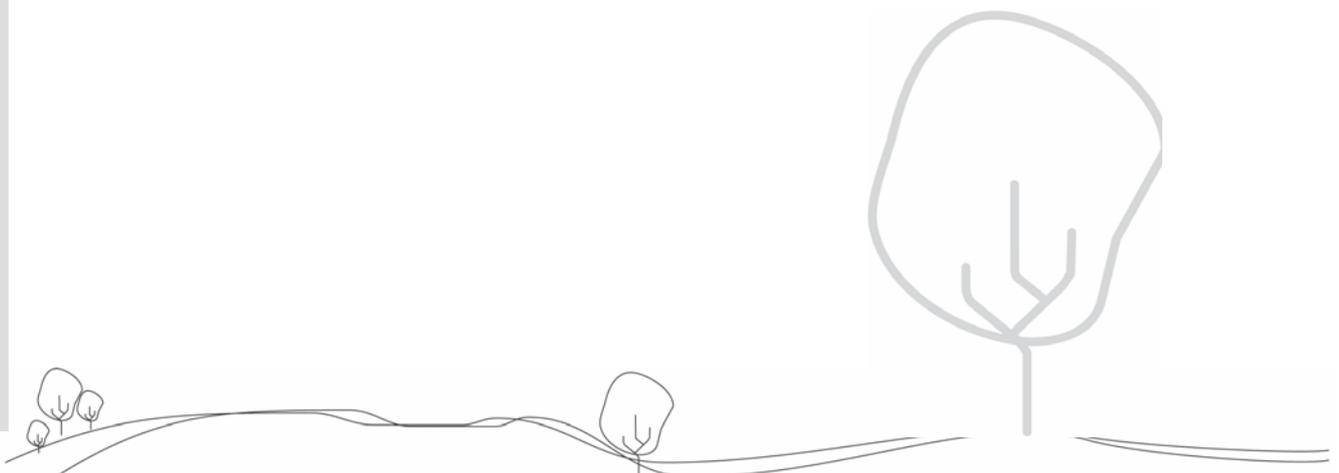


Teachers developing as researchers: Teachers investigate their use of questions in mathematics

**Linda Bonne and Ruth Pritchard
with
Shane Gault, Vanessa Hendry, Paulette Holland, Gillian Kissling,
Susan Kliffen, Mark Kyne, Catherine Miller, and Jan Treeby**

Redwood School and Victoria University of Wellington College of Education

2007



Teaching and Learning Research Initiative

P O Box 3237

Wellington

New Zealand

www.tlri.org.nz

© Crown, 2007



Acknowledgements

This research was funded by the Teaching and Learning Research Initiative at the New Zealand Council for Educational Research (NZCER). We would like to thank the NZCER for the opportunity to do this research. In particular, we have been very appreciative of the interest shown by Robyn Baker (Director) and of the practical support given by Christina Smits (TLRI co-ordinator).

This project was reliant on our team of teacher researchers working collaboratively with us and with each other. We are grateful to them for their professional approach throughout the project and to their schools for supporting their participation.

We thank Dr Joanna Higgins, our research consultant, for continually challenging our thinking about the project's directions, and for supporting our development as researchers.

Both Redwood School and Victoria University of Wellington College of Education have supported us in our leadership of this research project. Having access to the university's considerable resources proved invaluable.

Dedication

This document is dedicated to the late Dr Don Miller who worked with considerable energy and good humour to help us in the proposal stage of this project.

Table of Contents

Acknowledgements	i
Dedication	i
1. Introduction	1
Report structure	1
2. Literature review	3
Teachers developing as researchers	3
<i>The nature of teacher research</i>	3
How teachers use questions to guide students' learning in mathematics	4
<i>The role of questioning in a social constructivist classroom</i>	4
<i>Research into questioning</i>	6
<i>Methods of research into questioning</i>	8
3. Research methodology	11
Aims, objectives, and research questions	11
Research design	12
<i>Selecting teacher researchers</i>	13
<i>Establishing the research team</i>	13
<i>Gathering the data</i>	14
<i>Data gathering process</i>	15
<i>Analysing the data</i>	16
<i>Interpreting findings</i>	17
<i>The report writing process</i>	18
Limitations of the research process	18
Ethical considerations	19
4. Findings: Teachers developing as researchers	21
Ownership of the research and roles of the research team	21
Changes to the methodology	24
Developing community and accessing support	27
Links to practice	30
Changing views of research	33
Further research questions	34

5. Findings: Teachers' use of questions in mathematics	37
Identifying the various kinds of questions teachers use in mathematics	37
<i>Definition of a question</i>	37
<i>Development of question categories</i>	37
<i>Open and closed questions</i>	40
<i>Questions in context</i>	41
<i>The effect of categorisation on teacher practice</i>	42
Explicating teachers' thinking about the use of questioning during lessons	43
<i>Formulating and presenting questions</i>	43
<i>Consideration of students' needs</i>	44
<i>Planning and adapting questions</i>	46
Describing patterns of teachers' questioning within mathematics lessons	48
<i>The number of questions in whole class and group teaching</i>	48
<i>The shape of questioning within a lesson</i>	51
<i>Relationships between question categories</i>	52
Identifying barriers which inhibit the use of questioning	53
<i>Teacher and student-related barriers</i>	53
<i>Environment-related barriers</i>	55
Examining conditions which support effective use of questioning	55
6. Conclusions	57
Implications	59
Dissemination of research findings	59
References	61

Tables

Table 1	Chronological list of project data sources	14
Table 2	The development of question category labels during the research project	40

Figures

Figure 1	Teacher researchers' responses to Question 7 from final questionnaire (see Appendix E)	23
Figure 2	Teacher researchers' responses from "Working as a teacher researcher" questionnaire	29
Figure 3	Total number of questions in a lesson—Cycle 2	48
Figure 4	Questions asked of lower and higher strategy stage groups, by number of questions	50

Appendices

Appendix A:	Classroom questioning by teachers	65
Appendix B:	Questions and issues arising from the analysis of transcript one	67
Appendix C:	Questionnaire: What are my beliefs about teaching and learning?	69
Appendix D:	Working as a teacher researcher	71
Appendix E:	Reflecting on your Involvement in our Research Project	73

1. Introduction

In this research project, a group of teachers developed their research capability through their investigation of the use of questioning to facilitate students' learning in mathematics. Eight teacher researchers worked in partnership with two research team leaders to analyse their own practice in order to identify aspects of questioning behaviour. During this one-year project, the teacher researchers had significant input into the shape and direction of the research. It was intended that this research project would build understanding by adding the teachers' perspectives of the strengths and weaknesses of current pedagogical practice to the existing body of research.

The project was closely aligned with the following principles of the Teaching and Learning Research Initiative (TLRI):

- Principle 1: Strategic relevance
- Principle 2: Research relevance
- Principle 6: Partnership between researchers and practitioners

The project was conducted over the 2006 school year, in five primary schools in the Wellington area.

Report structure

Section 2 is a review of the literature. This includes a summary of the literature relating to teachers as researchers, then the literature relating to the use of questioning.

Section 3 details the research questions and the methodologies used to collect and analyse data.

Sections 4 and 5 present the project findings. These are divided into two overarching strands: findings related to teachers as researchers, and findings related to teaching and learning.

The conclusions and implications of the research are discussed in the final section.

Where appropriate, sections of this report have been written in a style that is intended to convey the parallel research activity of the teacher researchers and the research team leaders, as well as reflecting the notion of partnership that was central to the project; the "voices" of the teacher researchers and the research team leaders were equally significant to this research, so are presented side by side.

2. Literature review

Teachers developing as researchers

The nature of teacher research

Until relatively recently, there have been “prevailing concepts of the teacher as technician, consumer, receiver, transmitter, and implementer of other people’s knowledge” (Cochran-Smith & Lytle, 1999, p. 16). The creation of a knowledge base for teaching has been largely perceived as belonging in the domain of the universities’ academic researchers. This view is perpetuated by the way in which “some consider the kind of knowledge that teacher research produces to be inferior to, and less valuable than, other kinds of academic work” (Roulston, Legette, DeLoach, & Buckhalter Pitman, 2005, p. 182).

Carr and Kemmis (1986) suggest that most teachers regard research “as an esoteric activity having little to do with their practical concerns” (p. 8). Gould (2005) identified the need to reduce the “gap” that exists between research and practice in classrooms. This gap is described by Cochran-Smith and Lytle (1990):

What is missing from the knowledge base for teaching, therefore, are the voices of the teachers themselves, the questions teachers ask, the ways teachers use writing and intentional talk in their work lives, and the interpretive frames teachers use to understand and improve their own classroom practice. (p. 2)

In response to this, they advocate approaches which encourage teachers to research their own practice. Teacher research is defined as “a systematic and intentional inquiry carried out by teachers” which represents a “significant way of knowing” about teaching (Cochran-Smith & Lytle, 1993, p. 43). This means that traditional views about the relationships of knowledge and practice and the roles of teachers in educational change are challenged, “blurring the boundaries between teachers and researchers, knowers and doers, and experts and novices” (Cochran-Smith & Lytle, 1999, p. 22). Teachers can be mentored to become researchers within the context they know best, by researchers who can offer advice and support in methodologies and interpretative frameworks. Such approaches can produce opportunities for a “hybrid discourse” between practitioners and university researchers based on “democratic research relationships” (Paugh, 2004) that result in increased learning for both partners, and substantial contributions to the knowledge base of teaching.

By participating more significantly in research, teachers are able to offer fresh insights in this field, as well as develop their own skills as researchers which are more likely to have an effect on their practice: “Experienced teacher-researchers become the high risk-takers we need to develop innovative practice” (Mitchell, 2002, p. 253). This may, in turn, encourage other teachers to more closely examine their own pedagogical practice: “Teachers may be influenced to change their practices more readily by reading reports of research by other teachers ... rather than university researchers” (van Zee, 1998, p. 792). Dissemination of such research findings, however, can be problematic. In their investigation of the ways such research had had an effect on schools, Berger, Boles, and Troen (2004) found it difficult to find schools where teacher research was making a difference to the teaching and learning culture of an entire school. They established a number of paradoxes which exist within schools which inhibit the effective undertaking and application of teacher research. Other difficulties with teacher research are discussed by a variety of writers: issues of power and ownership (Cochran-Smith & Lytle, 1999; Paugh, 2004), access to resources, isolation (Mitchell, 2002), and possibilities for manipulation and exploitation (Cochran-Smith & Lytle, 1993).

In New Zealand, teacher research is being encouraged by initiatives such as the Teaching and Learning Research Initiative (TLRI), which aims to foster partnerships between practitioners and researchers. Oliver’s (2005) research confirms the positive effect of the TLRI on teacher-researcher partnerships. A practical guide published by researchers Robinson and Lai (2006) to support teachers to do research in the context of their classroom also helps bridge the gap between research and practice.

How teachers use questions to guide students’ learning in mathematics

The role of questioning in a social constructivist classroom

The benefits of social constructivist approaches to teaching have been well-documented (Brooks & Brooks, 1993; Cobb, 1994; Windschitl, 1999). In a social constructivist environment, the teacher’s role is seen not so much as a “traditional” role of transmitting knowledge or providing information on a certain topic, but one in which the teacher orchestrates the environment and provides opportunities for students to create meaning through active and relevant experiences. Power and interactive relationships are continually renegotiated as students become active partners in the learning process.

The New Zealand Curriculum, Draft for Consultation 2006 says that “Learning is inseparable from its social and cultural context” (Ministry of Education, 2006b, p. 24). This statement indicates a social-cultural constructivist underpinning. In New Zealand, a growing number of teachers are exploring aspects of constructivist teaching within their classroom practice. Professional development initiatives and curriculum documents encourage teachers to embed such

approaches as: considering students' background knowledge and experiences; situating learning in "authentic" contexts; engaging students in learning conversations with peers; and encouraging them to strive for deeper understanding of core ideas. The constructivist origins of the *Mathematics in the New Zealand Curriculum* document (Ministry of Education, 1992), and the anticipated role of the teacher are shown in statements such as this:

As new experiences cause students to refine their existing knowledge and ideas, so they construct new knowledge. The extent to which teachers are able to facilitate this process significantly affects how well students learn. It is important that students are given explicit opportunities to relate their new learning to knowledge and skills which they have developed in the past. Factors such as out-of-school experience and language have profound effects on the way students learn mathematics. (Ministry of Education, 1992, p. 12)

However, much of the discussion about what constructivist teaching involves has been defined through drawing contrasts between this and "traditional" approaches to instruction. This is evidenced in perceptions of the teacher's role: in a social constructivist context, the teacher's role is talked about as questioning rather than telling, which is attributed to traditional, transmission approaches. Brooks (1990) describes the teacher's role in this way: "... it is the teacher's job to help students negotiate the frictions that inevitably arise in settings that provoke them to challenge ideas" (p. 70). In a social constructivist classroom, students' misunderstandings are recognised by the teacher, made explicit, and worked on, whereas a teacher with a transmission orientation is likely to see students' misunderstandings as the result of failure to grasp what was being taught and seek to remedy this by reinforcing the "correct" method (Askew, Brown, Rhodes, Wiliam, & Johnson, 1997; Brooks, 1990).

Exactly what constructivist teaching looks like in the classroom and how the teacher's instructional strategies should be modified, is essentially unclear and idealised. Windschitl (1999) notes that superior pedagogical skills are required by teachers in a constructivist classroom and describes the difficulty of the task:

Crafting instruction based on constructivism is not as easy as it seems. Educators struggle with how specific instructional techniques ... fit into the constructivist model of instruction". (p. 753)

McClain and Cobb (2001) described certain socio-mathematical norms that reflect and enhance constructivist approaches to learning in mathematics classrooms. These norms include such expectations as students explaining and justifying their reasoning and their attempts to explain being valued, and students listening to and attempting to understand others' explanations.

Social constructivist approaches to the development of mathematical thinking view the learner as actively engaged in building mathematical thinking within their social context (Carpenter, Fennema, & Franke, 1996; Stigler & Hiebert, 1998; Windschitl, 1999). Discourse is an important aspect of mathematics classrooms which fosters student enquiry and explanation of solution methods (Cobb, 1994; McClain & Cobb, 2001) and the teacher's role is defined by ways in which the teacher initiates, guides, and intervenes in this process. The use of questioning is a key

strategy in providing such guidance; it establishes a means by which learners can make links to prior knowledge, develop their thinking, and explore new possibilities.

Boghossian (2006) describes the tension that exists between constructivist ideas and the “Socratic pedagogy”.¹ There is likely to be a similar tension between teacher questioning and constructivist approaches in the classroom as teachers encourage learners to discover and explore established “truths” about subject matter. Myhill and Dunkin’s (2005) research concluded that, despite a national initiative in the United Kingdom that promoted greater interactivity between teacher and students, “teachers use questioning to maintain control and to support their teaching, rather than pupil learning” (p. 415).

How, then, does a social-constructivist approach to teaching in a mathematics classroom have an effect on such fundamental pedagogical practices as questioning?

Research into questioning

Of the many skills that are required for effective teaching and learning, one core skill is questioning. Classroom questions may be implicit or explicit. A question is “a sentence worded or expressed so as to seek information”, or “a problem requiring an answer or solution”, according to the *Concise Oxford Dictionary* (Allen, 1990, p. 980). In the classroom context, questions might be expressed as “Tell me more” or “What comes next in the pattern?”. Teachers spend much of their time asking questions, reportedly one to two every minute (Gall, 1971; Wragg & Brown, 2001). In the classroom, questions and questioning are pervasive (Hyman, 1974).

Several intense reviews of questions and questioning occurred in the 1970s and 1980s. However, the 2001 edition of the *Handbook on Research on Teaching* (Richardson, 2001) gives only two index references: one to higher education and the other to reading comprehension. This receding interest was also reflected in the *Handbook of Research on Teacher Education* (Houston, Haberman, & Sikula, 1990; Sikula, Buttery, & Guyton, 1996) neither of which contains any index entry for questions or questioning.

A comprehensive review by Doenau (1987) portrayed research evidence as inconsistent across each of four main areas of investigations: questioning frequency, relationships between cognitive features of questions and student achievement, relationships between higher order questioning and student achievement, and teacher-training experiments. While Doenau concluded that the research conducted since the 1970s had produced no conclusive evidence about the correlates of effects or questioning frequency, he noted Nuthall and Church’s (1973) findings that “teaching content through a strong reliance on questioning was more effective than teaching it predominantly through information” (cited in Doenau, 1987, p. 410). Recent investigations in this field (Livdahl,

¹ “The presupposition of the Socratic method is that there is a truth of the matter and that that truth can be known through discourse ... or, more specifically, a systematised question and answer process that is directed by the teacher and depends upon student involvement” (Boghossian, 2006, p. 716).

