Professional Development as a Catalyst for Changes in Beliefs and Practice: Perspectives from the Early Numeracy Research Project

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Professional development programs usually aim to support teachers as they explore innovative approaches to making their teaching more effective The experience of the Early Numeracy Research Project is discussed, indicating that change in teacher beliefs and classroom practice can be an outcome of a major professional development project It is posited that seeing teachers as co-researchers and reflective professionals contributed to teacher professional growth in this project

Few would dispute that the knowledge, beliefs and practice of the teacher are major influences on learning in the mathematics classroom As a result, those responsible for preservice and inservice teacher education seek to assist preservice and inservice teachers to develop the beliefs, attitudes, knowledge and skills likely to increase their effectiveness

In "traditional" mathematics classrooms, mathematics is assumed to be a "static, bounded discipline" (Romberg & Carpenter, 1986, p 851), suggesting that mathematics is considered "a body of infallible, objective knowledge" (Ernest, 1991, p xii) The alternate view of mathematics as a dynamic, growing field of study "posits that mathematical knowledge is internal and therefore subjective is not so much discovered as created by social groups knowing and doing [mathematics are] inseparable" (Fisher, 1990, p 82) In the traditional paradigm, the focus is on mathematics as content that is external to the learner; from the alternate viewpoint mathematics is a process, and knowledge is internal

Among teachers, varying views of mathematics are held Although current documents encourage the view of mathematics as an active process and some teachers do appear to have made associated changes in their teaching methods (Forgasz, Landvogt & Leder, 1997), the majority of teachers appear not to have rejected an authoritarian, transmission style of teaching (e g , Becker & Selter, 1996; Romberg & Carpenter, 1986)

Researchers have reported varying degrees of consistency between teachers' professed beliefs about the nature of mathematics and their instructional practices (Thompson, 1992) However, it is generally accepted that there is a relationship between teacher beliefs and attitudes and teacher practice (e g , Koehler & Grouws, 1992) Questions have arisen as to the focus that should be taken when developing professional development programs for teachers Models of teacher growth help us to consider such questions

Guskey (1986) claimed that teachers change their beliefs through changing their practice and reflecting on the result His model challenged the idea that it was necessary to change beliefs in order to bring about changes in practice As shown in Figure 1, the Clarke-Hollingsworth model (Clarke & Hollingsworth, 2002) developed further Guskey's model, viewing the process as cyclical with multiple entry points Their model of teacher professional growth took account of several spheres of influence to change The model assumes that change occurs through the mediating processes of reflection and enactment, in four distinct domains, which encompass the teacher's world: the Personal Domain, the Domain of Practice, the Domain of Consequence (salient outcomes such as improved student learning), and the External Domain (sources of information, stimulus or support)

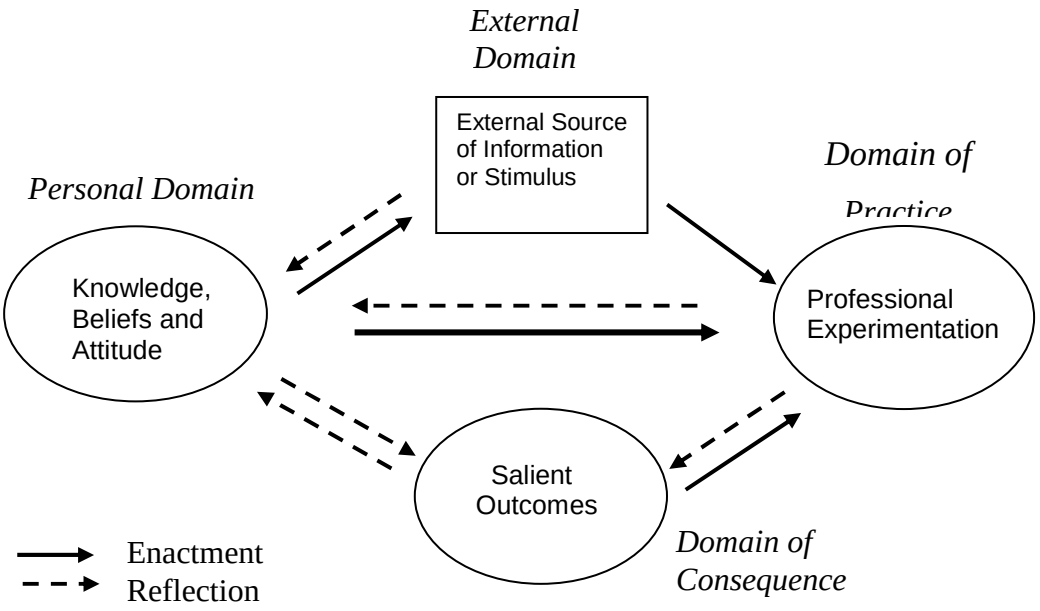

Figure 1 Clarke-Hollingsworth (2002) model of teacher professional growth

Professional Development in the Early Numeracy Research Project

The Early Numeracy Research Project (ENRP), a three year Victorian project (1999 to 2001), investigated effective approaches to the teaching of mathematics in the first three years of schooling, and involved teachers and children in 35 project ("trial") schools and 35 control ("reference") schools (Clarke, 2001; Clarke, et al , 2002) There were three key components within this professional development project:

- the development of a research-based framework of "growth points" in young children's mathematical learning (in Number, Measurement and Space);
- the development of a 40-minute, one-on-one interview, used by all teachers to assess aspects of the mathematical knowledge of all children at the beginning and end of the school year (February/March and November respectively); and
- extensive professional development at central, regional and school levels, for teachers, coordinators, and principals

While these three key components of the ENRP informed, involved, and potentially empowered the project teachers, it was the teachers, professional learning teams, and schools who ultimately made the decisions of whether and how the information and experiences provided within the project would impact upon their classroom practice The approach taken fits with Doyle's (1990) "reflective professional" paradigm "Rather than a recipe, the notion of rich ingredients that are combined to meet the needs of individual children, the mathematics and the teaching context, using the professional judgement of teachers" (Clarke et al , 2002, p 18), was the approach taken From the first professional development session, the research team attempted to make it clear that they regarded project teachers as co-researchers It was explained that there was much to be learned by all involved, and that a collaborative approach was the desired one

The ENRP professional development program occurred (formally) at three levels The 250 or so teachers from trial schools met with the research team each year for about five full days, spread across the year, with the focus on understanding the framework and

interview, and on appropriate classroom strategies, content, and activities for meeting identified needs of their students On four or five occasions each year, the teachers met in regional cluster groups for two hours, usually after school There was usually a time of sharing, during which teachers discussed readings or particular activities or approaches that they had tried since last meeting together This was followed by the content focus for the day, and further tasks were set that needed to be completed before the groups met again

The third level of professional development took place at the school and classroom level The cluster coordinator visited each school approximately three times per year, spending time in classrooms team teaching or observing, participating in planning meetings, jointly leading parent evenings, and acting as a "sounding board" for teachers, coordinators and principals In addition, the Early Numeracy Coordinator conducted weekly or fortnightly meetings of the "professional learning team", to maintain continuity, communication, cohesion and purpose For further information, see Clarke et al (2002)

The Clarke-Hollingsworth model of teacher professional growth finds considerable harmony with the approach to professional development of the ENRP The ENRP was part of the External Domain for project teachers; it was developed as a source of information, stimulus and support Change is a complex and slow process, and multiple levels of support are required for lasting professional growth (Guskey, 1986)

Evidence of Teacher Growth Within Professional Development Programs

Previous major research-based, professional development projects have seen growth in teacher practice and changes in beliefs and attitudes The Cognitively Guided Instruction (CGI) project reported that teachers demonstrated fundamental changes in beliefs and instruction over the four years of the study (Fennema, Carpenter, Franke, Levi, Jacobs, & Empson, 1996) At the core of the CGI project was a research-based model of children's thinking, presented to participant teachers through workshops and interpreted by teachers in relation to their own students The model acted as a "catalyst between teachers' intuitive knowledge and principled knowledge of their own students' thinking which they developed as they taught" (Fennema et al , 1996, p 431) Explicit guidelines for instruction were not provided; teachers had to decide, for example, "how to consider students as they selected problems, how to question children, how to organise their classrooms" (p 432)

The combination of a framework of research-based stages of development in young children's mathematical thinking and a one-to-one interview that enabled teachers to construct cognitive profiles of individuals and groups of children has been a feature of a number of research-based projects in Australia and New Zealand, (Bobis, Clarke, Clarke, Gould, Thomas, Wright, & Young-Loveridge, 2005) Having the knowledge and language to describe children's mathematical thinking and a clearer picture of children's understanding led to enhanced classroom practice and changes in stated beliefs

Evidence of Growth in Teacher Practice Within the ENRP

Change became evident within a range of aspects for ENRP teachers In October 2001, all ENRP trial school teachers were asked, through an open response question, how their teaching had changed due to their involvement in the ENRP Of the seven most common categories of response, five related to changed practice within teaching programs:

- Using more open-ended tasks and activities
- Using more probing questioning/ asking why and how/ valuing children's thinking
- Challenging and extending children/ higher expectations

- Using more practical/ hands-on activities
- Having a greater emphasis on reflection/ sharing