1995; Nathan & Knuth, 2003) have not necessarily treated questioning as an isolated technique, but have incorporated it into research that examines effective teaching practices, or classroom discourse in general.

Links between questioning and learning have been explored by a number of writers in different contexts. Chuska (1995) promotes appropriate teacher models of questioning to assist students in developing their own questions to promote learning, and also aid their metacognitive processes:

Questions are fundamental to teaching because they encompass the three central components for effective teaching; they provide information: they help students connect that knowledge to previous and subsequent learning; and they take students to the highest levels of learning. (Chuska, 1995, p. 7)

Fraivillig, Murphy, and Fuson (1999) highlight the importance of the teacher's role in intervening to advance students' thinking in mathematics. Their framework points to the importance of questions in eliciting, supporting, and extending thinking. In New Zealand, mathematics curriculum documents highlight the role of teachers' questioning in scaffolding students' learning:

“Good” teacher questions expand and extend students' thinking by encouraging them to seek their own solutions to problems. Open questions that stimulate discussion reveal students' thinking to teachers and are useful for diagnosing learning needs. (Ministry of Education, 1997, p. 22)

Many writers suggest that higher level questions produce deeper levels of learning (Gall, 1984; Marzano, Pickering, & Pollock, 2001; Redfield & Rousseau, 1981). A number of studies (Gall, 1984; Perry, VanderStoep, & Yu, 1993; Stigler & Hiebert, 1999; Wragg, 1993) have highlighted the low proportion of “high-level” questions to “low-level” ones when questions are categorised according to taxonomies such as those devised by Bloom (1956). Fraivillig et al. (1999) found that teachers used a higher frequency of supporting strategies when teaching mathematics, but attempts to elicit and extend thinking in students were less frequent. However, the link between higher level questions and deeper learning is tenuous and disputed by researchers such as Dillon (1988) who argues that the supposition that “higher order” questions stimulate higher levels of student thinking has no empirical evidence. Kawanaka and Stigler (1999) found that higher order teacher questions did not necessarily promote higher order responses by students.

Several writers have examined how patterns of questioning develop within the classroom context. Much classroom discourse is thought to be characterised by a pattern of Initiate, Respond/Reply, Evaluation/Feedback (Cazden, 1988; Mehan, 1979) where the teacher initiates, a student responds, then the teacher gives the student evaluative feedback. This pattern places the teacher in a central role and acts to test a student's knowledge, rather than to encourage them to elaborate on their ideas or to extend their thinking. Other patterns described include “funneling and focusing” (Wood, 1998), and the “reflective toss” (van Zee & Minstrell, 1997) which can act to transfer responsibility for learning from the teacher to the learner.

International comparative studies, such as *The Third International Mathematics and Science Study* (TIMSS) (Stigler & Hiebert, 1999), have suggested that cultural differences exist in

pedagogical practices such as questioning. The accumulated research has occurred primarily in three national systems—Australia, England, and the United States—that feature primary school classroom practices that differ in subtle though significant ways from those in New Zealand. A key difference is that for several decades, New Zealand primary classrooms have incorporated effective small group teaching strategies, reflecting a child-centred approach to teaching and learning.

Much of the recent focus in New Zealand education has been on effective pedagogy (Alton-Lee, 2003; Anthony & Walshaw, 2007; Hattie, 2003; Ministry of Education, 2006b). The synthesis of research by Alton-Lee (2003) describes questions and prompts as elements of “quality teaching”, forming an important aspect of pedagogy which supports students’ task engagement (p. 74), and serving to “provide scaffolds to facilitate student learning” (p. ix).

Many professional development initiatives have focused on pedagogical approaches, aligning classroom practices with research findings about teaching and learning. In professional development programmes, such as the New Zealand Numeracy Development Project (Ministry of Education, 2006a), teachers have been encouraged to use questioning to support students’ strategic and higher order thinking. Many teachers participating in such professional development have reported changed pedagogical practices within their mathematics teaching (Higgins, 2002; Irwin, 2003; Thomas & Ward, 2002). Within the context of mathematics teaching and learning in New Zealand, research has explored students’ discussion with their peers (Thomas, 1994). In relation to the New Zealand Numeracy Development Project, patterns of teacher–student interactions have been described (Higgins, 2003), and discourse used in mathematics has been explored (Irwin & Woodward, 2005). What is not known, though, is how the professional development has influenced the kinds of questions teachers are asking, how frequently teachers are asking questions, and the kind of thinking that is informing the process of formulating and selecting questions.

Methods of research into questioning

A number of supporting texts and professional development programmes related to teacher questioning have presented improvement in questioning practices as a technical matter which takes practice: “... good questioning is both a methodology and an art; there are certain rules to follow....” (Ornstein & Lasley, 2000, p. 184). In New Zealand, lists of scaffolding questions to pose at various stages of the problem-solving process are available to teachers on the Ministry of Education’s mathematics website (<http://www.nzmaths.co.nz>). However, it has also been argued that while furnishing teachers with a list of possible questions may give them a starting point, the most effective questions cannot be pre-planned, and must occur in response to a student’s action or idea (Jacobs & Ambrose, 2003). Formulating questions within a lesson is a complex process driven by a range of variables, and analysis of this process requires more than categorising and counting by researchers: “Real insight into questioning needs to take on board contextual factors which are too subtle for the classification systems to handle” (Kerry, 2002, p. 71).

Up until now, categorisations of teachers' questions have predominantly been carried out by researchers who focus on only a selection of the questions asked by teachers during a lesson. Some research has allowed for categorisation of questions by general intention rather than "type" (Morgan & Saxton, 1991), allowing for a focus on the function of a question rather than form (Cazden, 2001). Perry, VanderStoep, and Yu (1993) coded questions about addition and subtraction asked in 311 lessons in Japan, Taiwan, and the United States. They deliberately excluded questions they deemed non-mathematical or questions that were asking for agreement. Vale (2003) devised question categories to accommodate the question types teachers nominated they used most often. The teachers in this study also indicated the type of question they would like to ask more often. Other researchers have observed "expert" teachers and synthesised how questions can be used in mathematics lessons to develop students' thinking (Fraivillig et al., 1999; Jacobs & Ambrose, 2003). In all of these cases, many questions asked in a lesson were excluded from the research.

A limitation of the research to date is the lack of investigations that report teachers' views. A review of comprehensive research syntheses (Houston et al., 1990; Richardson, 2001; Sikula et al., 1996; Wittrock, 1986) did not reveal any studies deeply grounded in teachers' perspectives. Much of the research on teachers' questioning has been synthesised from data gathered by researchers observing in classrooms. The existing knowledge base reflects a "looking from the outside in". A search of the literature located studies that reported teachers' questions and questioning, but few investigations were identified that looked from the "inside out". Walsh and Sattes (2005) identify a mismatch between teachers' perceptions of their questioning practices and the practices observed by researchers. Perhaps this mismatch has occurred because the research has not accurately reflected the complexity of questioning practices from the perspective of the teacher. Little has been documented about the ways in which teachers view the role and formulation of questions, nor how questioning is shaped by contextual factors within a mathematics lesson—in the "reflection-in-action" mode (Schön, 1983). The factors that influence teachers' decision-making processes when framing and selecting questions are also largely unexplored.

3. Research methodology

Aims, objectives, and research questions

The research aim for this project was developed from the research team leaders' shared interest in observed numeracy teaching practice where questions clearly dominated the teacher–student interactions. The principal aim was for a group of teacher researchers to collaborate with the research team leaders to investigate primary teachers' questioning in mathematics to facilitate student learning and achievement.

The project had two strands that were closely interwoven by the involvement of teachers as partners in the research team. One strand focused on building research capability of teachers. The capabilities arose from within the school context by the participation of teachers as full members of the research team (TLRI Principle 6: Partnership between researchers and practitioners). This built upon New Zealand-based research by adding the teacher's voice, of which little has been heard until now (TLRI Principle 2: Research relevance).

Capability building objectives were to:

- create opportunities through which experienced teachers can develop a greater capacity and capability for engaging in and undertaking quality research
- conduct research in the context of schools and classrooms in order to “look from the inside out”
- demonstrate methodological capacities that arise from teachers' existing skills, strategies and thinking, through which the knowledge base of teaching embedded in teachers' everyday work can be made explicit.

Related key questions addressed were:

- What support is needed to enable teachers to research effectively in the context of their classroom?
- How do teachers view their role within a research team?
- How does engaging with the process of research help teachers to improve their teaching practice?
- To what degree do teachers' interpretations of their findings align with current research?
- How does teachers' involvement in research affect their understanding of the relationship between research and practice?

The second strand was focused explicitly on substantive aspects of teachers' views "from the inside out". The project sought to build understanding based on the teachers' perspective of the strengths and weaknesses of current pedagogical practice (TLRI Principle 1: Strategic relevance). It was intended that the outcomes would increase potential for improving student achievement based on teachers' insights into their own teaching practices.

The objectives that focused on teaching and learning were to:

- identify the various kinds of questions teachers use in mathematics
- explicate teachers' thinking about the use of questioning during lessons
- describe patterns of teachers' questioning within mathematics lessons
- identify barriers which inhibit the use of questioning
- examine conditions that support effective use of questioning.

Related key questions addressed were:

- How do teachers categorise questions they ask during a numeracy lesson?
- What were the teachers' purposes behind these questions?
- What informed teachers as they formulated questions during lessons?
- How does the process of devising common question categories within a team impact on teachers' thinking?
- Can the effective use of questioning be defined, and if so, what might this look like?
- What are the factors that support teachers to use questions effectively, and what can hinder this?

Research design

This project drew on methodologies established in the field of action research (Carr & Kemmis, 1986) where researchers aim to improve "their own educational practices, their understandings of these practices, and the situations in which they practice" (p. 180). The teacher researchers were encouraged to act as reflective practitioners (Schön, 1983) and contribute to formulating their own interpretive frames (Cochran-Smith & Lytle, 1990) to make sense of the data gathered. Data-gathering methods were chosen to enable teachers to have maximum control over the process, and were responsive to the direction of the project as it evolved with input from the teacher researchers over the year, reflecting a grounded theory approach, such as that described by Strauss and Corbin (1998).

Over the course of the project, two sets of data were collected. While the teacher researchers gathered the data that were to inform the examination of questioning, the research team leaders collected data relating to the teacher researchers' involvement in the research process. The data gathering methods used to track the teacher researchers' experience of their involvement in the research, and to yield background information about the teacher researchers, were designed as research team leaders identified a need for them.

Selecting teacher researchers

During the formulation of the research proposal, the research team leaders approached teachers with whom they had established professional relationships. These relationships varied in nature; one research team leader had worked with several of the teacher researchers in her role as a numeracy adviser, while the other research team leader and one of the teacher researchers had worked alongside one another as advisers. Each of the teachers had recently participated in a common in-depth professional development programme: the Numeracy Professional Development Projects (Ministry of Education, 2006a). This meant that each had explored common ideas about mathematics education and effective pedagogical practices. From the research team leaders' observations, they believed that the teachers had incorporated many of these ideas into their practice and that their classrooms reflected constructivist principles (Windschitl, 1999). The teachers had also demonstrated a willingness to share and examine their practices.

Each of the eight teachers was keen to participate in the research, and they were all respected members of their teaching communities; several were lead teachers of numeracy in their schools. The teachers taught at a variety of year levels, and were drawn from urban schools in communities with varied socioeconomic backgrounds. The schools ranged from decile 1 to 10;² one teacher researcher was from a decile 1 school, one from a decile 2 school, one from a decile 8 school, and four teacher researchers taught at decile 10 schools. Two of the teachers who had originally agreed to participate in this project withdrew before the project began because of changes in their teaching responsibilities.

Establishing the research team

At the introductory meeting of the research team, the teacher researchers met for the first time. The roles of the teacher researchers, the research team leaders, and the research consultant were clarified. The research aims for the project were shared, and interview questions were composed with the teacher researchers.

The teacher researcher who had undertaken a trial of the research methods described her experience of the data gathering and analysis processes. These processes were discussed by the team, and instructions for the "F-sort" (Miller, Wylie, & Wolfe, 1986) data categorisation method were presented (see Appendix A). This method allowed teachers to freely generate their own categories for their questions, and provided access to the teachers' ideas and language about categories of questions from the outset of the project. The team members then familiarised themselves with the method by carrying out a sorting activity in small groups. The teacher researchers were familiarised with the "notetaker" cassette recorders that they would use to

² "A school's decile indicates the extent to which it draws its students from low socioeconomic communities. Decile 1 schools are the 10% of schools with the highest proportion of students from low socioeconomic communities. Decile 10 schools are the 10% of schools with the lowest proportion of these students. A school's decile does not indicate the overall socioeconomic mix of the school" (Ministry of Education, 2006c).

audiotape their lessons. The proposed timetable for the first cycle of data gathering and analysis was distributed.

Gathering the data

Table 1 shows the data that were gathered during the project by the teacher researchers and the research team leaders. The data collected by the teacher researchers related to their use of questioning; data collected by the research team leaders was to do with the teacher researchers' experience of the research processes, as well as what the teacher researchers were learning by analysing and reflecting on their teaching practices.

Table 1 **Chronological list of project data sources**

School terms	Teacher researchers	Research team leaders
Term 1	Data from the trial: <ul style="list-style-type: none"> annotated lesson transcript, audiotape and videotape of lesson transcript analysis sheet categorised questions 	Data from the trial: <ul style="list-style-type: none"> research team leaders' categorised questions from teacher researcher's transcript annotated lesson transcript interview summary and audiotape
Term 2	<ul style="list-style-type: none"> annotated lesson transcripts, audiotapes & videotapes of lessons transcript analysis sheets "key episodes" details categorised questions graphic representations of questions 	<ul style="list-style-type: none"> interview summaries and audiotapes notes from team meeting teacher researcher questionnaire: "Questions and issues arising from the analysis of transcript 1"
Term 3	<ul style="list-style-type: none"> annotated lesson transcripts, audiotapes & videotapes of lessons transcript analysis sheets categorised questions frequency tables from Lesson 2 	<ul style="list-style-type: none"> interview summaries and audiotapes audiotape of, and notes from, team meeting teacher researcher questionnaire: "Working as a teacher researcher" teacher researcher questionnaire: "What are my beliefs about teaching and learning?" teacher researcher questionnaire: "Features of an ideal maths lesson"
Term 4		<ul style="list-style-type: none"> teacher researcher questionnaire: "What have you learnt about questioning?" final teacher researcher questionnaire: "Reflecting on your involvement in our research project"³ audiotapes of, and notes from, team meetings

³ Some of the questions in the final questionnaire, "Reflecting on your involvement in our research project", were adapted from Oliver (2005).

For the purposes of this report, excerpts from the original proposal and the quarterly milestone reports have been included. Team emails have been referred to, as well as quotations from the research team leaders' ongoing reflection journal.

In this part of the report, the parallel research activity of the teacher researchers and the research team leaders are presented side-by-side. This is intended to reflect the notion of partnership that was central to the project; the “voices” of the teacher researchers and the research team leaders were equally significant to this research. Later in the report, in Section 4, quotations from the research team members will illustrate their perspectives of these processes.

Data gathering process

Teacher researchers	Research team leaders
<p><i>There were two cycles of data gathering for the teacher researchers, each taking five days and occurring in each of the middle two terms of the school year. A timetable was developed for the research team to ensure that the transcribing, analysing, and interviewing components were synchronised for each teacher researcher, and also that the research team leaders interview schedules were manageable. Each teacher researcher was required to record two consecutive lessons, and choose one to analyse. After the second lesson the teacher researcher sent their audiotape to be transcribed; some audiotapes were couriered while others were collected by the research team leaders for delivery to the transcriber.</i></p> <p><i>The transcription was returned to the teacher researcher two mornings later to enable them to analyse their lesson while it was still relatively fresh in their mind. At the end of the second day of analysis, the teacher researcher discussed their findings with one of the research team leaders in a semi-structured, one-to-one interview (Denscombe, 1999).</i></p> <p><i>To enable the teacher researchers to have maximum control over the data-gathering process, each teacher researcher worked independently to set up a video camera which remained in one position throughout the lesson, and placed a “notetaker” cassette recorder with built-in microphone, around their neck. Teacher researchers themselves were responsible for setting up the technology and the recording procedures, and this ensured ownership of the process—no one else was “present” in their classroom. The teacher researchers were</i></p>	<p>Each research team leader held one-to-one interviews with four teacher researchers at the conclusion of their data gathering and analysis. The interviews were audiotaped for later summary by the research team leaders. These summaries were emailed to the originating teacher researcher for their verification. In Cycle 2, each research team leader interviewed the four teacher researchers they had not interviewed in Cycle 1.</p> <p>At the research team meeting at the end of Cycle 1, the teacher researchers were asked to record any questions and issues arising from the analysis of their first transcript. Their responses were to be used to inform the future direction of the project.</p> <p>The research team met again before the second cycle began. At this session, the teacher researchers completed a questionnaire that was intended to make explicit their beliefs about teaching and learning in mathematics (see Appendix C). In relation to this questionnaire, they listed four important features of a mathematics lesson along with why they believed these were important.</p> <p>At the same meeting, the teacher researchers responded to a series of questions aimed at revealing their experience as a teacher researcher up to that point in the project (see Appendix D).</p> <p>The next team meeting was after Cycle 2, and the teacher researchers were asked to identify three things they had learnt about questioning, and to highlight evidence of these in their lesson transcripts, where they could. As a follow-up to this session, the teacher researchers were emailed a final questionnaire (see Appendix E). The research team leaders asked them to write reflective</p>

encouraged to introduce the video camera to the classroom environment prior to the actual recording days, to help reduce the impact of its presence. Only the audio recordings were transcribed and access to these transcripts was restricted to the teacher concerned, the transcriber and the two research team leaders.

Between the two cycles, the research team met to debrief the process and also to amalgamate the teacher researchers' question category labels into some common category headings. The headings were to be further refined after Cycle 2.

responses that could then be included in the final report.

Several team meetings were audiotaped to capture quotations for the final report.

Throughout the project, the research team leaders kept a reflection journal.

Analysing the data

Teacher researchers
<p><i>When the teacher researcher had chosen a lesson for analysis, they recorded their initial impressions about their questioning within the lesson, which they later compared to their analysis.</i></p> <p><i>On receipt of their transcript, each teacher researcher was released for two days to analyse their lesson, using their reading of the transcript alongside their recent recollections of the lesson that were assisted by viewing the videotape footage. They reviewed the lesson, making notes as they read through their transcript. They identified key episodes within the lesson, and examined these in some detail. Key episodes were chosen by the teacher researchers, who were asked to describe why they considered these to be key.</i></p> <p><i>The main analytical activity involved the identification and categorisation of questions within the lesson. This was achieved by physically extracting their identified questions from a hard copy of their transcript, then sorting them into groups of similar questions for which they then devised labels (Miller et al., 1986). The teacher researchers were furnished with instructions for the sorting process (see Appendix A). The second cycle's analysis involved similar activities, except that questions were categorised under commonly agreed headings, and teacher researchers also completed a frequency table based on the categories.</i></p> <p><i>During the afternoon of the second analysis day each teacher researcher was interviewed by a</i></p>

Research team leaders
<p>Overall, the data were analysed using the three main stages of data reduction, data display, and drawing and verifying conclusions (Miles & Huberman, 1994). Most of the data collected were qualitative. The research team leaders used the same sorting process that the teacher researchers had used to identify themes emerging from the two sets of interview summaries; this helped to reduce the collected data to its essence. The reduced data were then displayed to help identify trends.</p> <p>Responses to the various questionnaires were compiled to support the identification of similarities and differences in the responses.</p> <p>Numeric data from the completed frequency tables (showing the number of each category of question included in the teacher researchers' second lessons) were collated and graphed.</p> <p>The quantitative data were considered alongside the qualitative information in order to identify similarities and differences. The research team leaders discussed and debated apparent themes.</p>

research team leader, usually at the teacher researcher's workplace. This interview supported the teacher researcher to reflect on aspects of their findings, and facilitated the communication of the teacher researcher's thinking. Summaries of the interviews were later sent to the teacher researchers for verification, and findings were shared in subsequent group meetings.

Group discussions formed a key aspect of the analysis and interpretation of findings. Each member of the team shared their findings, and similarities and differences were explored and debated. The Cycle 1 group discussion began the process of establishing common categories with which to analyse the lesson in Cycle 2. A further session was held for three teacher researchers to enable further input into this process.



Interpreting findings

Teacher researchers
<p><i>The teacher researchers contributed to the process of interpreting findings at all stages of the project by responding to summaries of emerging ideas presented by the research team leaders.</i></p> <p><i>Group meetings were a key aspect in distilling meaning from findings as they emerged throughout the project. The teacher researchers interpreted their findings in light of current research, which they discussed in a group meeting.</i></p> <p><i>The research consultant also made a presentation to the first meeting in Term 4, and this allowed the teacher researchers to interpret their findings in a broader context.</i></p> <p><i>In relation to the frequency table data, the teacher researchers made a number of suggestions for variations in the number of questions asked.</i></p>

Research team leaders
<p>The research team leaders verified their interpretations of the data with the teacher researchers by feeding speculations back to them at research team meetings for discussion and comment.</p> <p>The research team leaders met following the interviews with the teacher researchers to share and compare findings, and then sorted responses from the interviews, enabling themes to emerge.</p> <p>With a collection of data available from each of the eight teacher researchers, apparent findings were readily triangulated by checking all the data from a single teacher researcher, and by checking across the group. Discussion and debate between the two research team leaders also contributed to the rigour of the processes and the findings. Findings were also discussed at meetings with the research consultant.</p>

The report writing process

Teacher researchers	Research team leaders
<p><i>The eight teacher researchers were unable to be fully involved in writing the final report. Instead, they wrote reflective responses to the final questionnaire, and these responses were used to amplify the teacher researcher's "voice" in later sections of this report.</i></p> <p><i>As well as this, teacher researchers have contributed quotations which have been drawn from a range of sources, including:</i></p> <ul style="list-style-type: none"><i>• interviews with research team leaders</i><i>• research team meetings</i><i>• other teacher researcher questionnaires.</i> <p>At the final team meeting, the teacher researchers were presented with an initial draft of the section on findings from this report for their comment. The teacher researchers received a final draft of the report before publication.</p>	<p>Part-way through the project, the literature review from the proposal was revised for the teacher researchers, to provide them with a background of the research literature.</p> <p>Following the completion of data gathering and analysis, the research team leaders worked intensively for two weeks, spending considerable time discussing, analysing, and reflecting on the collected body of data. It was decided that the style of presentation in the final report would reflect the partnership between the research team leaders and the teacher researchers.</p> <p>The research consultant was asked to give critical feedback on drafts of this report.</p>

Limitations of the research process

Some issues related to the data-gathering tools emerged early in Cycle 1. Using the audio and video technology presented a few minor problems; for example, the notetaker had a facility to record at various speeds which proved unhelpful.

Another issue was the timely delivery of transcripts to the teacher researchers. The timetable was very tight, leaving no margin for the late arrival of transcripts. Some of the teacher researchers commented on the inaccuracy or absence of the students' comments in the transcripts; it had been difficult for the transcriber to decipher parts of some of the audiotapes.

A couple of research team meeting dates had to be changed; in one instance, this was to accommodate a particularly busy time for some of the teacher researchers who were involved in major school events. In a few cases, a teacher researcher was unable to attend a team meeting.

The timing for writing this report coincided with the competing demands of the end of the university and school years, including writing students' end-of-year reports, devising class lists for the following year, and planning for camps. The extended deadline for completion of this report made the task manageable.

Ethical considerations

Informed consent was sought from each of the teacher researchers before their participation in the project. The teacher researchers were provided with a consent letter for parents of students in their class that explained that the students were not the “target” of the research. Principals, as the board of trustees’ representative for each school, signed statements giving their support to the project. The transcriber completed a confidentiality agreement.

During the report writing process it became evident that if the partnership was authentic, and the teacher researchers’ “voice” was to be as strong as it was intended, then the teacher researchers should be acknowledged as co-authors, although the use of pseudonyms throughout the report would be maintained. This entailed an addendum to the original consent form being signed. The principals of participating schools were also asked to give their consent, because by identifying the teacher researchers their schools could readily be identified.

4. Findings: Teachers developing as researchers

Ownership of the research and roles of the research team

An important principle of teacher research is that teachers have a “sense of ownership and control of their research” (Mitchell, 2002, p. 250). Current definitions of teacher research describe the selection and development of research questions as emerging from the teachers’ own practices (Cochran-Smith & Lytle, 1993). Although each of the teacher researchers joined the team with an awareness of the field they were to research, the requirements for the funding for this research had meant that the research questions and aims were established before they met together as a team. The research questions emerged from the research team leaders’ close links to teaching practice, both in their current and recent classroom teaching experience, and in the considerable number of mathematics lessons they had observed as numeracy advisers.

The project methodology was intended to ensure the teacher researchers assumed a sense of ownership of the project through major responsibility for the classroom-based data-gathering and analysis. As the project progressed it became apparent that much of the responsibility for its direction and the interpretation of findings also needed to be shared with the teacher researchers. Assumptions made by the research team leaders about the shape and course of the project were challenged as the teacher researchers took on greater ownership.

The research team leaders’ sense of ownership was strong at the onset of the proposal process as initiators of the research questions and the methodology. This sense of ownership diminished as the proposal progressed and as the three institutions involved established areas of territory and accountability. Ownership was further dispersed as the research team leaders continued to work with the teacher researchers. It became apparent that the research team leaders had begun the project expecting significant but limited input from the teacher researchers rather than an authentic partnership. Thus, to ensure the development of research capabilities of the teacher researchers, and to increase the validity of the findings, it was felt necessary to share the “power”. This was not easily achieved, as teacher researchers demonstrated differences in perceptions of their role and the research team leaders’ role. When asked to describe these roles within the research project, (see Appendix E, final questionnaire, Question 6) a number of common verbs were used in descriptions for both roles: provide, analyse, advise, develop, conclude, reflect and share. However, verbs used exclusively for research team leaders seemed to reflect the perception of research team leaders as project drivers, initiators and interpreters of findings: lead, organise,

drive, generate, co-ordinate, facilitate, assist, support, encourage, interview, synthesise, question, and open. These verbs contrasted with ideas of the teacher researchers as workers and learners: gather, collect, complete, contribute, work, categorise, establish, challenge, debate, help, process, understand, learn, bring, impart, and review. It would seem that the co-researcher relationship “was infiltrated by the discursive positionings more in common in relationships between academics and teachers, or teachers and students” (Honan, 2007, p. 622).

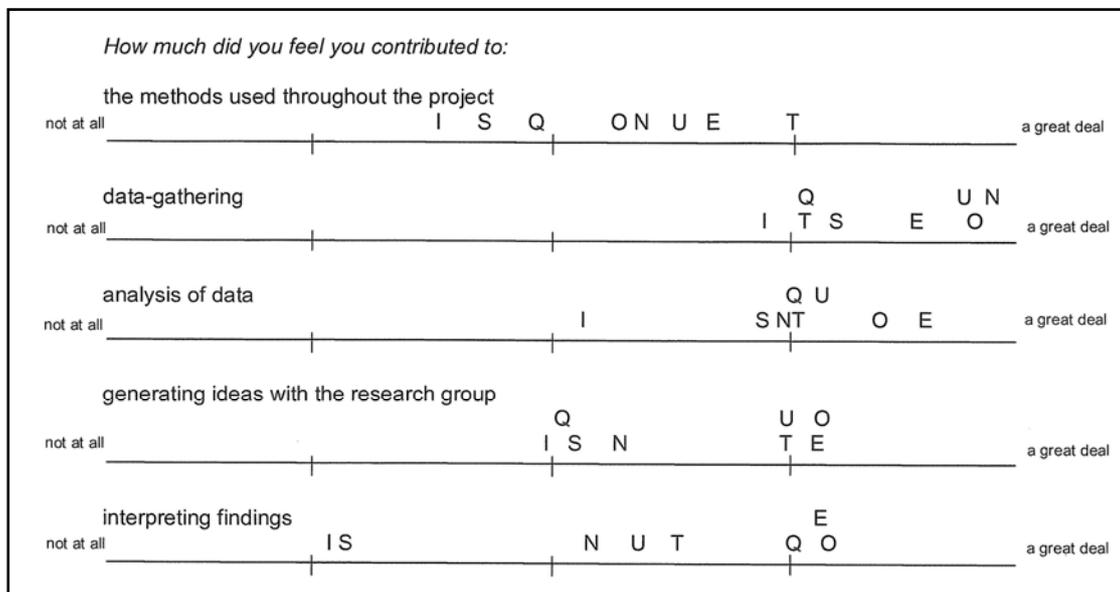
Perceptions of roles were further complicated by the relationships previously established by the research team leaders as mentors and advisers within the context of in-depth professional development. Having previously assisted the teachers to analyse aspects of their mathematics teaching practice, the research team leaders were, to some extent, regarded as “experts” in the field under research. The diversity of perception of roles is apparent in the following quotations and excerpts.

Teacher researchers	Research team leaders
<p><i>Researchers appeared to give direction to the project and confidence that outcomes would be achieved. Researchers have provided the enthusiasm and momentum. Good support in terms of providing readings.</i> Natalie, final questionnaire</p> <p><i>I felt that at times there was a slight lack of direction during the meetings.</i> Truman, final questionnaire</p> <p><i>We did have some partnerships although I think a partnership is a sharing of ideas and a forming of ideas together. In this form the researchers were facilitators but didn't necessarily work on completing the same tasks.</i> Ingrid, final questionnaire</p> <p><i>Leaders provided a great idea and framework. They were always confident about our role in the team, and were enthusiastic and supportive.</i> Ursula, final questionnaire</p>	<p>Part of this tension may have arisen because both of the research team leaders have acted as mentors in the context of mathematics education. Similar relationships exist with other members of the research team. This highlights the importance of clearly communicating to the teacher researchers our different role as co-researchers in this project. <i>Milestone Report 1</i></p> <p>... clarified that my role is as a fellow researcher, not adviser. <i>Research team leader comment from teacher researcher interview 1 summary</i></p>

Figure 1 shows a range of perceptions expressed by the teacher researchers about their contributions to various aspects of the project.

Figure 1 **Teacher researchers' responses to Question 7 from final questionnaire (see Appendix E)**

(letters in the figure refer to the initials of the teacher researcher pseudonyms)



In Cycle 1 of the data gathering and analysis, some of the teacher researchers described difficulty with the initial sorting of questions into categories. At this early stage, the teacher researchers tended to draw on frameworks and language about questioning that were previously known to them. In some cases they struggled to produce efficient descriptors from their own language to label groups of questions.

Had difficulty finding words to describe categories.

Ingrid, interview 1 summary

First time putting the questions into categories felt like you were on your own and didn't have a clear picture of what to do.

Stephanie, final questionnaire

One of the teacher researchers resorted to searching for question categories on the internet and many of the categories developed at this stage reflected the language in established taxonomies.

Perhaps this indicated the teacher researchers' doubt that what they had to say would have validity or authority in the research project. The teacher researchers may have seen the research in traditional terms such as those described by Cochran-Smith and Lytle (1993) as "outside-in", or as research which "constructs and pre-determines teachers' roles in the research process" (p. 7).

Teacher researchers	Research team leaders
<p><i>Sometimes I think we are our hardest critics and this has helped to confirm or not confirm certain ideas I have had.</i></p> <p style="text-align: right;">Quentin, final questionnaire</p> <p><i>We sound more knowledgeable than we thought we were!</i></p> <p style="text-align: right;">Ursula, final evaluation meeting</p>	<p>Much of the research undertaken to investigate teachers' questioning has been synthesised from data gathered by researchers observing in classrooms. There is little known about ways in which teachers view the role and formulation of questions within a mathematics lesson.... The extant knowledge base reflects a "looking from the outside in." Our search of the literature located quite a few studies reporting teachers' questions and questioning, but no investigations were identified that looked from the "inside out."</p> <p style="text-align: right;"><i>TLRI Proposal for funding</i></p>

The process of sorting their questions had meant that the teacher researchers were encouraged to take responsibility for generating language and ideas, and the commonly agreed categories developed in the forum reflected their own language.

During the second cycle of data gathering and analysis, their sorting experience was more positive:

Felt better this time—having some categories to put the questions into, having some understanding of what she was doing, not feeling lost time.

Ingrid, interview 2 summary

The question categories worked—I could place all questions.... Analysis was easier with predetermined headings.

Quentin, interview 1 summary

Changes to the methodology

Aspects of the methodology were continually adjusted to allow the teacher researchers to develop a greater sense of control within the project.

Teacher researchers	Research team leaders
<p><i>The approach was good because it was flexible and allowed the group to have true ownership. The “organic” nature of the form of our meetings allowed researchers to listen without taking over with pre-determined paths.</i></p> <p style="text-align: right;">Erin, final questionnaire</p>	<p>The task of sorting their individual question categories didn’t go as intended. We had planned for the teacher researchers to work in 2 groups.... However ... [one of the teacher researcher’s] suggested they undertake the task as one group. We OKed this as we wanted to be responsive to the group—give them a sense of control over the process....</p> <p style="text-align: right;"><i>Research team leaders’ reflection journal</i></p>

In some respects this flexibility paralleled the way the teacher researchers responded to their students, (see Findings: Questions—planning and adapting questions) changing direction and transferring power within their classroom practice:

One thing I’ve really enjoyed about the research, is that it’s just confirmed for me a lot of good teaching practice.... It’s made me be a little bit more relaxed about letting the children take control.... I like to have clear learning intentions and know where I’m going and how I will know that the children have got there, but maybe I’m thinking I need to be a little bit more relaxed about that, so they can take the lesson where they want it to go a little more.... And I think to have less control you have to be more secure in yourself and you also have to be more secure in yourself to guide—not in a pushy way—but to guide as a good teacher.