Two of these points are now discussed below to exemplify the changes

Using more Probing Questioning

Forty-nine trial school teachers gave responses related to changes to their teaching (October 2001) that fell into the category of more probing questioning/ asking why and how/ valuing children's thinking This was the third highest category of response

Responses to the planning questionnaire given to teachers in August 2000 indicated that teachers asking students to explain their own strategies was increasingly common in trial teachers' mathematics classrooms Approximately 86% of trial school teachers reported that they asked students for explanations at least a few times a week compared to 65% of reference school teachers More than one-third of trial school teachers asked students to explain their own strategies every day compared to one-fifth of reference school teachers These data suggest that trial school teachers gave more emphasis than reference school teachers to children explaining their answers and strategies

Data from intensive ENRP case studies (Clarke et al , 2002; Clarke & Clarke, 2004; McDonough & Clarke, 2003) contribute to the picture of more probing questioning with the theme of "use a range of question types to probe and challenge children's thinking and reasoning" apparent within the classrooms of at least four of the six case study teachers "Ms Prep" reported that she often asked "how did you work that out?" to encourage children to think about whether their answer was wrong, to reinforce strategy use, and "with other children listening so that they can perhaps pick up on the child's strategy" Her probing questioning provided information for the teacher and for children to reflect upon

These data indicate that use of more probing questioning was one example of changed practice within the ENRP

Challenging and Extending Students' Higher Expectations

In October 2001, 28 trial school teachers referred to one of their greatest changes as related to challenging and extending students and having higher expectations This was the fifth-highest category of response This theme emerged also as a feature within case studies of particularly effective individual teachers and professional learning teams As a Grade 2 teacher expressed, "I didn't extend my kids as much as I do now … you tended to work from minimums rather than maximums " Teachers at that school extended children beyond curriculum guidelines where appropriate A highly effective teacher spoke of no longer stopping at curriculum recommendations as she had in the past

> I think back five years, … you tended to start at the same point and teach to the same point and not beyond it whereas now … the whole spectrum is open … you're trying to find out what the children know and, no matter what they know, to extend on it There's a lot more extension and it's just so broad now (Ms Grade 1/2)

One Prep teacher referred to now going beyond CSF (*Curriculum and Standards Framework*, Board of Studies, 2000) outcomes depending on where the children "are at" and because of her higher but realistic expectations, children had grown more in their mathematical understandings:

> I would say that I have higher expectations of Preps since I've been in the project it's been a big eye-opener for me to see exactly what some Preps can do and that, if you stick to that exact [CSF] level, you're holding a lot of children back So I find I cater much more for all those children and

I'd say that's how my planning and teaching has changed I have higher expectations but not unrealistic expectations and I think the children have improved a lot because of that (Prep teacher)

Evidence of Changes in Teacher Beliefs and Attitudes Within the ENRP

Beliefs About the Nature of Mathematics

In both an entry and exit questionnaire to the project, teachers completed this sentence starter: "Write enough to convey your view of the nature of mathematics Mathematics is " The open responses were then categorised into themes Table 1 shows the frequencies of each of the themes in teachers' responses in the entry and exit questionnaires The teachers were not limited in their number of responses and the number of categories each teacher included was greater for the exit questionnaire

The increase in the number of categories can be taken reasonably as illustrating a broadening of their views about the nature of mathematics Considering those categories that might represent Ernest's (1991) conceptions relating to the "trained artesan" (mathematics as an everyday skill, as a list of topics, as number only or as useful and purposeful—the first, fifth, sixth and eighth listings in Table 1), at entry 106 of the teachers had responded within this group, while at exit the number was only 57

Table 1
Frequencies of Themes from Entry and Exit Questionnaires (Nature of Mathematics)

Themes	Entry Frequency (n = 192)	Exit Frequency (n = 221)
Everyday skill/life	111	116
Central to education	16	12
Helps us to understand the world	22	45
A way of thinking	13	45
As content e g , list of topics	57	57
As number only	27	32
A source of enjoyment/challenge/motivation	20	52
Useful and purposeful e g , application to work	14	25
Process	20	9
Interconnected	0	23
Problem solving	0	37
Other	7	12

Problem solving and interconnected were categories that emerged only in 60 responses in the exit questionnaire It is noteworthy that 52 teachers volunteered statements relating to affective aspects of mathematics, including regarding it as a source of enjoyment, challenge, and motivation at the end of the project, compared with 20 at the beginning

From the research team's perspective, responses on the open question regarding the nature of mathematics illustrated that teachers developed a richer view of the nature of mathematics over the period of the ENRP It is a reasonable conclusion that many teachers have taken on the dynamic, problem-driven view of mathematics (Ernest, 1991)