Erin, interview 2 summary

It was originally intended that the research team leaders would conduct an analysis of each lesson at the same time as the teacher researchers, reading the transcript and viewing a video of the lesson. Their analysis would then be “compared” with the teacher researcher’s findings. However after the initial trial phase, it was decided that the teacher researchers would be solely in charge of the analysis process. This meant that the teacher researchers’ own observations and views on their lessons were paramount. The trial teacher referred to the interview process following the analysis as a “grilling”, so the subsequent interviews were conducted by only one research team leader, and preparation consisted of familiarisation with the lesson transcript. The interview then served as an aid to reflection, rather than as a comparison of findings.

Teacher researchers	Research team leaders
<p><i>Interviews were a supportive and positive process.</i></p> <p>Stephanie, final questionnaire</p>	<p>Another factor that may have contributed to the tension in the interview was the presence of both research team leaders and the fact that we did not provide the teacher researcher with the interview questions before we met. At a later meeting with [the research consultant], it was agreed that it would be better for the teacher researchers to work as a team, along with the research team leaders, to develop questions to be discussed at the interview. This is more in line with our aim of developing the teacher researchers' research capabilities and sits more comfortably within our project. It was also decided that only one team leader would be present at each interview.</p> <p><i>Milestone report 1</i></p>

Along with the generation of interview questions, other measures were taken to encourage ownership of the project during group forum sessions, such as writing a definition of a question, establishing category labels and defining “effective questioning”. Following each of the interviews, interview summaries were sent to each of the teacher researchers for verification.

An important aspect of developing the teachers' capability as researchers was introduced between the two cycles of data gathering. At the suggestion of the research consultant, relevant research readings were sent to the teacher researchers for discussion at the forthcoming meeting. The themes for these readings were established in response to ideas emerging throughout the interviews and in the second research team meeting, and were also directly indicated by the teacher researchers in their responses to questions and issues arising from the analysis of transcript 1 (Appendix B). An additional day was allocated to discuss these and other relevant themes, to enable the teacher researchers to see their current research in the context of other research in this area. This also allowed them access to language and ideas when examining and discussing their questioning in Cycle 2; for example, the use of the phrases “reflective toss” (van Zee & Minstrell, 1997), “funnelling and focusing” (Wood, 1998), “classroom norms”, and “socio-mathematical norms” (McClain & Cobb, 2001) in subsequent interviews and group forums.

Discussions with two research consultants prompted moves to incorporate the teacher researchers' “voice” more prominently in the writing aspects of the research. The teacher researchers' workloads did not allow for a period of sustained, focused writing; it was decided that a questionnaire would allow them maximum opportunity to review the research outcomes and processes, and contribute reflective and crafted responses which could be incorporated into the report. The style of the written report would also reflect the partnerships developed in the project, making visible the key role the teacher researchers had throughout by anchoring interpretations of findings in their statements. Aligning the research team leaders' contributions, observations, and

interpretations alongside those of the teacher researchers' further reflected this partnership. A well-developed draft of the findings in Sections 4 and 5 were shared with the teacher researchers for their editorial comment at the final evaluation meeting.

Developing community and accessing support

The research team meetings were important in refining the methodology and allowing the research team to discuss and interpret findings. They contributed toward establishing a shared understanding of the research question and a common language to discuss findings, generated common categories for coding questions, and assisted the teacher researchers to establish a common interpretation of findings. These forums also provided the collaborative support necessary for such projects highlighted in Mitchell (2002).

Being away from the school environment and discussing ideas with other teachers was a definite plus. Obtaining other people's perspective on issues surrounding them. Developing relationships with similar people in similar roles [worked well].

Quentin, final questionnaire

Mitchell notes the loneliness of the process often present in such studies which was also identified within our project, as the following quotations show.

Teacher researchers	Research team leaders
<p><i>First time putting the questions into categories [you] felt like you were on your own and didn't have a clear picture of what to do.</i> Stephanie, final questionnaire</p> <p><i>For the first release days I felt isolated and completely lost.</i> Ingrid, final questionnaire</p> <p><i>I was wondering if by doing some of the work in teams might have helped relationships between the teachers to develop. I found it was just my ideas and me.</i> Olivia, final questionnaire</p>	<p>How are we mentoring our teacher researchers as researchers? ... Perhaps we need to formally set up a buddy system, and give the teacher researchers purposes for communicating with each other to break down isolation? <i>Research team leaders' reflection journal</i></p>

At times, interactions at the research team meetings caused concern. The fact that three of the teachers were drawn from one school, and knew each other well, may have affected the group dynamics:

Teacher researchers
<p><i>The main issue when working together would be the dynamic or mix of the group where people had strong views and opinions, and decisions were sometimes dominated and preconceived.</i> Quentin, final questionnaire</p> <p><i>I also felt disadvantaged by not having someone to talk to and felt that three teachers from the same school had an advantage over everyone else.</i> Ingrid, final questionnaire</p> <p><i>Group putting all questions into categories—some too dominant and some not assertive enough! (Hadn't established a sense of the group working together.)</i></p> <p><i>More work [was needed] to establish an environment for all the group to feel comfortable where all ideas would be valued. (This did become better during the project.)</i> Stephanie, final questionnaire</p> <p><i>I know we did share in the wider group, but not everyone felt comfortable doing that.</i> Olivia, final questionnaire</p>

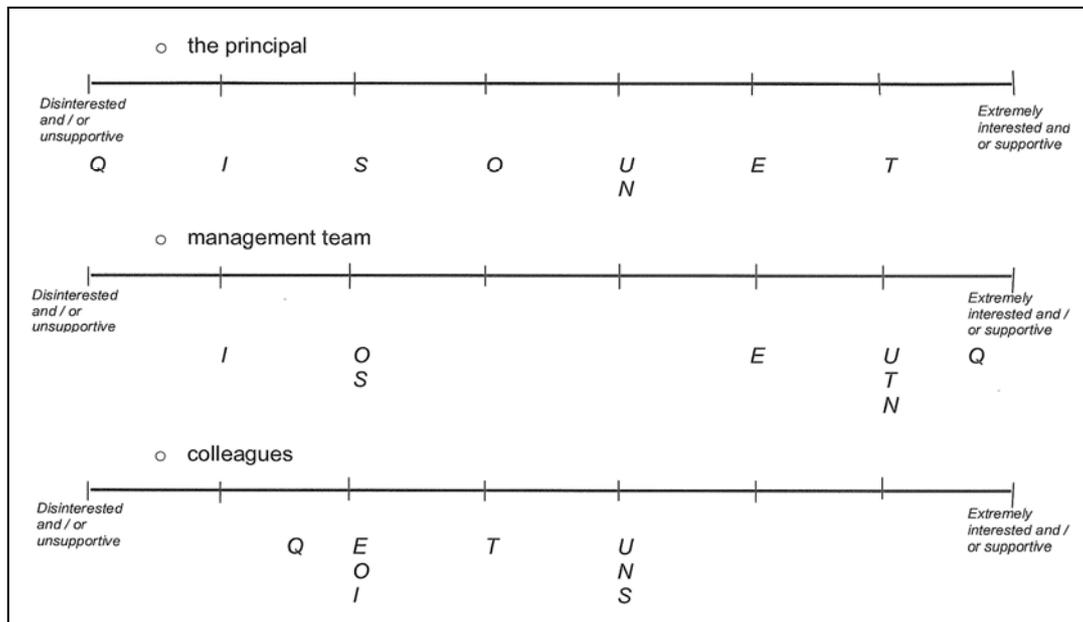
Research team leaders
<p>More significant was an issue that emerged at our second meeting of the research team. In order to develop common question categories, the teacher researchers were asked to each take their own sorted questions, with category labels they had devised, and see how they could group them together where categories were alike. There was a lot of very rich, and at times animated, discussion during this sorting task. However, some of the teacher researchers found a number of difficulties with aspects of this task and remained on the fringe of the activity. The research team leaders have done several things to determine why they did not fully engage with this work. We have:</p> <ul style="list-style-type: none"> • spoken individually with the teacher researchers concerned, to seek their point of view about what was going on during the meeting • met several times since the meeting to discuss the possible underlying reasons • discussed the issue with our research consultant • emailed an international mathematics education researcher to ask for his thoughts about how the research work unfolded. <p style="text-align: right;"><i>adapted from Milestone Report 2</i></p> <p>To enable them to contribute more significantly to the process, these teacher researchers were released to attend an extra half-day meeting with the research team leaders. This enabled them to include their ideas with those of the group, and to refine the question categories which were then disseminated to the rest of the team.</p> <p style="text-align: right;"><i>adapted from Milestone Report 3</i></p>

As Cochran-Smith and Lytle note: “Participation in teacher research requires considerable effort by innovative and dedicated teachers to stay in their classrooms and at the same time carve out opportunities to enquire and reflect on their own practice” (1993, p. 20). An awareness of the issue for the teacher researchers of managing their research project commitments along with teaching workloads was evident throughout:

Teacher researchers	Research team leaders
<p><i>The amount of time involved was underestimated and at times it got stressful with other demands of work.</i> Stephanie, final questionnaire</p> <p><i>Was concerned about amount of time out of class and scheduling relievers, etc., as well as added workload for us!!</i> Ursula, "Working as a teacher researcher" questionnaire</p> <p><i>Concerned over scheduling release time and added workload.</i> Natalie, "Working as a teacher researcher" questionnaire</p>	<p>Thanks everyone for this round of data-gathering—we realise it's been difficult to complete this with everything going on in your schools at the moment!</p> <p>As we have received some objections to the proposed date for our next meeting in the holidays, but none for the new proposed date of 24 October ... our next meeting is now set for ...</p> <p style="text-align: right;"><i>Email to team, September</i></p>

Oliver (2005) found that school support was a significant factor in the success of teacher research projects. Responses to a questionnaire given to the teacher researchers midway through the research (Appendix D) described a full range of support from the teachers' schools, as shown in Figure 2.

Figure 2 **Teacher researchers' responses from "Working as a teacher researcher" questionnaire**



Following the questionnaire, the research team leaders sent out a letter to participating principals to update them on the progress of the research.

Teacher researchers	Research team leaders
<p><i>This was viewed as something extra I was doing and not really seen as part of my work so didn't really get support from school.</i> Stephanie, final questionnaire</p>	<p>We thought it was time we updated you on your teacher's participation in our Teaching and Learning Research Initiative project. We are aware that teachers need support within your school, and that you need to be well informed in order to provide this!</p> <p>... We are very appreciative of the hard work your teacher is doing as a valuable member of our research team. Examining one's teaching practice as closely as the Teacher researchers are doing is a potentially isolating experience; the support and interest you show in the challenging work in which your teacher is engaged plays an important role. We would also like to thank you for allowing your teacher to be released from their normal duties, to spend time reflecting on and analysing their practice. This time factor has been essential for the success of the project.</p> <p>Thanks again for the support you are showing your Teacher researcher and the work they are engaging in as key members of our research team. <i>Letter to principals, prior to Cycle 2</i></p>

External systemic support (Osler & Flack, 2002) was also essential to the project. Money allocated from funding provided through the Teaching and Learning Research Initiative allowed the teachers to have release time to analyse their lessons in detail, and to attend meetings.

... having the days provided to analyse the transcript helped with workload.

Natalie, final questionnaire

Process of video/taping and sending off to get transcribed was great. It was fantastic to receive the time to do this properly.

Ursula, final questionnaire

Links to practice

The research process was seen as being of significant relevance and having an immediate effect on the teacher researchers' own classroom practice.

Teacher researchers	Research team leaders
<p><i>This project is about your daily maths teaching, it is highly relevant to classroom teaching.</i> Natalie, final questionnaire</p> <p><i>I have developed an awareness of the types of questions that I can use to get responses from the children. Teacher-directed to more child-centred.... I always knew that learning and teaching run together but the research has helped to identify a specific area of focus and thought and therefore it must have an impact back in the classroom.</i> Quentin, final questionnaire</p> <p><i>I have learnt a lot more about me than I ever thought I was going to. This has identified needs and gaps in my questioning and there have been surprises in other areas. I have enjoyed the experience and would do it again.</i> Olivia, final questionnaire</p> <p><i>Has made me reflect more deeply on my daily practice and the types of questions I ask. It has made me consider more carefully the purpose of questions. Videoing lessons also gave me lots of feedback about all aspects of my teaching.</i> Ursula, final questionnaire</p> <p><i>Through video, transcribing etc. have just thought more about the purpose of questions. Why am I actually asking this question? Moreover, after doing this, I can sense when the questioning direction is not as effective as it could be and know (mostly) where I need to lead it!</i> Truman, "What have you learnt about questioning?" questionnaire</p>	<p>The outcomes [from the research] will increase potential for improving student achievement based on teachers' insights into their own teaching practices.</p> <p style="text-align: right;"><i>TLRI Proposal</i></p>

The teacher researchers also described possible directions for further research about their own practice:

Maybe the biggest question for me personally is how to take the information I have now about my questioning and find practical ways to implement change in the class. Maybe I need to do more reading about that.

Olivia, final questionnaire

It would be interesting to look again at the types of questions asked at which part of the lesson. I found the frequency table interesting and it would have been good to have another one to compare. I would also like to compare the frequency of questions between different levels. Are there any significant shifts in the types of questions asked?

Stephanie, final questionnaire

Early on in the project the teacher researchers recognised that this research should be able to inform the wider teaching community, and five of them described possibilities for dissemination (“Working as a teacher researcher” questionnaire).

Research within the real context of the classroom has a higher degree of validity and acceptability to other teachers.

Erin, final questionnaire

When the teacher researchers were asked to consider possible wider applications of what they had learnt from their research, it was the research process rather than their findings about their use of questioning that they considered important in developing teaching practice:

Having the opportunity to micro-analyse within a subject area has heightened my awareness of the strengths and weaknesses of my own classroom practice. This in turn has challenged me to either strengthen those practices that are valuable and to adjust/ improve those practices that are weak.

Erin, final questionnaire

The research has allowed me to look at myself as a practitioner. I did not really have an opinion about questioning before I started this research but through this process I have been able to focus more on developing questions that require more input from the student.

Quentin, final questionnaire

The teacher researchers found it difficult to be specific about exactly how the research findings relating to questioning might be useful to teachers in general. The suggestion was made that the categories may be useful for planning, and one teacher described how she had placed a list of the categories on her classroom wall so that she could refer to them during a lesson. The categories were seen as useful to the teachers involved in the project, as they had created them and “owned” them. There was a lack of confidence that other teachers would find them useful.

We need to be careful with transferring research to their [other teachers’] situations—qualify it with the fact that it is for “here and now” and may be less relevant when different factors are taken into account.

Ursula, final questionnaire

This was an interesting exercise and I wonder how it can be brought back into a school setting for whole staff development. It could be a nightmare to organise and facilitate, let alone fund!

Stephanie, final questionnaire

This research was done by a small group of teachers. What are the implications for other teachers? How would it transfer across to other teachers? How does questioning measure up against other factors to produce effective outcomes for children?

Natalie, final questionnaire

Perhaps this reflects findings from Mitchell (2002), who noted: “teacher researchers are more interested, at least initially, in finding what may appear to be context-specific solutions in their

own classrooms” and that many aspects of the research process are personal: “[I]n some important ways, the journey is experiential—some parts of the story cannot be told, they must also be experienced” (pp. 262–263).

Changing views of research

Osler and Flack (2002) found that skills to be developed by teacher researchers included: “reflection, articulation, familiarity with research literature, linking their own work to the work of others, writing and presentations” (p. 243). The development of each of these skills was in evidence in various forms throughout the project. The developing capability of the teachers as researchers was reflected in their changing views about the nature of research. They showed an ability to reflect on and articulate their practice:

Classroom research helps you to reflect on what you do and can only benefit student and teacher learning.

Ingrid, final questionnaire

It is a huge learning curve because you see things from a different perspective. You’re not critical but more reflective of how things are.

Quentin, final questionnaire

Research was seen as a vehicle for sharing, challenging or confirming existing ideas and introducing new ones. One aspect described by the teacher researchers was the complexity and scale of the research process:

Research is fascinating when you are involved in it!! It is really difficult to do. [There are] heaps of factors to consider. It doesn’t always give us answers.

Ursula, final questionnaire

It has been fun, scary, challenging and time consuming.... I realise how much work goes into these projects.

Olivia, final questionnaire

That it involves many facets and ideas ... the sharing of thoughts with other researchers and the intricacies involved.