Beliefs About their Role as Mathematics Teachers of Young Children

In both the entry and the exit questionnaires, teachers responded to the open question "What do you see as the most important elements of your role as a mathematics teacher of

young children?" The responses are categorised in Table 2 On average, teachers offered more statements in the exit questionnaire than was the case in the entry questionnaire One possibility is that they were more able and willing to articulate their role

It needs to be recognised that open questions provide teachers with the freedom in their choice of discussion, but also the possibility of reflecting the messages of the professional development To reduce the possible effect of this, the exit questionnaire was completed as the first item on the program for the last professional development day, so that comments would not be unduly influenced by the events of the day Of course there is also the issue of whether the language that has developed as part of the ENRP results in different ways of expressing the same thing

With those provisos, some general patterns are of interest At the beginning of the project, teachers saw their role as building understanding through the selection of learning context and developing positive attitudes At the end of the project these teachers elaborated the role more fully with some shifts in their role

Table 2
Frequencies of Themes in Responses in Entry and Exit Questionnaires (The Role of the Teacher)

Themes	Entry Frequency (n = 198)	Exit Frequency (n = 219)
To convey understanding/meaning/build knowledge	80	101
To provide contexts for mathematics learning/learning opportunities	74	41
To give purpose/appreciation of maths	8	17
To encourage, highlight success/have high expectations of children	21	26
To connect to other Key Learning Areas and life	20	38
To teach the language of mathematics	1	4
To structure sequential activities	7	5
To allow for a range of responses and styles/stimulate learning	9	20
To make maths enjoyable/foster positive attitudes/confidence	66	103
To be able to explain	6	7
To facilitate the sharing of ideas/guiding/modelling	13	43
To motivate/inspire/interest	29	41
To evaluate children's knowledge to inform teaching and develop children/cater for needs/potential	18	48
To allow time	4	2

The building of understanding was given even greater emphasis with a focus on developing meaning There was also an increase in the teachers' appreciation of affective issues in the learning of mathematics There was a shift towards responses that exemplify a valuing of children's thinking including allowing for a range of responses, facilitating the sharing of ideas and evaluating children's knowledge to inform their teaching The responses suggest that over the period of the ENRP, teachers moved toward a more *learner-focused* view of how mathematics should be taught

Confidence in Teaching Mathematics

Involvement in the ENRP appeared to increase many teachers' confidence in teaching mathematics Table 3 shows the various themes that emerged from the responses to the

question “How do you feel about teaching mathematics?” The number of teachers whose responses were categorised as being positive or confident in their teaching of mathematics increased from 47 to 103 and the number who volunteered that they were lacking in confidence decreased from 26 to 11

Table 3
Frequencies of Themes in Teachers' Responses in Entry and Exit Questionnaires (Attitude to and Confidence in Teaching Mathematics)

Themes	Entry Frequency (n = 195)	Exit Frequency (n = 220)
Confident/positive	47	103
Enjoy it	110	133
Okay	12	17
A challenge/keen to improve	13	21
Important educationally/sense of obligation to do it well	5	12
Lacking in confidence	26	11
Other	6	7

In addition to this question, there was a 0 to 10 scale on which teachers were asked to indicate how confident they felt in their teaching of mathematics This item was on both questionnaires For those teachers who responded to both the entry and exit questionnaires (n = 103), there was an increase in the mean from 6 94 to 7 93; which using a *t test* proved to be a highly significant difference (df = 102, p < 0 001) The following quote focuses clearly on the impact on teachers' confidence:

> The main thing that has changed is my confidence in my maths teaching, because I have more knowledge of how children learn maths, what they should know and some ideas of how to get them there My lessons are more varied and fun now

Conclusion

The data presented above indicate that the ENRP was successful in creating a professional development environment in which teachers reflected upon and made changes in their teaching practice A further outcome of the project was changed beliefs about the nature of mathematics and about their role as teacher of mathematics to young children Attitudinal changes were evident also

The Clarke-Hollingsworth model of teacher change suggests that there are multiple influences on, for example, the practices and beliefs of teachers Teachers within the ENRP received many forms of professional development from state-based meetings to professional learning team meetings at their school The experience of conducting a one-to-one interview with each child in their class at the beginning and end of each year appeared to be a powerful form of professional development in itself Thus the exact elements that were most influential in any changes in teaching practice, beliefs and attitudes cannot be concluded

The outcomes of teacher growth within the ENRP are not exclusive to that project It appears that the common factor of providing teachers with a model or framework, as well as opportunities to interpret and reflect were common underpinnings of teacher professional growth within other projects discussed in this paper It appears that the philosophical approach of the ENRP in seeing teachers as co-researchers and reflective practitioners may have played a key role in facilitating change

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