Quentin, final questionnaire

Some major shifts in understanding about research were evident.

Teacher researchers
<p><i>When we first started out I was not sure of what I was getting into and therefore my mind was a bit of a blank slate. I think there is a definite need for teacher research to continue as it informs practice and changes views and brings together your own personal experiences which must be better for your classroom.</i></p> <p style="text-align: right;">Quentin, final questionnaire</p> <p><i>Research doesn't always provide you with answers. It often provides more questions. There isn't always a neat, tidy conclusion that can be drawn.</i></p> <p style="text-align: right;">Natalie, final questionnaire</p>

Research team leaders
<p>This [the project] will develop skills and understandings about the nature of research....</p> <p style="text-align: right;"><i>TLRI Proposal</i></p>

An opportunity for a teacher researcher and a research team leader to present aspects of the research process at a national conference further contributed to the development of research skills. This enabled the research partnership fostered during the project to be made visible. It also allowed the teacher researcher to be included in the national research community and aspects of the research to be critiqued.

Further research questions

Throughout the research, areas for future investigation continually arose.

Teacher researchers
<p><i>Discussed whether we might be limiting students' responses by the questions we ask them.</i></p> <p style="text-align: right;">Ursula, interview 1 summary</p> <p><i>Natalie wondered why she had asked so many more closed than open questions.</i></p> <p style="text-align: right;">Natalie, interview 1 summary</p> <p><i>Maybe when you put the open question is key?</i></p> <p style="text-align: right;">Natalie, interview 2 summary</p> <p><i>"Is that the easiest way to do that?" Ursula is reflecting on the wording of this question—is there a better way to ask students to evaluate strategies?</i></p> <p style="text-align: right;">Ursula, interview 1 summary</p>

Research team leaders
<p>What is the role of telling students, in relation to using questioning?</p> <p style="text-align: right;"><i>Research team leaders' reflection journal</i></p> <p>What does make a teacher change their practice?</p> <p style="text-align: right;"><i>Research team leaders' reflection journal</i></p> <p>Do patterns of questioning change over the school year, e.g., would a teacher be more focused on fostering student interaction as they establish the class culture at the start of the year?</p> <p style="text-align: right;"><i>Research team leaders' reflection journal</i></p>

At the completion of the research, a range of diverse questions for further research had emerged from the group:

Teacher researchers	Research team leaders
<p><i>Do teachers need more time to plan and think about questions to ask in lessons?</i> Ingrid, final questionnaire</p> <p><i>Have we swung the pendulum too far ... Can there be too much talk in the classroom?</i> Erin, final questionnaire</p> <p><i>Outcomes are extremely difficult to measure. How can we make judgements about effectiveness of questioning, when we are only looking at questions, not really comparing effectiveness of individual lessons?</i> Ursula, final questionnaire</p>	<p>There seems to be a trend towards asking more higher order questions of more able students. Is this pedagogically justifiable? <i>Research team leaders' reflection journal</i></p> <p>If decisions about questions are made "in action", how do teachers know where to go next? <i>Research team leaders' reflection journal</i></p>

5. Findings: Teachers' use of questions in mathematics

Identifying the various kinds of questions teachers use in mathematics

Definition of a question

The research team devised a working definition of what constitutes a question. For this project, a question was “any form of language that is aimed at eliciting a response”. This is a broader definition than that found in the *Concise Oxford Dictionary* (Allen, 1990). This extended what might be identified as a question beyond a sentence that ended with a question mark in the lesson transcripts, so that utterances such as, “Listen carefully to what Lily is saying and let’s see if we can understand how the mirror, how their hands coming together helped” (Erin, lesson transcript 2), were counted as a question. Although the definition included “any form of language”, the methodology of the project allowed for a focus only on oral questions.

Development of question categories

In the first cycle of data gathering and analysis, the teacher researchers worked independently to devise their own question categories to include every question they asked during one numeracy lesson. The teacher researchers created between six and 17 categories for the questions, with three people each devising eight categories. The research team met at the end of this cycle, with the main purpose of developing shared question categories from the teacher researchers' individual ones. This proved to be a complex task that could not be completed with sufficient discussion and debate within the time available. The seven teacher researchers who were at the meeting had varying degrees of input into this process.

After this meeting, the research team leaders met with three of the teacher researchers to further refine the categories. These were subsequently presented at the next team meeting for discussion and feedback. At this point, seven categories of question had been developed (question examples are drawn from teachers' categorised questions):

- checking understanding
 - Okay, but say again, you took the 3 away first you said and then you took away ...?*
 - Do you understand that, David?*
- getting a sharp, clear, anticipated response
 - Good boy, so that equals ...?*
 - Is there a 3 in the hundreds?*
- guiding and supporting (clarifying, repeating, rephrasing, taking another look)
 - Excellent, so you would take away the 6 and 3 because you know they actually make 9?*
 - So you said that you would have 24 and then you would ...?*
- explaining how and why
 - Why is using different colours helpful, do you think?*
 - How did that make it easy for you?*
- making connections and links
 - What is the relationship between 4 and 8?*
 - Is it a "-ty"? Where are some other "-ty" numbers?*
- management
 - Who is your partner, Victoria?*
 - Joseph, do you want to roll the dice?*
- fostering student interaction
 - So what's the number sentence, give me thumbs up if you agree with Trent.*
 - Ana, why are you shaking your head; do you disagree?*

The teacher researchers used these seven common category labels when they analysed their second lesson in Cycle 2. From the interviews the research team leaders held with the teacher researchers, it was apparent that the categories would need further refinement:

It was harder this time—last time I was focusing on categories of question, focused on what the question looked like. This time I thought more about what the purpose of my question was, why I actually asked the question. The “Anticipated response” category could have been done away with as we were usually checking for understanding or for the purpose of guiding the next step—help them to use that knowledge.

Ursula, interview 2 summary

“The question categories worked—I could place all questions.” Thinks the “short, sharp, anticipated response” questions could largely be re-classified as “checking understanding”. Could “Management” be included in “Guiding & supporting”? Thought we could get it down to 4 or 5 headings.

Quentin, interview 2 summary

At the second post-analysis meeting of the research team, the teacher researchers realised that questions in the category “getting a sharp, clear, anticipated response”, had been categorised according to the students’ responses, rather than the teachers’ purposes for asking the questions. It was therefore agreed that this category label was redundant, and that all questions currently in this category could be better accommodated under other category labels, such as “checking understanding”.

Other categories generating discussion were “management” and “fostering student interaction”. Having explored the notion of classroom norms at our previous meeting, the teacher researchers suggested that the questions labeled “management” were asked with purposes relating to establishing or maintaining norms. Similarly, it was agreed that questions aimed at “fostering student interaction” also had a strong connection with classroom norms. Consequently, these two categories were combined under the label, “fostering student interaction in a learning community”. The final five categories of questioning developed by the research team are shown below in Table 2.

Table 2 **The development of question category labels during the research project**

Initial categories (one teacher researcher's categories): May	Research team's initial combined categories: June	Research team's modified categories: August	Research team's final categories: October
<ul style="list-style-type: none"> • Clarifying students' ideas • Supporting students to change their mind • Supporting students to explain their own idea • Looking for patterns • Making connections with different materials • Clarifying the learning intention • Encouraging disagreement or questioning • Finding out how they solved a problem • Pushing students to see/use a different way • Justifying others'/own idea • Describing someone else's way • Finding out a different way of solving a problem • Extending vocabulary • Drawing students' attention to material to confirm or question their idea • Finding out a student's answer • Proving on materials • Self-evaluation 	<ul style="list-style-type: none"> • Clarifying understanding • Guiding and supporting • Explaining how and why • Transfer/application/links • Management • Getting an initial response • Odds and ends (questions that had not been included in other categories) 	<ul style="list-style-type: none"> • Checking understanding • Guiding and supporting • Explaining how and why • Making connections and links • Fostering student interaction • Management • Getting a sharp, clear, anticipated response 	<ul style="list-style-type: none"> • Checking understanding • Guiding and supporting • Explaining how and why • Making connections and links • Fostering student interaction in a learning community

Table 2 shows that for one teacher researcher the process of developing categories meant that their 17 categories reduced to just five categories by the end of the project.

Open and closed questions

Open questions remove the risk of failure.... Closed questions were less inclusive.

Truman, interview 1 summary

In the early stages of the research, the teacher researchers often referred to questions as open or closed (25 references in first interviews).

There were a lot of questions which were, basically, if you take this away from this, what will you have left? And that's quite a closed question but with this particular group of kids I think you sort of had to do that. Because otherwise they wouldn't have got to that point on their own.

Ursula, interview 1 summary

Later in the project, the teacher researchers reported that their thinking about questions had moved beyond this straightforward dichotomous categorisation. Open and closed questions were referred to less often (11 references in second interviews), and the complexities of these ideas were explored:

Open and closed questions were misleading—whole range of questions are needed to suit where a child is at a certain time. Open questions were not necessarily productive—sometimes too big for them.

Natalie, interview 2 summary

Previous discussions on questioning had been about open and closed questions but this has extended my thinking about the purpose of the questions. Teachers ask questions for so many different purposes to support children's thinking and learning.

Stephanie, final questionnaire

I think initially you kind of looked at the question as a separate entity and I was thinking, "Is this a closed question or an open question?" You were kind of looking at the wording of the questions, but you very quickly realised that actually that wasn't what was relevant, it was the whole purpose thing. So I think that was really useful. It made you think more about what the purpose is behind the questions.

Ursula, final evaluation meeting

In the final analysis, the teacher researchers agreed that in each of the final categories, they could find examples of questions that might be considered to be both "open" and "closed".

Questions in context

... when she considered the purposes of her questions, she decided that what may have appeared to be "eliciting" questions could be thought of as "extending questions", when examined in context.... Pointed out that the questions needed to be read in the context of the lesson to decide which category was the best fit; some questions could sit in several categories.

Natalie, interview 1 summary

Context shaped the teacher researchers' categorisation of their questions. They had decided that a useful way to establish categories was by examining a question in terms of the purpose they had in mind when they asked it. The importance of uncovering the teacher's purpose in such research is supported by Erickson (1993): "The teacher comes to know teaching from within the action of it, and a fundamentally important aspect of that action is the teacher's own intentionality" (p. viii). The teacher researchers reported that the actual purpose of a particular question could not be determined by looking at the question in isolation from the context in which it was asked. To identify the purpose of a question, it was necessary to know the conversation that happened before and after the question. Furthermore, even by referring to the full lesson transcripts and viewing the videotapes of lessons, members of the research team felt it was not possible to accurately categorise another person's questions according to purpose.

The research team leaders attempted to identify questions that would be illustrative of each category, only to find that they had insufficient information to do so with any degree of reliability. For example, the research team leaders thought the question, “How are you going, Jo, alright?” might have been classified as a “management” question. The teacher researcher in whose transcript the question appeared considered it fitted best in the “checking understanding” category, as this was the purpose she had in mind when she posed the question. Similarly, the question, “I have taken away 4. That leaves me with ...?” might be perceived by one person to be a “guiding and supporting” question, but the teacher researcher classified it as “checking understanding”.

One teacher researcher described an incident in which she had classified the question “What do you think, Sara?” as a “Sharp, clear, anticipated response” question. This was because she had targeted the question to a particular child whom she knew would provide her with an anticipated answer. Her purpose in generating such a response was to set up a conflict for the group to explore to address a misconception that had developed. These purposes show clear links to constructivist aspects such as “uncovering alternative conceptions” and promoting conflict (Brooks, 1990). For the questions to be categorised in terms of purpose, rather than form or function, the categorising must be done from the “inside out”. Only the teacher had the in-depth knowledge of each student’s learning needs required to identify the specific purpose for which they had asked each question.

Making the categorisation of questions still more complex was that questions were asked with varying purposes in mind; similar questions were asked of different students for different purposes, according to the students’ needs. For example, the question “So, what do you get if you add three more?” might be asked of one student with the purpose of checking their understanding, while for another student it might be asked in order to guide and support their learning.

Guiding questions are only for certain children which you have in mind. Maybe the same question could be a different category if targeted at a different child.

Natalie, interview 2 summary

Teachers also discussed the way in which they regarded many of their questions to have primary and secondary purposes. Sorting out which of these purposes were dominant formed part of the process of categorisation.

Lots of cross-overs—questions that lent themselves to several categories. So had to make a call.

Quentin, interview 2 summary

The effect of categorisation on teacher practice

I think I’ve changed my thinking from the initial questions that we did, because this is focused on those particular headings. It might’ve been symptomatic of knowing what my headings were, so I kind of tailored it towards those types of questions.... Having categories heightens the teacher’s awareness of questions and their purposes. I was really aware of

asking questions that “guided and supported” etc—was able to target particular types of questions. I felt my questioning was more focused—avoided trivial questions.

Quentin, interview 2 summary

Some of the teacher researchers described how the establishment of question categories influenced their practice in the second cycle of data gathering and analysis. It was possible that the teacher researchers may have felt compelled to categorise their questions so that they had some questions in every category, as they seemed to have some notion of what might constitute an ideal spread of questions across the given categories:

A good balance of questions, according to his beliefs about what constitutes good maths teaching.

Truman, interview 1 summary

Erin was happy with the proportions of the various categories here.

Erin, interview 2 summary

Whether there might, in fact, be some ideal ratio of question types, and what that might be, are questions for further research.

Reflection on findings highlighted some potential issues in the teacher researcher’s practices; for example, whether teachers might rely too heavily on questions when, sometimes, it might be more helpful to explain something to a student; or the possibility that teachers may be bombarding students with language:

Do I rely on questions too often to get children to explain ideas or would it be more efficient at times for me to just explain a concept rather than getting it from the children, particularly if the children are not very articulate in explaining their ideas or have not got the language necessary.

Natalie, final questionnaire

Have we swung the pendulum too far? Can there be too much talk in the classroom?

Erin, final questionnaire

Explicating teachers’ thinking about the use of questioning during lessons

Formulating and presenting questions

As teachers formulated questions, they brought together a complex combination of considerations that included:

- *Purpose*—What is the purpose of my question? Where am I heading? What is the learning intention? How will I know when the students have achieved it? What will be the next steps?

- *Student needs*—What are the needs of the students: their age, language needs (ESOL),⁴ perceived abilities, established understandings? What do they already know? What pace will best suit them? How attentive are they?
- *Scaffolding*—What will help scaffold their learning in terms of equipment and student interactions? What mathematical language or ideas do I need to include in my question in order to support the students' learning?
- *Who to ask*—To whom will I direct this question: to the whole class or to an individual student, and in this case, which student (for a variety of purposes, for example, deliberately setting up conflict of ideas, uncovering a suspected misconception, to quickly get the correct answer, or to re-engage a student)?
- *Timing*—When should the question be asked? At what point should the teacher intervene when a student is struggling, for example? How much wait-time should they allow? Is there sufficient time left in the lesson for the discussion this question might elicit?
- *Predicted responses*—What responses do I expect? How am I, in turn, likely to need to respond? What equipment is immediately accessible to support directions in which the discussion might head?

(developed from the final evaluation meeting)

Consideration of students' needs

The type of questions I might use to ask a five-year-old will be quite different to what I might use for a Year 5.... I change the language to suit the student's ability. My manner is quite different with younger children compared to older children—language and tone. I would be more directive with the younger children, although probably would demonstrate the same range of question categories with both groups. Quite a few ESOL children, so that adds to the thinking about the language and vocabulary you use.

Erin, interview 1 summary

All the teacher researchers talked about adjusting their questions according to the students' learning needs, which were related to such factors as the students' ages, their numeracy strategy stages,⁵ and the teacher researchers' perception of the students' abilities.

Might push the group who were good at explaining to go further.

Stephanie, interview 1 summary

First group was more able; the questions tended to be more open. Group two were less able and the closed questions led to answers rather than thinking.

Natalie, interview 1 summary

⁴ Students with limited knowledge of English language.

⁵ The overview of strategy stages, detailed in *The New Zealand Number Framework* (Ministry of Education, 2006d), describes a progression of strategies that students use to solve number problems as their thinking becomes more advanced.

I learnt that I tended to ask questions that reflected the children's need and abilities. ESOL children—very basic, children with greater understanding more complex words and sentence structures.

Olivia, "What have you learnt about questioning?" questionnaire

With the more able group, I felt I could give them more information. I felt I had talked more, there was a different pace—I moved a lot quicker because they had more strategies to use. I felt I was broadening them out. There is a complete difference to my approach with less able students.

Quentin, interview 1 summary

The teacher researchers consistently reported that they differentiated their questions according to students' perceived abilities and identified learning needs (see "Describing patterns of teachers' questioning within mathematics lessons"). One teacher researcher questioned the effect of presenting different combinations of questions from the various categories to different groups of students:

Discussed whether we might be limiting students' responses by the questions we ask them.

Ursula, interview 1 summary

The teacher researchers described how they would target a particular student with a question for various reasons, including supporting the student to articulate their thinking in an "Aha!" moment, for the benefit of that student as well as others; helping them to resolve a misconception; or to be inclusive:

She would call on particular children at particular times—quite strategic who she would ask. May offer something that you could work with, we need a bit of explaining in here, or someone to pick up what the error is, so would choose a particular child.

Natalie, interview 2 summary

Sometimes tags a question with a child's name to encourage participation and build confidence.

Erin, interview 1 summary

... having an in-depth conversation with one child can benefit others, rather than making sure you have a one-off interaction with every child in the group. A number of students not very verbal so perhaps it would be better to have longer conversations with more verbally able students, providing models for the others.

Ursula, interview 1 summary

Depends on the child—effective questions are ones which help the child. She has different children in mind when she asks a question. Asks "to-the-group" questions and "to-the-child" questions.

Olivia, interview 1 summary

Planning and adapting questions

... the questions changed because of students' response, put in some open questions for children who she knew were able; for those who didn't get it, came back together and nailed it down.... The kinds of questions changed because of the response of the children.

Natalie, interview 2 summary

Questions were formulated "in the moment" according to students' responses. The teacher researchers reported difficulty in devising questions when the students did not provide them with responses on which they could readily build.

I can't say I was thinking a lot about the questions during the actual lesson, coz once you get in, it just goes, and you just go with what's happening.

Stephanie, final evaluation meeting

Watching the directions teaching heads in, in response to what the children have said—sometimes you go off on another tangent.

Stephanie, interview 2 summary

One question, "How do you know it's five?"—Thought about developing this idea, but didn't know how to, didn't get a steer from the kids, so dropped it.

Ingrid, interview 1 summary

... you need the feedback to form your next thought. It's not just one-way communication ... you need something to build off, so you need interaction back.... Questions are adapted to the needs of the students in context"

Quentin, interview 2 summary

The possibility of planning questions to ask during a lesson arose during the interviews with the teacher researchers as well as during the research team meetings. One teacher researcher had initially thought about planning questions for the lessons she was going to record for later analysis. Her thoughts had changed further into the research project:

I wondered whether specific questions should be planned before the lesson, but this could have taken a lot of time.

Ingrid, interview 1 summary

I thought of planning some questions, but decided that the questions in the numeracy books had it covered.... These are generally the kinds of questions I would be asking in any lesson.... That's why it's hard to plan for them as well, because you don't know what direction—I mean, both lessons on both days, two of the activities I prepared for two different groups were too easy for them, and I had to adapt to that straightaway and do what good teachers do and think on their feet.

Ingrid, interview 2 summary

This is reinforced by Quentin's observation:

You can't pre-plan all questions. It becomes a conversation of ideas with the teacher having to think on their feet—a more “off the top of the head” approach, apart from the lead-in questions.

Quentin, final questionnaire

While all questions could not be planned, most teacher researchers reported planning the initial questions in a lesson, or using the categories to think about the types of question which they would include to achieve their learning intentions:

Have you got the right type of questions? What sort of purpose are you going to use, so what sort of questions are you going to ask? ... are you going to make connections here, or are you going to dig deeper, or, you know, what is your purpose for asking your questions when you plan?

Olivia, final evaluation meeting

You have to think about children's possible responses when you prepare your questions, because if you think about what responses they might make and the track they might go down it actually effects your questioning and you have to be flexible enough to let them lead.

Erin, interview 1 summary

The teacher researchers talked frequently of the need to adapt their questions and be flexible and responsive as a lesson progressed. In traditional transmission classrooms, the teacher controls the pattern of talk as well as the knowledge (Windschitl, 1999). In a social constructivist classroom, the teacher aims to interact with the students' ideas, rather than be a keeper of knowledge that is handed down to the students (Askew et al., 1997). For teachers to yield some of the control to students requires the teacher to have a secure pedagogical content knowledge (Alton-Lee, 2003; Anthony & Walshaw, 2007; Shulman, 1986).

I like to have clear learning intentions and know where I'm going and how I will know that the children have got there, but maybe I'm thinking I need to be a little bit more relaxed about that, so they can take the lesson where they want it to go a little more.... And I think to have less control you have to be more secure in yourself and you also have to be more secure in yourself to guide—not in a pushy way—but to guide as a good teacher. Because it's much easier for us to work out where we want to go and just go our own little way, and do it the way our brains work.

Erin, interview 2 summary

While it may not be possible to predict the exact course a lesson will take, the teacher needs to have an endpoint in mind when formulating questions.

The learning intentions guide the teacher's thinking when asking questions. They can motivate the learner and teacher towards the intended goal, to think mathematically using strategies.

Olivia, interview 2 summary

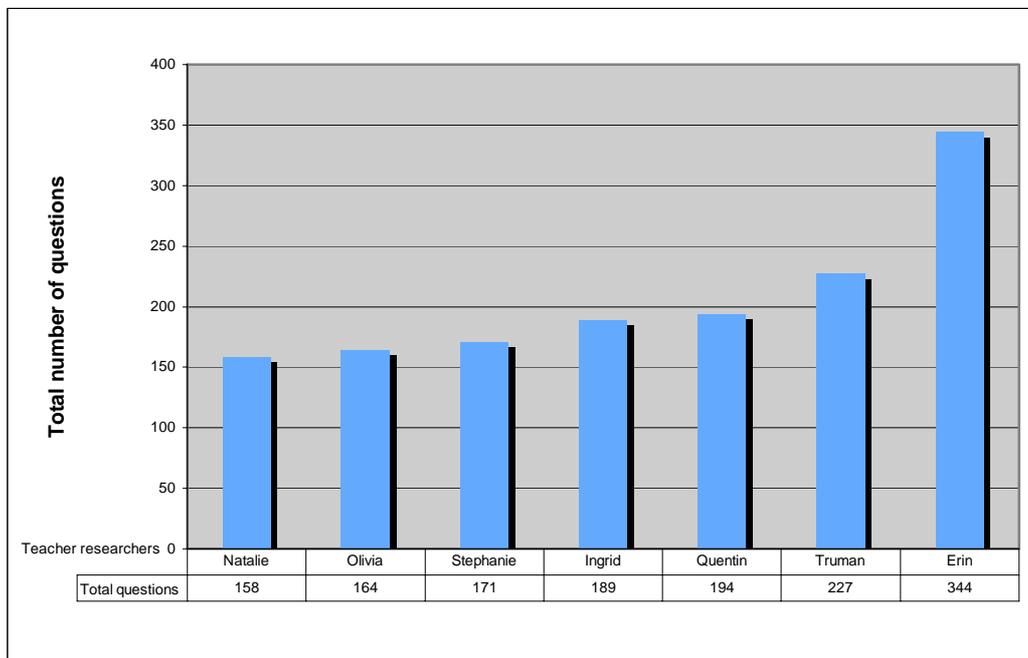
Describing patterns of teachers' questioning within mathematics lessons

The number of questions in whole class and group teaching

Completed frequency tables were intended to provide the project team leaders with quantitative data that could provide valid comparisons. However, it became clear that the unit of a question had been interpreted in more than one way. For example, when identifying her questions, one teacher researcher had separated every individual question in her transcript so that: “What’s 3 and 3?” and the next utterance, “3 and 3?” (Erin, sorted questions, Cycle 2) were counted as separate questions. Others had counted as one question instances when a question was repeated, so that: “You can do 2 plus 5 equals 7. What would you do if you had to change that into a take away? How can you do 2 plus 5 equals 7 as a take away sentence?” (Ingrid, sorted questions, Cycle 2) were classified as one question.

Seven of the eight teacher researchers completed a frequency table as part of Cycle 2. The total number of questions identified in the second lesson ranged from 158 to 344 (see Figure 3), with a mean of 207 questions. There was no apparent pattern to the total questions asked that related to the age group taught, or to the associated strategy stages taught.

Figure 3 **Total number of questions in a lesson—Cycle 2**



We ask loads of questions for a variety of reasons. All types of questions appear to be useful, depending on the purpose.

Ursula, final questionnaire

A high rate of questioning was evident in the lesson transcripts. Given a maximum lesson time of one hour, the rate of questioning was somewhere between two and six questions per minute; this is considerably higher than the one to two questions every minute reported in the literature (Gall, 1971; Wragg & Brown, 2001). Several teacher researchers remarked in the first interview that they had been surprised to find they had asked so many questions. While throughout the project the teacher researchers indicated their heightened awareness of the number of questions they had asked, none of the teacher researchers commented that this was an issue until the latter stages, when several teacher researchers showed growing concern over this:

I want to learn to ask less questions—less questions, but more effective!

Erin, “What have you learnt about questioning?” questionnaire

. . . reminding myself that I should be asking fewer questions.

Truman, “What have you learnt about questioning?” questionnaire

I ask too many questions and I don’t wait to get the answers.

Stephanie, interview 2 summary

It has heightened my awareness of the nature of the questions that I ask, the number of questions I ask, when and why I ask them.

Erin, final questionnaire

Did my lesson have too many questions? Did I try too hard to ask a lot of questions and will I continue to use as many questions?

Natalie, final questionnaire

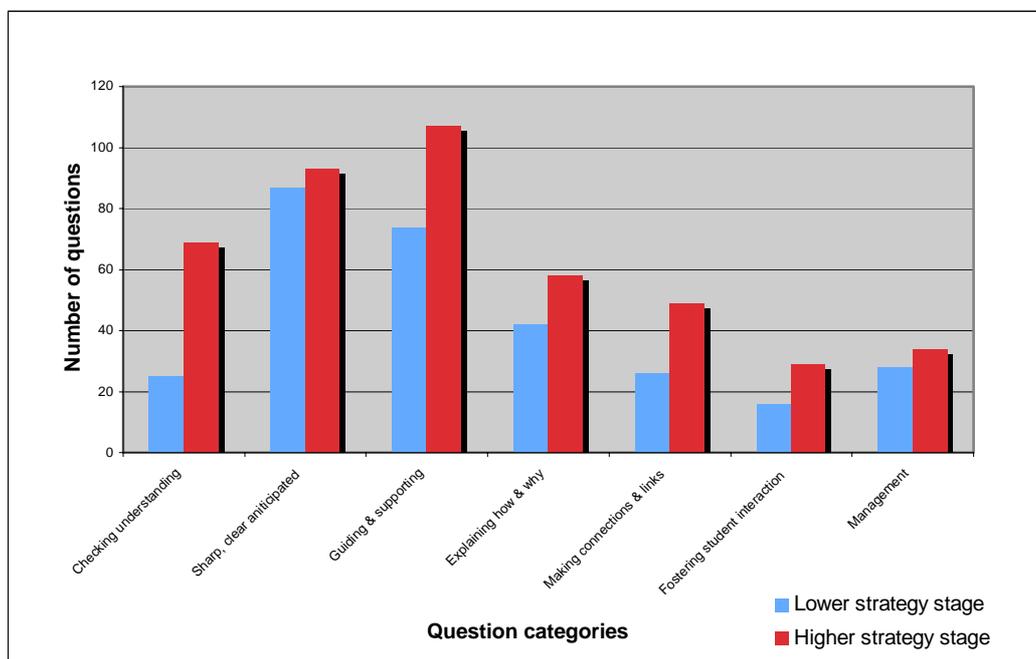
It was also suggested that there could be a connection between the number of questions and the area of mathematics being taught.

More questioning would have happened in numeracy than in statistics.

Ingrid, interview 1 summary

The teacher researchers were asked to indicate which of their groups were working at the lower strategy stage and which were at the higher strategy stage. There was a clear difference in the total number of questions the teacher researchers asked the students in the lower stage groups compared to those in the higher strategy stages (see Figure 4). A total of 298 questions were asked in six teacher researchers’ lessons with students in the lower stage groups, compared to 439 questions asked of their higher strategy stage students—close to 50 percent more questions.

Figure 4 **Questions asked of lower and higher strategy stage groups, by number of questions**



The teacher researchers proposed a number of possible reasons for the differing quantities of questions for the two groups. One suggestion was that teachers might see the higher groups less frequently, so perhaps their session times were of extended duration. Further ideas were:

- Perhaps the expectations differed for the two groups; “the higher group was going somewhere” (Ursula, final research team meeting), and teachers were more active in pursuing this.
- For the higher strategy stage group, the strategies were more complex, so more guidance was required.
- The lower strategy stage group tended to be less verbal, so teachers had less to work with.
- Students in lower strategy stage groups took longer to work through tasks and wait time needed to be longer.
- The lower strategy stage groups tended to rely more on materials, and fewer questions were asked because they were modelling their thinking.

All of these conjectures warrant further investigation.

The graph in Figure 4 also shows the proportion of categories of questions within the identified ability groups. Although there are minor differences between the proportions within each of the categories, the general shape of the graph for each of the groups is very similar. This means that although the number of questions differed for each of the groups, the weighting of the kinds of questions asked was essentially the same. The teacher researchers expressed surprise at this as

they had previously described ways in which they perceived questions for groups of different ability differed:

She tends to ask different questions to different groups of children, e.g., second group [less able] had lots of “sharp, clear, anticipated response” questions and were supported with materials, teacher modelled and stated the problem for them... Maybe because they have less knowledge to link to, so the teacher is focusing on helping them to build knowledge. More able children probably are asked more “explaining how and why” questions; probably don’t use “checking understanding” as much.

Ingrid, interview 2 summary

I think if I was working with more able children I would try really hard to not ask those kind of closed questions ever. But I think with less able ones you do actually sometimes need to ask a much more direct, closed question, but make sure you follow it up with another one, and then another one, and then another one till you get to a point where they sort of understand a bit more of the process.

Ursula, interview 1 summary

This illustrates a mismatch between teachers’ perceptions of their questioning practices, and research findings as identified by Walsh and Sattes (2005).

The shape of questioning within a lesson

She established a pattern whereby sometimes she asked an open focusing question, they don’t get it so you focus them down, and funnel some of the questions, and then you ask more of the “explaining why” questions. Do we narrow it down and open it wide, and then narrow it down if they haven’t got it?

Natalie, interview 2 summary

The teacher researchers were asked to describe any patterns of questioning that they used during a mathematics lesson. The frequency tables helped them to identify the numbers of each category of questions that they asked during different stages of their lesson. During their first lesson analysis, they had identified key episodes in their lessons and had considered the particular questions included in these. The teacher researchers were reluctant to pinpoint significant individual questions in their key episodes, asserting that it was sequences of questions that were important. Both the frequency table and the key episode analysis helped the teacher researchers to identify patterns in their questioning.

Questions form a spiral... They are cyclical: initial questions fostering interaction, check common understanding/knowledge, explaining with guiding and supporting, making links, then repeating your “why” question.

Ursula, interview 2 summary

She identified a sequenced approach: ask them what they think, find out how they got there, see if other children agree or disagree, then reframe the question to double check that they got it.

Erin, interview 1 summary

[The pattern was] Initial question (“fostering student interaction”)—“anticipated response”—[if the child] showed understanding—checking understanding of that next step.

Stephanie, interview 2 summary

The suggestion was made that the teacher’s questioning might change over the course of a lesson:

I think our questions get more efficient as we get into a lesson. I think your earlier questions, often you’re kind of grasping a bit for the right kind of question to ask, and then as you get more from the children—I think it’s as you get more feedback from them—you probably get more efficient with what it is that you’re actually really aiming for.... Earlier questions tend to be a bit more general, but until you know where the students are at, you can’t refine your questioning.

Ursula, interview 1 summary

As he warmed up during group sessions, there were more predicting, scaffolding and prompting questions. He felt his questioning became more honed as the lesson progressed and they got into the subject matter.

Truman, interview 1 summary

Asked lots of questions—more questions as time progressed.

Ursula, interview 2 summary

Several teacher researchers noted that a number of questions from the same category were grouped together:

I have learnt that questions can be asked in a pattern eg. Checking understanding around a group or making connections—questions are grouped, and often the same to each child in the group. “How many frogs are in the pond? ... Three and how many frogs are out of the pond? ... How many frogs altogether? ... Five altogether. So that is three and two more equal five.”

Olivia, “What have you learnt about questioning?” questionnaire

My explaining how and why questions came in groups throughout the transcript—either at the end of the warm-up or where I was working with the groups.

Ingrid, “What have you learnt about questioning?” questionnaire

From the variety of descriptions given by the teacher researchers, no obvious single pattern of questioning over a lesson emerged.

Relationships between question categories

All the categories work together to give you the whole picture, and if you take one or two of them out, you don’t get to where you want to go.

Erin, interview 2 summary

Depending on the context in which the question is being used, they're all equally important. Depends on the teacher's purpose.

Ingrid, interview 2 summary

The general feeling among the group was that all question types are important in a lesson. No hierarchy of question types was evident to the teacher researchers; instead, they described a synergy between the categories. While there were no common patterns of questioning over a lesson identified during this research, it was clear that the teacher researchers believed it was the combinations of different categories of questions, rather than individual questions that were powerful in shaping students' learning.

Identifying barriers which inhibit the use of questioning

Teacher and student-related barriers

Do repeat questions a lot. Not sure if that's a good question—it sometimes stops their thought processes. A lot of times I asked a question and if I didn't get an immediate response, I asked the question again, and rephrased it a bit—maybe because the children I was working with were less verbal. Am I stopping them from thinking, by jumping in?

Ursula, interview 2 summary

The teacher researchers recognised that a teacher's lack of wait time, as well as the temptation to talk rather than listen, were potential barriers to the effective use of questioning.

It's so easy ... to put your voice in ahead of theirs ... you want to tell them something, but you don't give them an opportunity, necessarily, to articulate what they already know.

Quentin, interview 2 summary

Thinks she tends to cut children off and that she needs to develop a culture where the children start to ask questions of others and be confident to answer.

Olivia, interview 2 summary

I ask too many questions and I don't wait to get the answers. Conscious of them not responding, so I often rephrase to help with the language.

Stephanie, interview 2 summary

The teacher researchers did not specifically talk about the role of a teacher's pedagogical content knowledge (Shulman, 1986) as a potential barrier. They did, however, acknowledge that limited teaching experience affected their ability to respond to students:

So it's when I'm faced with a curly one when a child's going off on a tangent, or I'm just thinking, "Oh, my goodness! Now, how am I going to get them to understand this?" Because it hasn't gone as I thought it would and that's when I think the prompts of those category questions are helpful for me, because I haven't had all this experience with numeracy.

Erin, final evaluation meeting

Where to go next is [based on] experience. The ability to know where to go next must be about experience.

Olivia, final evaluation meeting

If it is not possible to plan all the questions that will be asked during a lesson because they need to be responsive to students' ideas, then it follows that the teacher will need a broad understanding around the topic being taught if they are to be knowledgeable enough to respond to the unique combination of students' responses.

You have to think about children's possible responses when you prepare your questions, because if you think about what responses they might make and the track they might go down it actually affects your questioning and you have to be flexible enough to let them lead.

Erin, interview 1 summary

The teacher researchers talked about how the priorities for formulating questions constantly shifted, depending, for example, on the teacher's stress or tiredness level, or external factors affecting the classroom. The effect of other adults observing the teacher was also reported as a potential barrier to effective questioning. In this situation, the teacher's priority shifted from being in tune with the students to thinking about, "What do other people expect to see from me?" and a heightened awareness of the need to be seen to be in control.

Another inhibiting factor was felt to be the need to cater for diverse needs within a class; cultural diversity, ESOL students, large class numbers, a range of abilities, and so on, could all limit possibilities for teachers' questions.

It is also interesting thinking about our Pacific Island students who don't respond to questions. They tend to sit and wait to be told—cultural expectations to sit and be quiet—listen to what you're told.

Ingrid, "What have you learnt about questioning?" questionnaire

A lack of response from the students, giving nothing for the teacher to build on, was acknowledged as a potential issue:

The quality of the lesson really depends on the outcomes, i.e., what you get back from the student, and if we are not getting high-quality responses, do we just need to be telling students rather than asking (this seems especially true when working with less able students, who cannot articulate clearly).

Ursula, final questionnaire

The teacher researchers also described ways in which the time of year affected their questioning. As the year progressed and classroom norms became established they felt there was less of a need to ask questions directed at building a sense of community.

Environment-related barriers

Unforeseen interruptions to the classroom programme were a clear barrier to the effective use of questioning:

It was an interrupted session; we had just moved and the children were excited and I was tired.... The environment wasn't set so the questions weren't as good.

Olivia, interview 2 summary

I have learnt that the environment has a huge bearing on how well you ask questions. Although well-planned, lack of equipment and routines are a factor that I didn't realise was as great as it was.

Olivia, "What have you learnt about questioning?" questionnaire

The teacher researchers also talked about how timing had an effect on question delivery. Questions requiring complex responses were more likely to be asked at the beginning of a lesson, but were less likely to happen near the end. One teacher researcher described how she would think, "Oh, have I got time to ask this kind of question ... ?" towards the latter part of a lesson (Ursula, final evaluation meeting).

Examining conditions which support effective use of questioning

If you don't ask questions, you don't get the children thinking, you're thinking for them. I want to see them learn. If I'm not asking questions that help them learn, maybe I need to look at the questions I'm asking.

Olivia, interview 1 summary

The teacher researchers described "effective use of questioning" as:

- questioning that provokes thinking
- questioning that extends thinking
- any form of language that successfully elicits a response
- asking the right question at the right time.

During their interviews, the teacher researchers described the question types that they found most effective in guiding students' learning, and these varied considerably from teacher researcher to teacher researcher in both lots of interviews.

Possibly “Explaining how and why” and “Checking understanding”, depending on the context in which the question is being used. They’re all equally important. Depends on the teacher’s purpose.

Ingrid, interview 2 summary

Thus the context is critical in identifying what is effective questioning: “The effectiveness of a teacher’s question can be determined only by considering how it is situated in the context of the teacher–student interaction” (Jacobs & Ambrose, 2003, p. 1).

6. Conclusions

I had the impression research was often done by a researcher to you, however this has shown that it can be embedded in your practice and the research can be for you.

Natalie, final questionnaire

Participation in this project had an effect on the teacher researchers' views of the relationship between research and teaching and provided opportunities to reduce the gap between research and practice. The process of researching their own teaching practices served to transform the apparent simplicity of the task of identifying and categorising questions, to a complex undertaking which confronted the teacher researchers with some of the essential elements implicit in their everyday teaching.

The structure of the initial research design was key in developing the teacher researchers' research capabilities as it scaffolded the data-gathering and analysis process. This structure allowed the teacher researchers maximum control over the selection of the primary level of data to be analysed and opportunities for in-depth reflection. Important features that contributed to the success of this process were:

- the use of accessible technology which the teacher researchers controlled
- the lesson transcript being made available to them within a short time frame
- the interaction between the printed transcript and the videotape
- the inductive categorising process used
- having immediate and concentrated time for analysis
- discussing their findings with a research team leader in a reflective interview.

Throughout the project, the teacher researchers encountered authentic research problems regarding methodology, analysis, and interpretation of data as they sought to make meaning from data gathered. Initially, they were faced with deciding what counted as a question, then with exploring and finding language to articulate their purposes and motivations during mathematics lessons. The process of categorisation caused them to question the nature and purpose of categories in organising their thinking, and challenged assumptions about types of questions, the balance of categorised questions within lessons, how interventions in the learning process are prioritised, and expectations held about students. Synthesising the variety of individually identified themes to form a cohesive and shared interpretive framework enabled the teacher researchers to further test and describe emerging ideas about their questioning practices.

The unique perspectives of these teacher researchers about questioning provide a valuable contribution to the knowledge base about teaching in this area. Their detailed examination of the thinking that underlies the formulation of questions enabled the teacher researchers to examine

their metacognitive processes, highlighting the complexities of questioning. Explaining their thinking to others compelled them to articulate their practice more precisely, and to discuss and debate related issues. The process of close analysis and discussion of their teaching practice was an outcome valued by the teacher researchers, and one which they saw as useful for other teachers. However, it was difficult for them to assess the value of their observations about the questions they asked and the categorisations they devised; they seemed unsure of the validity of their findings, perhaps due to the lack of sufficient time to fully explore patterns and commonalities which may have been present in their questioning practices.

The teacher researchers identified many diverse factors that influenced the formulation, selection and delivery of their questions within a mathematics classroom. These included such considerations as the purpose of a question, the perceived needs of students, the type of scaffolding required, the need to target particular students for a variety of purposes, timing within a lesson, and predicted student responses. Teacher questioning is a synergy of complex and interrelated factors that interact to determine the direction of teaching and learning within a lesson.

While the possible effect of particular combinations of question types was identified, the teacher researchers did not identify any clear, consistent patterns of questioning within their lessons. More time may have been needed for the teacher researchers to work with the final question categories in order to confidently classify their questions and to recognise significant patterns, if indeed any exist. Due to the complexity of questioning that became apparent during the project, and the fact that the teacher's decisions are so context-bound, it appears there are no formulae for effective questioning in mathematics.

Participants discovered the most useful way to categorise their questions was to reflect on the purpose for which they were asked. As the study progressed it became obvious to all the participants that such a process was a personal activity driven by knowledge of the students, personal experience, and context. How a question looks is not always indicative of its underlying purpose. The observation and classification of questions by an outside observer seems to be an unreliable method to uncover the purpose of a teacher's questions.

During the project, the teacher researchers condensed their question categories from a maximum of 17 categories to five general purposes that encompassed all the questions asked within their mathematics lessons. Categorising a question as open or closed did not prove helpful, as these categories were too broad and did not relate to the purposes of asking questions. Neither did other pre-existing matrices of question types match what the teacher researchers developed as a meaningful set of categories. The refined set of categories gave the teacher researchers a common language for discussing the role of questioning in their practice and, for some, helped to sharpen the focus on their purposes for questioning.

Much of the research examining questioning in classrooms highlights the high quantity within a lesson as an issue. The teacher researchers in this study identified at least 158 questions in their hour-long mathematics session and seemed to equate the high rate of questioning with effective

practice. This perception was still evident at the conclusion of the project, although some teacher researchers queried this. Also of interest was that the teacher researchers asked close to 50 percent more questions of students operating at more advanced strategy stages.

Further research is needed to establish the interrelationships between the types of questions used, the patterns of questions within a lesson, the number of questions asked, and their relationship to learning.

Implications

Support for further research that includes the teachers' perspective in the analysis of teaching practice is vital. To allow teachers to develop the research skills necessary to contribute their perspective in a meaningful and rigorous manner, teacher researchers must be provided with:

- sufficient release time to examine their practice in depth, and to attend research meetings
- access to experienced researchers to give guidance, direction, and encouragement
- research forums for discussing ideas with other teacher researchers
- interest and encouragement from management and colleagues within their schools.

For research to be more closely aligned with practice, research questions need to originate from teachers themselves. To enable teachers to be involved from the earliest stages of a research project such as this one, and to have authentic ownership, they need to be involved in the development stage of an expression of interest, and then the full proposal. Teacher initiation of such proposals could be encouraged by the inclusion of a research component into teachers' job descriptions.

In teacher research, consideration needs to be given to methods which enable teachers to have maximum ownership of processes throughout.

Dissemination of research findings

Teacher researchers have been encouraged to present and discuss the findings and methods of the research with their staff to contribute to developing a culture of inquiry within their schools.

Aspects of the methodology could be incorporated into professional development to enable teachers to reflect deeply on their practice. The methodology of the data-gathering and analysis process used in this research is relatively easy to set up by classroom teachers to record their lessons to provide a useful focus for self-reflection or discussion with a critical friend to improve practice.

At the end of 2006, aspects of findings were presented by a teacher researcher and a research team leader at the conference of the New Zealand Association for Research in Education (NZARE). In

2007, findings will be presented at a national hui for numeracy facilitators and researchers. This will highlight the need to include the teacher's perspective when describing and evaluating observed teaching practices. The research team leaders intend to present a paper about the project's findings at the Mathematics Education Research Group of Australasia (MERGA) conference and at other appropriate international conferences. Various aspects of the findings will be submitted to publications for teachers, and relevant academic journals.

I think research is essential. Teachers are frequently overloaded with professional development, changing curriculum and general workload and just don't have the time to look at things in as much depth as we did on this research project. Research within the real context of the classroom has a higher degree of validity and acceptability to other teachers.

Erin, final questionnaire

References

- Allen, R. E. (1990). *The concise Oxford dictionary*. Oxford: Clarendon.
- Alton-Lee, A. (2003). *Quality teaching for diverse students in schooling: Best evidence synthesis*. Wellington: Ministry of Education.
- Anthony, G., & Walshaw, M. (2007). *Effective pedagogy in Mathematics/Pangarau: Best evidence synthesis iteration [BES]*. Wellington: Ministry of Education.
- Askew, M., Brown, M., Rhodes, V., Wiliam, D., & Johnson, D. (1997). *Effective teachers of numeracy in primary schools: Teachers' beliefs, practices and pupils' learning*. London: King's College.
- Berger, J. G., Boles, K. C., Troen, V. (2004). Teacher research and school change: Paradoxes, problems and possibilities. *Teaching and Teacher Education, 21*(1), 93–105.
- Bloom, B. S. (Ed.). (1956). *Taxonomy of educational objectives: Handbook 1: Cognitive domain*. London: Longman.
- Boghossian, P. (2006). Behaviorism, constructivism, and Socratic pedagogy. *Educational Philosophy and Theory, 38*(6), 713–722.
- Brooks, J. G. (1990). Teachers and students: Constructivists forging new connections. *Educational Leadership, 47*(5), 68–71.
- Brooks, J. G. & Brooks, M. G. (1993). *In search of understanding: The case for constructivist classrooms*. Alexandria, VA: The Association for Supervision and Curriculum Development.
- Carpenter, T. P., Fennema, E., & Franke, M. L. (1996). Cognitively guided instruction: A knowledge base for reform in primary mathematics instruction. *The Elementary School Journal, 97*(1), 3–20.
- Carr, W., & Kemmis, S. (1986). *Becoming critical: Education, knowledge, and action research*. London: Farmer Press.
- Cazden, C. B. (1988). *Classroom discourse*. Portsmouth, NH: Heinemann.
- Cazden, C. B. (2001). *Classroom discourse: The language of teaching and learning* (2nd ed.). Portsmouth, NH: Heinemann.
- Chuska, K. R. (1995). *Improving classroom questions: A teacher's guide to increasing student motivation, participation, and higher-level thinking*. Indiana: Phi Delta Kappa Educational Foundation.
- Cobb, P. (1994). Where is the mind? Constructivist and sociocultural perspectives on mathematical development. *Educational Researcher, 23*, 13–20.
- Cochran-Smith, M., & Lytle, S. L. (1990). Research on teaching and teacher research: The issues that divide. *Educational Researcher, 19*(2), 2–11.
- Cochran-Smith, M., & Lytle, S. L. (Eds.). (1993). *Inside outside*. New York: Teachers' College Press.
- Cochran-Smith, M., & Lytle, S. L. (1999). The teacher research movement: A decade later. *Educational Researcher, 28*(7), 15–25.
- Denscombe, M. (1999). *The good research guide*. Buckingham: Open University Press.
- Dillon, J. T. (1988). *Questioning and teaching: A manual of practice*. London; Sydney: Croom Helm.
- Doenau, S. J. (1987). Soliciting. In M. J. Dunkin (Ed.), *International encyclopedia of teaching and teacher education* (pp. 407–413). Oxford: Pergamon.
- Erickson, F. (1993). Foreword. In M. Cochran-Smith & S. L. Lytle (Eds.), *Inside outside* (pp. vii–ix). New York: Teachers' College Press.

- Fraivillig, J. L., Murphy, L. A., & Fuson, K. C. (1999). Advancing children's mathematical thinking. In J. Sowder & B. Schappelle (Eds.), *Lessons learned from research* (pp. 37–38). Reston, VA: National Council of Teachers of Mathematics.
- Gall, M. (1971). The use of questioning in teaching. *Review of Educational Research*, 40, 707–721.
- Gall, M. (1984). Synthesis of research of teachers' questioning. *Educational Leadership*, 42(3), 40–47.
- Gould, P. (2005). From the hill to the swamp: Combining research and practice. In *Proceedings of the annual conference of Mathematics Education Research Group of Australasia* (pp. 50–53). Melbourne: Mathematics Education Research Group of Australasia
- Hattie, J. (2003, October). *Teachers make a difference: What is the research evidence?* Paper presented at the annual conference of the Australian Council for Educational Research, Melbourne.
- Higgins, J. (2002). *An evaluation of the Advanced Numeracy Project 2001*. Wellington: Ministry of Education.
- Higgins, J. (2003). *An evaluation of the Advanced Numeracy Project 2002*. Wellington: Ministry of Education.
- Honan, E. (2007). Teachers engaging in research as professional development. In T. Townsend & R. Bates (Eds.), *Handbook of teacher education: Globalisation, standards and professionalism in times of change* (pp. 613–624). Dordrecht: Springer.
- Houston, W. R., Haberman, M., & Sikula, J. (Eds.). (1990). *Handbook of research on teacher education*. New York, Macmillan.
- Hyman, R. T. (1974). *Ways of teaching*. New York: J. B. Lippincott.
- Irwin, K. C. (2003). *An evaluation of the Numeracy Project for Years 7–10, 2002*. Wellington: Ministry of Education.
- Irwin, K. C., & Woodward, J. (2005). Advancing Pasifika students' mathematical thinking. In F. Ell, J. Higgins, G. Thomas, T. Trinick, & J. Young-Loveridge, *Findings from the New Zealand Numeracy Development Projects 2005*. Wellington: Learning Media.
- Jacobs, V. R., & Ambrose, R. C. (2003, April). *Individual interviews as a window into teachers' practice: A framework for understanding teacher–student interactions during mathematical problem solving*. Paper presented at the annual meeting of the American Educational Research Association, Chicago.
- Kawanaka, T., & Stigler, J. W. (1999). Teachers' use of questions in eighth-grade mathematics classrooms in Germany, Japan, and the United States. *Mathematical Thinking and Learning*, 1(4), 255–278.
- Kerry, T. (2002). *Mastering teaching skills: Explaining and questioning*. Cheltenham: Nelson Thornes.
- Livdahl, B. S. (1995). *Stories from response centered classrooms: Speaking, questioning, theorizing from the center of action*. New York: Teachers' College Press.
- Marzano, R. J., Pickering, D. J., & Pollock, J. E. (2001). *Classroom instruction that works: Research-based strategies for increasing student achievement*. Alexandria, VA: Association for Supervision and Curriculum Development.
- McClain, K., & Cobb, P. (2001). An analysis of development of sociomathematical norms in one first-grade classroom. *Journal for Research in Mathematics Education*, 32(3), 236–266.
- Mehan, H. (1979). *Learning lessons*. Cambridge, MA: Harvard University Press.
- Miles, M., & Huberman, A. (1994). *Qualitative data analysis* (2nd ed.). Thousand Oaks, CA: Sage Publications.

- Miller, D. M., Wiley, D. E., & Wolfe, R. G. (1986). Categorization methodology: An approach to the collection and analysis of certain classes of qualitative information. *Multivariate Behavioral Research, 21*(2), 135–167.
- Ministry of Education. (1992). *Mathematics in the New Zealand curriculum*. Wellington: Learning Media.
- Ministry of Education. (1997). *Developing mathematics programmes*. Wellington: Learning Media.
- Ministry of Education. (2006a). *New Zealand Numeracy Development Projects*. Wellington: Ministry of Education.
- Ministry of Education. (2006b). *The New Zealand curriculum: Draft for consultation 2006*. Wellington: Learning Media.
- Ministry of Education. (2006c). *Frequently asked questions about deciles*. Retrieved 18 January 2007, from: <http://www.minedu.govt.nz/index.cfm?layout=document&documentid=7696&data=1>
- Ministry of Education. (2006d). *Book 1: The number framework*. Wellington: Learning Media.
- Mitchell, I. (2002). Learning from teacher research for teacher research. In J. Loughran, I. Mitchell, & J. Mitchell (Eds), *Learning from teacher research* (pp. 249–266). New York: Teachers' College Press.
- Morgan, N., & Saxton, J. (1991). *Teaching, questioning and learning*. London: Routledge.
- Myhill, D., & Dunkin, F. (2005). Questioning learning. *Language and Education, 19*(5), 415–426.
- Nathan, M. J., & Knuth, E. J. (2003). A study of whole classroom mathematical discourse and teacher change. *Cognition and Instruction, 21*(2), 175–207.
- Nuthall, G. A., & Church, F. (1973). Teaching content through questioning. In G. Chanan (Ed.), *Towards a science of teaching*. Windsor: National Foundation for Educational Research/Nelson.
- Oliver, A. (2005). *The TLRI: Teachers' perspectives on partnership and research*. Wellington: New Zealand Council for Educational Research.
- Ornstein, A. C., & Lasley, T. J. (2000). *Strategies for effective teaching* (3rd ed.). Boston: McGraw Hill Higher Education.
- Osler, J., & Flack, J. (2002). Tales from the poppy patch. In J. Loughran, I. Mitchell, & J. Mitchell (Eds.), *Learning from teacher research* (pp. 222–245). New York: Teachers' College Press.
- Paugh, P. C. (2004). “Making room”: Negotiating democratic research relationships between school and academy. *Teaching Education, 15*(2), 215–227.
- Perry, M., VanderStoep, S. W., & Yu, S. L. (1993). Asking questions in first-grade mathematics classes: Potential influences on mathematical thought. *Journal of Educational Psychology, 85*(1), 31–40.
- Redfield, D. L., & Rousseau, E. W. (1981). A meta-analysis of experimental research on teacher questioning behaviour. *Review of Educational Research, 5*(2), 237–245.
- Richardson, V. (Ed.). (2001). *Handbook of research on teaching* (4th ed.). Washington, DC: American Educational Research Association.
- Robinson, V., & Lai, M. K. (2006). *Practitioner research for educators: A guide to improving classrooms and schools*. Thousand Oaks, CA: Corwin Press.
- Roulston, K., Legette, R., DeLoach, M., & Buckhalter Pitman, C. (2005). What is “research” for teacher-researchers? *Educational Action Research, 13*(2), 169–189.
- Schön, D. (1983). *Reflective practitioner: How professionals think in action*. London: Temple Smith.
- Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4–14.
- Sikula, J., Buttery, T. J., & Guyton, E. (Eds.). (1996). *Handbook of research on teacher education*. New York: Macmillan.
- Stigler, J., & Hiebert, J. (1998). Teaching is a cultural activity. *American Educator, 22*(4), 4–11.

- Stigler, J. W., & Hiebert, J. (1999). *The teaching gap: Best ideas from the world's teachers for improving education in the classroom*. New York: Free Press.
- Strauss, A. L., & Corbin, J. (1998). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (2nd ed.). Thousand Oaks, CA: Sage Publications.
- Thomas, G. (1994). Peer discussion and learning in mathematics. In J. Neyland (Ed.), *Mathematics education: A handbook for teachers* (Vol. 1, pp. 319–329). Wellington: Wellington College of Education.
- Thomas, G., & Ward, J. (2002). *An evaluation of the Early Numeracy Project 2001*. Wellington: Ministry of Education.
- Vale, C. (2003). Questions in primary mathematics classrooms. In *Proceedings of the annual conference of Mathematics Education Research Group of Australasia* (pp. 688–695). Melbourne: Mathematics Education Research Group of Australasia.
- van Zee, E. H. (1998). Preparing teachers as researchers in courses on methods of teaching science. *Journal of Research in Science Teaching*, 35(7), 791–809.
- van Zee, E. H. & Minstrell, J. (1997). Using questioning to guide student thinking. *The Journal of the Learning Sciences*, 6(2), 227–269.
- Walsh J. A., & Sattes, B. D. (2005). *Quality questioning: Research-based practice to engage every learner*. Thousand Oaks, CA: Corwin Press.
- Windschitl, M. (1999). A vision educators can put into practice: Portraying the constructivist classroom as a cultural system. *School Science and Mathematics*, 99(4), 189–196.
- Wittrock, M. C. (Ed.). (1986). *Handbook of research on teaching* (3rd ed.). New York: Macmillan.
- Wood, T. (1998). Alternative patterns of communications in mathematics classes: Funneling or focusing? In H. Steinbring, M. Bartolini Bussi, & A. Sierpinska (Eds.), *Language and communication in the mathematics classroom* (pp. 167–178). Reston, VA: National Council of Teachers of Mathematics.
- Wragg, E. C. (1993). *Primary teaching skills: The report of the research findings of the Leverhulme Primary Project*. London: RoutledgeFalmer.
- Wragg, E. C., & Brown, G. (2001). (Rev. ed.). *Questioning in the primary school*. London: RoutledgeFalmer.

Appendix A: Classroom questioning by teachers

Classroom Questioning by Teachers

- an investigation of how teachers formulate, select and present questions to guide student learning

Working with the Transcript

Before beginning this process, please make sure you have recorded your initial overall impression of your use of questioning on the Transcript Analysis Sheet.

- ④ Save the electronic version of your transcript!
- ④ Read your transcript all the way through. In the right-hand column of your transcript, record what you were thinking. These reflections might include:
 - your concerns at this point of the lesson;
 - your intentions / where you were heading & why;
 - conceptual understandings / misconceptions;
 - students' specific learning needs.
- ④ Then highlight what you consider to be key episodes or moments in your lesson. Describe why you consider these to be key parts of the lesson, using the Transcript Analysis Sheet.
- ④ Next, sort all your questions, referring to the process outlined below.
- ④ After that, return to your identified key episodes. Comment on your use of questioning in these episodes, recording your ideas on the Transcript Analysis Sheet.

Process for Sorting Questions

1 The first task is to separate each question in your transcript. There are two ways you may like to do this:

- Either photocopy the transcript, perhaps enlarging the page from A4 to A3, number each question so that you can re-locate it in your transcript when necessary, then cut out each question, or
- Using your electronic version of the transcript, delete everything that is NOT a question, enlarge the font, and print before cutting up into individual questions. Remember to save this document with a different name.



2 i) Beginning with the first question – consider the question and think about: How does it facilitate learning? What kind of question is it? What kind of response did you require / expect? Why did you ask it? When you have decided, place the question in front of you and write a tentative label for this category of question.

ii) Take the next question. Consider the question and think about: How does it facilitate learning? What kind of question is it? What kind of response did you require / expect? Why did you ask it? If you consider it to be the same kind of question as the first question, place it with the first one. Otherwise begin a second group by placing the new question apart from the second question and making a new label for this second type of question.

iii) Continue by picking up one question at a time, considering the question and placing with one of the groups already formed or beginning a new one.



3 When you have placed all of your questions, go through the groups and review the ideas with special consideration for whether the questions belong together. You may make changes by dividing or combining groups or by switching questions around.



4 When you have completely reviewed your groupings, put a blank card on top of each group and write a word or a phrase that best describes the central idea that caused you to place the questions together in that particular group.



5 Finally, glue your questions onto sheets of newsprint. Include your labels for the categories you have sorted the questions into. These will be shared at our next research team meeting.

Appendix B: Questions and issues arising from the analysis of transcript one

Questions and issues arising from the analysis of transcript one

Please tick the following questions that are issues you identified with, then add any further issues which arose from your analysis. (Please write these as questions.)

We will use a compilation of these to inform where we head after today's session.

- Are our questions differentiated according to students' abilities? If so, how are they differentiated?

- Are certain question categories more effective than others for promoting students' learning?

- What is the relationship between the students' responses and the teacher's questions?

- Is there an appropriate quality and quantity of questioning during an 'ideal' lesson?

- How is effective questioning related to a teacher's content knowledge?

Appendix C: Questionnaire: What are my beliefs about teaching and learning?

Name: _____

What are my beliefs about teaching and learning?

1. In considering teaching and learning, I see:
 - A. teaching and learning as complementary;
 - B. teaching as taking priority over learning;
 - C. learning as taking priority over teaching.

2. Students learn through:
 - A. being challenged and struggling to overcome difficulties;
 - B. being introduced to one mathematical routine at a time and remembering it;
 - C. being 'ready' to learn certain mathematical ideas.

3. Numeracy teaching is based on:
 - A. dialogue between teacher and students to explore each others' understandings;
 - B. practical activities so that students discover methods for themselves;
 - C. verbal explanations so that students understand teachers' methods.

4. Becoming numerate is:
 - A. an individual activity based on actions on objects;
 - B. an individual activity based on following instructions;
 - C. a social activity based on interactions with others.

5. My favourite piece of maths equipment is:
 - A. A wafer;
 - B. Liquorice straps;
 - D. Pizza (or pi?)

6. Being numerate involves:
- A. the ability to perform set procedures or routines;
 - B. using both efficient and effective methods of calculation;
 - C. finding the answer to a calculation by any method.
7. Being numerate involves:
- A. Reasoning, justifying, and eventually proving results about numbers;
 - B. Being able to use and apply mathematics using practical apparatus;
 - C. Being able to 'decode' context problems to identify a particular routine or technique.
8. A numerate student shows:
- A. confidence and ability in mental methods;
 - B. confidence and ability in practical methods;
 - C. shows confidence and ability in paper and pencil methods.
9. The programme I would prefer to watch is:
- A. Desperate Housewives
 - B. Numbers (when it starts again soon)
 - C. Spongebob Squarepants
 - D. None of the above – I prefer reading women's magazines
10. In relation to students' strategies:
- A. students' own strategies are the most important: understanding is based on working things out yourself;
 - B. students' strategies for calculating are of little importance – they need to learn standard procedures;
 - C. students have calculating strategies but the teacher has the responsibility for helping them refine their methods.
11. Students' misunderstandings:
- A. are the result of failure to grasp what was being taught and need to be remedied by reinforcement of the 'correct' method;
 - B. need to be recognised, made explicit, and worked on;
 - C. are the result of students not being 'ready' to learn the ideas.
12. People who complete quizzes in women's magazines are:
- A. desperate
 - B. sick
 - C. very silly
 - D. all of the above

Appendix D: Working as a teacher researcher

Working as a teacher researcher

We would like to know about your experience of working as a teacher-researcher in your school. We are aware that your participation in this project is affected by many contextual factors.

Scheduling a lesson to record was:

- straightforward
- slightly problematic
- very difficult

Please explain:

The technology involved in recording my maths lessons:

- was easy to use
- necessitated asking a colleague to help
- proved problematic

Comments:

I found the lesson analysis to be:

- difficult
- interesting
- unhelpful
- useful

Comments:

Please use the continuum to indicate the level of interest and support from:

○ the principal

Disinterested and / or unsupportive |-----| Extremely interested and / or supportive

○ management team

Disinterested and / or unsupportive |-----| Extremely interested and / or supportive

○ colleagues

Disinterested and / or unsupportive |-----| Extremely interested and / or supportive

In what ways have they shown their interest and support?

To what extent do you see your participation in this research enhancing the learning community in your school?

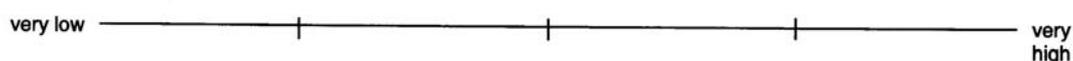
Appendix E: Reflecting on your Involvement in our Research Project

Reflecting on your Involvement in our Research Project

You as Teacher-Researcher

1. Please list any relevant details under these headings:

- Years of Teaching:
- Qualifications:
- In-depth professional development:
- Leadership within your school:
- Level of confidence in mathematics content and teaching:



2. What were your reasons for becoming involved in the project?

3. Have you had any previous research experience?

4. Prior to your involvement in this project, have you used research to inform your practice? In what ways?

The Research Team

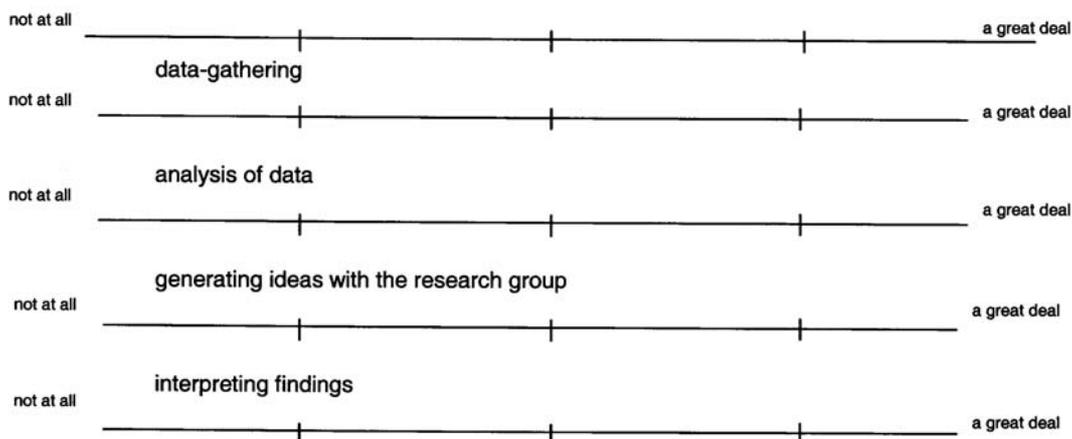
5. One of the goals of the project was to develop partnerships between teachers and researchers. How well do you think our project fitted your ideas of partnership?

- What worked well? What didn't work well? What could have been done differently?

6. What, in your view, were the roles of each member of the research team?

- Teacher-researchers (you)
- Project leaders (Linda and Ruth)
- Research consultant (Jo)

7. How much did you feel you contributed to:



Reflecting on the Project

12. How relevant did you feel the focus of the project was for your teaching practice?



Please explain:

- In what ways has your involvement in the project influenced your teaching practice?
- What relevance do you feel the research has for teachers in general?

13. What are the important ideas about questioning you discovered? How has the research changed your views about questioning?

14. What else has the research made you think about?

15. What have you learned about research in general and the relationship between teaching / learning?

- Have your views of research altered in any way? How?
- Why is research important?

16. What further questions about teaching/learning has it raised for you?

Any further comments?